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e-Navigation Journal

Original article

Study on Port Strategy of Shandong Peninsula Based on Game Theory

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Abstract

This paper seeks to enable the port of Shandong Peninsula to better handle the relationship between competition and cooperation and thus achieve common development. Based on an analysis of the current development of Shandong Peninsula ports, the paper proposes a port competition and cooperation strategy based on a Bertrand game. According to the game model, an income matrix of Qingdao Port and Rizhao Port, Yantai Port and Weihai Port is established and an analysis the income of each port under different strategic combinations is conducted to determine the strategy that is most conducive to the development of the ports. At the same time, we consider the instability of cooperation and establish a certain cooperation mechanism. Finally, an example is used to verify the effectiveness of the proposed port development strategy for Shandong Peninsula.

Keywords: Shandong Peninsula, ports, game theory, competition and cooperation

https://doi.org/10.52820/j.enavi.2021.16.001

1. Introduction

1.1 Background

With the continuous integration of Shandong Peninsula ports, its integrated development pattern has initially taken shape. Due to the initial stage of integration, various problems among ports have not been resolved, which is affecting the healthy and orderly development of Shandong Peninsula ports. In the new era, the problem of how to keep up with the sustainable development of Shandong Peninsula, together with avoiding waste of resources, improving the efficiency of port operation, and enhancing port competitiveness to enhance the regional economic growth of Shandong Peninsula, is becoming an important issue that urgently needs to be considered. Based on the recent research on the current development of Shandong Peninsula ports, this paper establishes a game model which takes Qingdao Port and Rizhao Port, Yantai Port and Weihai Port as examples to conduct empirical game analysis, then the competitive development strategy of Shandong Peninsula ports are concluded. The results of the research suggest coordination and unification among ports and the improvement of competitiveness of ports to achieve sustainable and healthy development.

1.2 Literature review

In the modern time, ports play as an important role to the economic development of a country or region. As a result, more and more scholars have used a variety of innovative research methods and technical means to study port development strategies.

Ishii M (2013) et al. established a non-cooperative game model based on the timing of port capacity investment to study the impact of port competition. Based on the deduction of the Nash equilibrium, taking the port competition between Busan Port and Kobe Port as an example, the competition strategy between the two ports is concluded. Do T M H (2015) et al. introduced two methods to solve the game, including uncertainty statistics and Nash equilibrium strategy. The results of the study put forward meaningful suggestions for the future competition planning of the two ports and suggest that Shenzhen is the leading port for the long-term competing strategy. Through the study of the latest competitive situation with uncertain demand in the game model, compared with the existing similar research results, it proves its uniqueness among existing literature. Park N K (2015) et al. established a cooperative and non-cooperative game model which takes North Korea's North Port and South Korea's Busan Newport as examples and concludes that non-cooperative and cooperative games are joint decisions of managers who try to overcome competition and ignore the game of common interests. Looking for a competitive equilibrium price and equilibrium profit, Song D P (2016) et al. considered the competition between two ports involving hinterland transportation and used the non-cooperative game model to derive the optimal port pricing and the carrier's port-of-call decisions. Zhang Q (2018) et al. developed a game theory model of port competition for multimodal transport network design and pricing strategy issues and solved it by using the Nash equilibrium solution algorithm. Nguyen M D (2020) et al. used the Bertrand-Nash game model to estimate the equilibrium loading and unloading charges and equilibrium market share of the container terminals in the region. The results of the game verify the content of price competition among container terminals and propose a competition strategy for further discussion.

With respect to previous literature on Shandong Peninsula ports, Wang H N (2015) et al. proposed planning and development goals of the comprehensive transportation system in the Shandong Peninsula Blue Economic Zone based on the preliminary formation of the new pattern of Shandong port development. Predictions and analyses are made on the development of the system. Besides, suggestions to the development strategy of the transport system in the area are also provided.

The current research on the competition and cooperation among ports is mainly based on the perspective of non-cooperative and cooperative games which lacks stability analysis. Among the relevant research on Shandong Peninsula ports, few scholars use the competition and cooperation game model among ports to analyse port development strategies. Besides, most of the research implements qualitative or quantitative analysis without considering the combination of both methods. In response to the above-mentioned shortcomings of the existing research, this article employs the relevant knowledge of game theory into the research on Shandong Peninsula ports. It establishes a competitive and cooperative game model based on Bertrand game, and adopts a combination of qualitative and quantitative methods to propose competitive development strategies for the prospected ports.

2. Development Status of Shandong Peninsula Ports

2.1. Overview of Shandong Peninsula ports development

The development of the port industry has continuously promoted the economic development of the Shandong Peninsula and foreign trade has also strengthened accordingly. The deep integration of port resources has achieved initial results. According to the statistical bulletin of the Shandong Provincial Bureau of Statistics, the cargo throughput of coastal ports on the Shandong Peninsula has reached 1.69 billion tons in 2020, a year-on-year increase of 4.9%. The nation's leading port throughput ranks Shandong Peninsula in an important position among the international shipping hubs in Northeast Asia.

After years of construction and development, the scale of Shandong Peninsula ports and the construction of infrastructure have been greatly improved. The coastline of Shandong Peninsula is more than 3,100 km, which ranks second in the national coastline rankings. The planned coastal port coastline is about 575 km, of which the deep-water coastline is about 368 km and the berth coastline is about 110 km.

2.2. Problems existing in the development of Shandong Peninsula ports

(1) Coastal ports are densely distributed with repeated construction. Besides, port infrastructure and its soft environment construction has failed to complement each other, resulting in idle port resources.

(2) Disorderly competition among ports has led to overcapacity. Several ports often operate at high speeds, and some small and medium-sized ones are often in the state of overcapacity. This situation has caused many ports to engage in price wars to attract goods, and the normal development order of ports on the Shandong Peninsula has been severely disrupted.

(3) The management system is scattered, and resources are seriously wasted. The decentralized management system makes it impossible to integrate the various resources of the port, and multiple ports coexist, which reduces the resource utilization rate of the port.

(4) Although the Shandong Peninsula has begun to integrate, in fact, the management and decision-making of ports are not as smooth as expected.

3. Analysis of Port Competition Model Based on Game Theory

3.1. Model assumptions

Assume that there are many competitive ports in a port group that provide services of a strong alternative type, and port operation costs are the main influencing factor of port demand. Since the demand of the port is affected by the transportation price of the port itself and the rival port, the price influence coefficient is introduced into the demand function of the port. The demand function of the port can be assumed as below.

$$D_i = \eta_i - \alpha_i P_i + \sum_{i \neq j} \beta_{ij} P_j \qquad (1)$$

Where D_i is the demand of port i; η_i is the maximum demand of port i that can be obtained without being affected by price factors; P_i is port i unit price of services provided; α_i is the price sensitivity coefficient of port i; β_{ij} is the price sensitivity coefficient of the change in the demand of the rival port.

In order to avoid the emergence of Bertrand's paradox, all ports provide the similar type of service that does not have complete substitution. Suppose the price sensitivity coefficient satisfies:

$$\alpha_i \neq \alpha_j > 0 \quad (2)$$

$$\beta_{ij} \neq \beta_{ji} > 0 \quad (3)$$

Assuming that the ports have the same variable cost, the port cost function is as follows.

$$C_i = VD_i + F_i \quad (4)$$

Where C_i is total cost of port i; V is unit variable cost; F_i is port i fixed cost.

Bringing its demand function (1) into the cost function (4), the following port revenue function can be obtained:

$$\pi_i = (P_i - V)D_i - F_i \quad (5)$$

Where π_i is port's revenue value.

Assume that two ports are randomly selected from many ports, and the two ports are in the same port group; and there is little difference in the cost of ports that provide the same service content. To facilitate research, the port's fixed cost is assumed to not exist ($F_i = 0$). Therefore, the revenue functions of the two ports are:

$$\pi_1 = (P_1 - V)(\eta_1 - \alpha_1 P_1 + \beta_{12} P_2) \quad (6)$$

$$\pi_2 = (P_2 - V)(\eta_2 - \alpha_2 P_2 + \beta_{21} P_1) \quad (7)$$

3.2. Model construction

(1) Competition-competitive strategy means that port 1 and port 2 simultaneously choose to compete in order to maximize their own interests. At this time, the conditions that should be met in order to achieve the Nash equilibrium are: $\frac{\partial \pi_1}{\partial P_1} = 0$; $\frac{\partial \pi_2}{\partial P_2} = 0$

The above equations respectively derive P_1 in equation (6) and P_2 in equation (7). According to the derivation results of the two equations, the equilibrium prices of the two ports are obtained as follows:

$$P_1^{jj} = \frac{\beta_{12}\eta_2 + 2\alpha_2\eta_1 + \alpha_2\beta_{12}V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{12}\beta_{21}} \quad (8)$$

$$P_2^{jj} = \frac{\beta_{21}\eta_1 + 2\alpha_1\eta_2 + \alpha_1\beta_{21}V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{12}\beta_{21}} \quad (9)$$

At this time, the equilibrium incomes of the two ports are as below.

$$\pi_1^{jj} = (P_1^{jj} - V)(\eta_1 - \alpha_1 P_1^{jj} + \beta_{12} P_2^{jj} \quad (10)$$

$$\pi_2^{jj} = (P_2^{jj} - V)(\eta_2 - \alpha_2 P_2^{jj} + \beta_{21} P_1^{jj} \quad (11)$$

(2) Competition-cooperative strategy means that port 1 chooses to compete in order to maximize its own interests; port 2 chooses to cooperate in order to maximize collective interests. At this time, the conditions that should be met to achieve the Nash equilibrium are: $\frac{\partial \pi_1}{\partial P_1} = 0$; $\frac{\partial (\pi_1 + \pi_1)}{\partial P_2} = 0$

In the same way, according to the derivative result, the equilibrium prices of the two ports can be obtained as:

$$P_1^{jh} = \frac{\beta_{12}\eta_2 + 2\alpha_2\eta_1 + \alpha_2\beta_{12}V - \beta_{12}^2 V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{12}^2 - \beta_{12}\beta_{21}} \quad (12)$$

$$P_2^{jh} = \frac{\beta_{12}\eta_1 + \beta_{21}\eta_1 + 2\alpha_1\eta_2 - \alpha_1\beta_{12}V + \alpha_1\beta_{21}V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{12}^2 - \beta_{12}\beta_{21}} \quad (13)$$

At this time, the equilibrium income of the two ports are:

$$\pi_1^{jh} = (P_1^{jh} - V)(\eta_1 - \alpha_1 P_1^{jh} + \beta_{12} P_2^{jh}) \quad (14)$$

$$\pi_2^{jh} = (P_2^{jh} - V)(\eta_2 - \alpha_2 P_2^{jh} + \beta_{21} P_1^{jh}) \quad (15)$$

(3) Cooperation-competitive strategy means that port 1 chooses cooperation in order to maximize collective interests, and port 2 chooses competition in order to maximize its own interests. At this time, the conditions that should be met in order to achieve Nash equilibrium are: $\frac{\partial (\pi_1 + \pi_2)}{\partial P_1} = 0$; $\frac{\partial \pi_2}{\partial P_2} = 0$

In the same way, according to the derivative result, the equilibrium prices of the two ports can be obtained as:

$$P_1^{hj} = \frac{\beta_{12}\eta_2 + \beta_{21}\eta_2 + 2\alpha_2\eta_1 + \alpha_2\beta_{12}V - \alpha_2\beta_{21}V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{21}^2 - \beta_{12}\beta_{21}} \quad (16)$$

$$P_2^{hj} = \frac{\beta_{21}\eta_1 + 2\alpha_1\eta_2 + \alpha_1\beta_{21}V - \beta_{21}^2 V + 2\alpha_1\alpha_2 V}{4\alpha_1\alpha_2 - \beta_{21}^2 - \beta_{12}\beta_{21}} \quad (17)$$

At this time, the equilibrium income of the two ports are:

$$\pi_1^{hj} = (P_1^{hj} - V)(\eta_1 - \alpha_1 P_1^{hj} + \beta_{12} P_2^{hj}) \quad (18)$$

$$\pi_2^{hj} = (P_2^{hj} - V)(\eta_2 - \alpha_2 P_2^{hj} + \beta_{21} P_1^{hj}) \quad (19)$$

(4) Cooperation-cooperative strategy means that Port 1 and Port 2 choose to cooperate at the same time in

order to maximize collective benefits. At this time, the conditions that should be met in order to achieve the Nash equilibrium: $\frac{\partial(\pi_1+\pi_2)}{\partial P_1}=0$; $\frac{\partial(\pi_1+\pi_2)}{\partial P_2}=0$

In the same way, according to the derivative result, the equilibrium prices of the two ports can be obtained as:

$$P_1^{hh}=\frac{2\alpha_2\eta_1+\beta_{12}\eta_2+\beta_{21}\eta_2+\beta_{12}\alpha_2V-\beta_{21}\alpha_2V+2\alpha_1\alpha_2V-\beta_{12}\beta_{21}V-\beta_{12}^2V}{4\alpha_1\alpha_2-\beta_{12}^2-\beta_{21}^2-2\beta_{12}\beta_{21}} \quad (20)$$

$$P_2^{hh}=\frac{2\alpha_1\eta_2+\beta_{12}\eta_1+\beta_{21}\eta_1+\beta_{21}\alpha_1V-\beta_{12}\alpha_1V+2\alpha_1\alpha_2V-\beta_{12}\beta_{21}V-\beta_{21}^2V}{4\alpha_1\alpha_2-\beta_{12}^2-\beta_{21}^2-2\beta_{12}\beta_{21}} \quad (21)$$

At this time, the equilibrium income of the two ports are:

$$\pi_1^{hh}=(P_1^{hh}-V)(\eta_1-\alpha_1P_1^{hh}+\beta_{12}P_2^{hh}) \quad (22)$$

$$\pi_2^{hh}=(P_2^{hh}-V)(\eta_2-\alpha_2P_2^{hh}+\beta_{21}P_1^{hh}) \quad (23)$$

3.3. Stability analysis

Two ports are randomly selected from many competing ports to take part in the game, and each port has two strategies of competition and cooperation. We supposed that starting from a certain moment, the probability of a port adopting a cooperative strategy is ε, and the probability of a port adopting a competitive strategy is $1-\varepsilon$. According to the calculation results of the equilibrium income, the competition and cooperation income matrix of the two ports is constructed as below.

Tab.1 Profit matrix of port competition and cooperation

Player/Strategy		Port2 Competition	Port2 Cooperation
Port1	Competition	$(\pi_1^{jj},\ \pi_2^{jj})$	$(\pi_1^{jh},\ \pi_2^{jh})$
	Cooperation	$(\pi_1^{hj},\ \pi_2^{hj})$	$(\pi_1^{hh},\ \pi_2^{hh})$

The expected benefit of port 1 adopting cooperation and competition strategies and the difference between the two are as below:

$$E_1^h=(1-\varepsilon)\pi_1^{hj}+\varepsilon\pi_1^{hh} \quad (24)$$

$$E_1^j=(1-\varepsilon)\pi_1^{jj}+\varepsilon\pi_1^{jh} \quad (25)$$

$$\Delta E_1=E_1^h-E_1^j=(\pi_1^{hj}-\pi_1^{jj})+\varepsilon(\pi_1^{hh}+\pi_1^{jj}-\pi_1^{hj}-\pi_1^{jh}) \quad (26)$$

The expected benefits of port 2 adopting cooperation and competition strategies and the difference between the two are as below:

$$E_2^h=(1-\varepsilon)\pi_2^{jh}+\varepsilon\pi_2^{hh} \quad (27)$$

$$E_2^j=(1-\varepsilon)\pi_2^{jj}+\varepsilon\pi_2^{hj} \quad (28)$$

$$\Delta E_2=E_2^h-E_2^j=(\pi_2^{hj}-\pi_2^{jj})+\varepsilon(\pi_2^{hh}+\pi_2^{jj}-\pi_2^{hj}-\pi_2^{jh}) \quad (29)$$

By calculating the expected return difference between the port's cooperation and competition strategies, the stability of the cooperation strategy can be analyzed. Ports will choose a strategy with higher returns because they are completely rational. When both ports meet $\Delta E>0$, the ports will obtain higher returns when they choose cooperation, which means the cooperation between ports is stable; when at least one port meets $\Delta E<0$, the ports will obtain higher returns when they choose competition, which means the cooperation between ports is not stable.

4. Case Study on Competitive Strategy of shadong Peninsula Ports

4.1. Game analysis of ports in Shandong Peninsula — Taking Qingdao Port and Rizhao Port as examples

Supposed that Qingdao Port is Port 1 and Rizhao Port is Port 2. According to the model, the port demand, loading and unloading operation cost and variable cost of Qingdao Port and Rizhao Port at time t are respectively:

$D_1=2201$, $D_2=486$, $P_1=480$, $P_2=468$, $V=100$.

Meanwhile, with an effort to analyze the value range of the influence coefficient of price changes, we supposed two extreme situations. One is that the demand functions of the two ports only change due to changes in their own prices; the other situation is that the demand of one port will all be transferred to the other port, and the following conditions need to be met at this time:

$$D_i = \eta_i - \alpha_i P_i \geq 0 \quad (30)$$

$$\eta_j \geq \beta_{ij} P_j \quad (31)$$

It can be deduced from this to get:

$$0 \leq \alpha_i \leq \frac{\eta_i}{P_i} \quad (32)$$

$$0 \leq \beta_{ij} \leq \frac{\eta_j}{P_j} \quad (33)$$

At this time, the value ranges of the influence coefficients of price changes are as follows: $\alpha_1 \in [0，4.58]$; $\alpha_2 \in [0，1.03]$; $\beta_{12} \in [0，1.03]$; $\beta_{21} \in [0，4.58]$, Looking at the literature, we can see that the comprehensive competitiveness of Qingdao Port is greater than that of Rizhao Port, and ports with greater comprehensive competitiveness are more sensitive to price changes.

By calculating the model parameters as determined above, we can get the respective incomes of Qingdao Port and Rizhao Port when they choose combined strategies. The final Qingdao Port - Rizhao Port competition and cooperation game income matrix is shown in the following table.

Tab.2 Income matrix of competition and cooperation game between Qingdao port and Rizhao Port

Player/Strategy		Rizhao port	
		Competition	**Cooperation**
Qingdao port	**Competition**	$\pi_1^{jj} = 67.13$ $\pi_2^{jj} = 28.37$	$\pi_1^{jh} = 71.83$ $\pi_2^{jh} = 27.20$
	Cooperation	$\pi_1^{hj} = 64.80$ $\pi_2^{hj} = 37.78$	$\pi_1^{hh} = 67.82$ $\pi_2^{hh} = 39.56$

(Unit: 100 million yuan)

As the table shows, Qingdao Port will choose a dominant strategy, that is, a competitive strategy out of rational considerations. Meanwhile, Rizhao Port does not have a dominant strategy. However, since Qingdao Port chooses to compete, Rizhao Port will also choose to compete for higher returns out of rationality. With competitive strategy, it can obtain 2.837 billion yuan which is greater than 2.72 billion yuan under cooperation strategy. Therefore, Qingdao Port and Rizhao Port will eventually choose to compete. Nevertheless, under the competition circumstance, the two ports are not able to obtain the maximum value of return, and the value of return is lower than the that obtained when they choose to cooperate at the same time. As a result, cooperation is more beneficial to the two ports.

Since more competitive ports have more advantages in the attracting cargo sources compared with less competitive ones, their willingness to cooperate is becoming less. Also, the competitiveness of Qingdao Port is significantly higher than Rizhao Port. We assumed that Qingdao Port chooses the probability of cooperation strategy of 0.4; the probability of Rizhao Port's choice of cooperation strategy is 0.6, the stability analysis is carried out according to the returns of the four game strategies as follows.

① The expected benefits of Qingdao Port adopting cooperation and competition strategies and the difference between the two are: $E_1^h = 66.612$; $E_1^j = 69.95$; $\Delta E_1 = -3.338$

② The expected benefits of Rizhao Port's cooperation and competition strategies and the difference between the two are: $E_2^h = 32.144$; $E_2^j =$

32.134; $\Delta E_2 = 0.01$

Since $\Delta E < 0$, Qingdao Port will obtain higher profits by choosing competition, and the cooperation between ports is unstable.

The following scenarios are assumed.

(1) $\alpha_1 = 2.0$; $\alpha_2 = 1.0$; $\beta_{12} = 0.5$; $\beta_{21} = 1.0$, Substituting the above parameters into the strategy combination, the following results are calculated:

It can be seen from the above table that the three-year data comparison results bring out the same conclusion, that is, the cooperation strategy is the most favorable choice for the two players. However, there is always one port's cooperation and competition strategy where the expected return difference $\Delta E < 0$. At that time, the cooperation strategy of the two ports is not stable.

(2) $\alpha_1 = 1.0$; $\alpha_2 = 0.5$; $\beta_{12} = 0.25$; $\beta_{21} = 0.5$ Substituting the above parameters into the strategy combination, the following results are calculated:

From the above table, it can be seen that after price changes cause the sensitivity coefficient α to changes its own demand and the sensitivity coefficient β to changes in the demand of rival ports, the income values of Qingdao Port and Rizhao Port under different strategic choices are both significant. However, and the change in the sensitivity coefficient has a more obvious impact on Qingdao Port.

(3) $\alpha_1 = 1.0$; $\alpha_2 = 0.5$; $\beta_{12} = 0.3$; $\beta_{21} = 0.6$, Substituting the above parameters into the strategy combination, the following results are obtained:

The table shows that after individually increasing the sensitivity coefficient β of changes in the demand of other ports caused by price changes, the income value of Rizhao Port has increased significantly. In particular, when Qingdao Port shifts from a competitive strategy to a cooperative strategy, the income value of Rizhao Port increase the approximation twice as much as the original. The price changes of Rizhao Port are likely to lead to the chang in the demand of Qingdao Port. This situation is conducive to Rizhao Port to obtain higher returns.

4.2. Game Analysis of Shandong Peninsula Ports—Taking Yantai Port and Weihai Port as Examples

Supposed that Yantai Port is Port 1 and Weihai Port is Port 2, the port demand, loading and unloading operation costs and variable costs of Yantai Port and Weihai Port at time are respectively: $D_1 = 330.02$, $D_2 = 122.33$, $P_1 = 745$, $P_2 = 732$, $V = 100$,Set the parameter value as: $\alpha_1 = 0.2$; $\alpha_2 = 0.15$; $\beta_{12} = 0.12$; $\beta_{21} = 0.16$. The established model is used in this article to analyze the game between Yantai Port and Weihai Port, and bring the above parameters into the model to calculate the gain matrix of competition and cooperation between the two ports as shown in the following table:

Tab.3 The comparative study on the game profit between Qingdao port and Rizhao Port 1

Port	Years	Revenue value of competition and cooperation game (100 million yuan)				Expected return difference
		Strategy 1	Strategy 2	Strategy 3	Strategy 4	ΔE
Qingdao port	2020	67.13	71.83	64.80	67.82	-3.338
	2019	60.56	64.80	58.53	61.29	-2.918
	2018	50.40	53.94	48.76	51.08	-2.372
Rizhao port	2020	28.37	27.20	37.78	39.56	0.01
	2019	25.01	23.95	33.30	34.85	-0.016
	2018	20.43	19.53	27.20	28.45	-0.04

Tab.4 The comparison of the game profit value between Qingdao port and Rizhao Port 2

Port	Years	Revenue value of competition and cooperation game (100 million yuan)				Expected return difference ΔE
		Strategy 1	Strategy 2	Strategy 3	Strategy 4	
Qingdao port	**2020**	143.68	153.76	138.93	145.50	-6.856
	2019	130.08	139.21	125.93	131.96	-6.01
	2018	108.99	116.64	105.63	110.74	-4.884
Rizhao port	**2020**	58.90	56.36	78.41	82.05	-0.068
	2019	52.05	49.72	69.29	72.46	-0.13
	2018	42.69	40.72	56.83	59.40	-0.154

Tab.5 The comparison of the game profit value between Qingdao port and Rizhao Port 3

Port	Years	Revenue value of competition and cooperation game (100 million yuan)				Expected return difference ΔE
		Strategy 1	Strategy 2	Strategy 3	Strategy 4	
Qingdao port	**2020**	156.91	173.66	146.92	151.33	-17.394
	2019	142.03	157.79	133.27	137.48	-15.69
	2018	119.03	131.73	111.88	115.56	-12.562
Rizhao port	**2020**	77.82	74.96	120.93	140.09	5.948
	2019	69.04	66.40	107.28	124.28	5.216
	2018	56.88	54.64	88.39	102.40	4.26

Tab.6 Income matrix of competition and cooperation game between Yantai port and Weihai Port

Player/Strategy		Weihai port: Competition	Weihai port: Cooperation
Yantai port	Competition	$\pi_1^{jj} = 24.43$ $\pi_2^{jj} = 15.02$	$\pi_1^{jh} = 33.25$ $\pi_2^{jh} = 14.11$
	Cooperation	$\pi_1^{hj} = 23.40$ $\pi_2^{hj} = 26.98$	$\pi_1^{hh} = 29.61$ $\pi_2^{hh} = 41.82$

(Unit: 100 million yuan)

Observing the above table, we can get conclusions similar to those of Qingdao Port and Rizhao Port. For Yantai Port and Weihai Port, it can be concluded that cooperation is the most beneficial strategic choice for the two ports. Through stability analysis and calculation, the expected return difference of Yantai Port is -2.596, and that of Weihai Port is 5.35. This means Yantai Port and Weihai Port do not have the stability of cooperation, as a result, the two ports also need a mechanism to promote the development of cooperation between the two ports.

5. Competitive Development Strategy of Shandong Peninsula Port

(1) Speed up port function positioning and improve infrastructure construction

For Shandong Peninsula ports, the level of infrastructure construction should be improved, function positioning should be accelerated, and a unique port cooperation situation should be formed. All ports in the group are suggested to build large-scale container terminals that meet their own development needs as well as improve the efficiency of cargo handling. Furthermore, there is a need to strengthen the cooperation between ports and rationally position the functions of ports at all levels.

(2) Establish a complete information service platform to share more port information

Through information sharing, port operation efficiency will be greatly improved. Ports can learn more about cargo, ships and other ports on the information service platform. Besides, timely and accurate service information can improve the overall operation of the port group system's effectiveness.

(3) Establish an effective management organization and improve the port management system

For Shandong Peninsula ports, it is necessary to continue to establish a strong management organization to coordinate the interests of the ports. The government should make unified arrangements for the construction and development of ports at a higher level, promote cooperation between ports, form a joint force for their respective contribution capabilities.

(4) Accelerate the integration of ports and promote the integration of coastal areas

Shandong Peninsula's ports continue to integrate, and the effective promotion of resource integration has released the development vitality of the ports in the group. Shandong Peninsula should accelerate the promotion of port integration and make breakthroughs in the integration of the coastal areas.

6. Conclusion

The main conclusions of the research are as follows:

(1) Together with the existing literature, the paper claims that the current development of Shandong Peninsula ports shows various problems which are lacking unified management, serious duplication of construction and so on.

(2) In applying game theory to the current development of ports, the Bertrand game model of competition and cooperation was established to form four strategy combinations which are competition-competition, competition-cooperation, cooperation-competition and cooperation-cooperation. Qingdao Port and Rizhao Port are taken as examples. From a quantitative point of view of the game analysis of the two ports, it is concluded that Qingdao Port is more sensitive to the price influence coefficient. Qingdao Port needs to strengthen cooperation. At the same time, the game analysis of Yantai Port and Weihai Port was carried out, and similar conclusions were obtained. Therefore, the game model in this article can be extended to other ports with strong alternative services in Shandong Peninsula to analyze the competition and cooperation relationship among ports, and to draw the most favorable strategy choice for port development.

(3) If the Shandong Peninsula port group desires to achieve better and faster development, it must make overall planning, rational division of labor, speed up the function positioning of the port, optimize the construction of infrastructure, establish a strong management organization, plan and effectively manage the port group. All ports should strengthen cooperation and seek for development through cooperation in order to accelerate the economic growth of Shandong Peninsula and ensure the sustainable development of Shandong Peninsula ports.

Acknowledgements

The authors would like to acknowledge the Natural Science Foundation of China (61873071, 51911540478, G61773015), Shandong Jiaotong University PhD Startup foundation, key research and development plan of Shandong province (2019JZZY020712).

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Received **14 June 2021**
Accepted **16 June 2021**