Container Terminal Competition Considering Blockchain and Government Support

Mingzhu Yu [1, a], Zhen Huang [2, b], Haoran Yang [2 *]

mzyu@szu.edu.cn[a], 2947917587@qq.com[b], * Corresponding author: 2210474193@email.szu.edu.cn

College of Management, Shenzhen University, Shenzhen 518060, China[1]

Department of Transportation, College of Civil and Transportation Engineering, Shenzhen University, Shenzhen 518060, China[2*]

Abstract. Blockchain technology is considered an effective solution for addressing the issue of information silos in terminal management. This study investigates the competitive strategies of container terminals considering blockchain technology and government support for hinterland logistics development. We constructed a two-stage game model to examine the impact of terminal service prices and hinterland logistics levels on competition. Basing a regional port system with two ports, each equipped with a container terminal, we explored four scenarios based on whether the terminals adopt blockchain technology. We analyzed the effects of these decisions on terminal operators' strategies. Finally, we summarized the following managerial insights: for terminal operators, we recommend actively adopting blockchain technology to address information silos and enhance competitiveness. Furthermore, terminals are more inclined to jointly adopt blockchain technology only when it provides high levels of information transparency.

Keywords: Container terminal competition; Blockchain; Regional ports

1 Introduction

With the growth of regional economies and increasing integration of supply chains, terminals within regional port system worldwide are experiencing intensified competition. Studying competitive strategies of container terminals is crucial for shipping market. Zhou and Kim[1] propose a game theoretic model for optimizing terminal handling charges in multiple container terminals, considering both competitive and cooperative game scenarios. Asadabadi and Miller-Hooks[2] employ a multi-level multiplayer game approach, resulting in increased demand, market share, and improvements in port services. Gleser et al.[3] examine the competitive dynamics and hinterland connectivity of ports in the European northern range. Using a simulation model, it assesses the potential hinterland scope of each port and mode in NRW, along with the impact of increasing carbon tax rates. Borger et al.[4] examine the duopolistic pricing strategies adopted by congestible ports which also share a congested downstream transport network with other users in their respective hinterlands. However, none of these studies considere the impact of blockchain technology.

Blockchain technology has proven highly beneficial in many industries, including maritime shipping. Choi et al.[5] explore how customer risk attitudes influence pricing decisions for on-

ICBBEM 2024, March 29-31, Wuhan, People's Republic of China

DOI 10.4108/eai.29-3-2024.2347468

demand service platforms, emphasizing the role of blockchain technology in facilitating customized pricing strategies based on risk preferences. Wang et al.[6] conduct research into the two heterogeneous ports when blockchain technology is applied under inter-port competition. Liu et al.[7] conduct a comprehensive review and investigation to address the absence of blockchain application in the maritime supply chain, and obstacles facing the blockchain-based maritime supply chain system. Czachorowski et al.[8] present insights into leveraging blockchain technology to reduce pollution in the maritime industry, highlighting its potential for enhancing environmental efficiency, supply chain connectivity, data transparency, and regulatory compliance while reducing operational costs and increasing security. However, research on the application of blockchain technology in the maritime shipping industry is relatively limited. This paper integrates blockchain technology into the study of port competition, exploring its impact on port competition.

This paper establishes a two-stage game model to depict competition between ports and local governments. By analyzing and solving the model through backward deduction, equilibrium solutions for ports and city governments are obtained under different scenarios and compared. Additionally, the study investigates the impact of blockchain on port operators' strategies. Since we have derived the closed-form solutions of the equilibria, the sensitivity analysis of the model is carried out through numerical experiments by setting specific values of the parameters directly.

2 Model Construction and Analysis

This study focuses on a regional port system consisting of two port cities, where each port has a container terminal. city i owns terminal i, and city j owns terminal j. We assume that terminal i and terminal j are homogeneous. At the governmental level, higher government investment in hinterland logistics infrastructure leads to a more comprehensive hinterland logistics level for the terminal, thus increasing its competitiveness. At the terminal level, higher terminal service levels correspond to stronger competitiveness. The study categorizes containers into two types: local import-export containers and transshipment containers. Local import-export containers typically refer to containers used for domestic import and export cargo transportation. Transshipment containers are containers transshipped at the port, thus not undergoing hinterland transportation. We consider the impact of blockchain technology, where the adoption of blockchain by terminals would increase their container throughput, but it also introduces risks of privacy leakage. In addition to this, we also consider the supportive role of the government, which provides subsidies to terminals adopting blockchain technology. The subsidies are divided into two parts: subsidies for terminal operating costs and subsidies for blockchain adoption fixed costs.

In the subsequent sections of this chapter, we model different scenarios based on the decision of whether two container terminals adopt blockchain technology. We analyze the terminal service prices, container throughput, and hinterland logistics level under each scenario and derive equilibrium solutions.

2.1 Parameter Settings

The parameters involved in the model are listed in Table 1.

Table 1. Notations.

Parameter	
M	Market potential for transshipment container throughput.
N	Local import-export container throughput.
a	Hinterland logistics level unit service benefits to terminals.
t	Unit transportation cost of container hinterland transportation.
α, β	Sensitivity of transshipment container throughput to the price of services at terminal *i* and terminal *j*. $\alpha \geq \beta$
γ, μ	Sensitivity of transshipment container throughput to the level of hinterland logistics in terminal *i* and terminal *j*. $\gamma \geq \mu$
ω_i, ω_j	Revenue per unit of container throughput for city *i* and city *j*.
ϕ_i, ϕ_j	Unit investment costs for city *i* and city *j* for the construction of hinterland logistics facilities.
p_i, p_j	Unit price of container service at the terminal *i* and terminal *j*.
x_i, x_j	The hinterland logistics level of city *i* and city *j*.
c	Unit cost of container service at the terminal *i* and terminal *j*.
λ	Factor of increase in market potential from blockchain adoption; $\lambda \geq 1$.
θ	Privacy costs
δ	Subsidy factor for unit operating cost granted by the government. $\delta > 0$.
ζ	Subsidy factor for fixed cost granted by the government.$\zeta > 0$.
f	Fixed costs of adopting blockchain.

The decision variables are:

D_i^O, D_j^O: Import-export container throughput at terminal *i* and terminal *j*;

D_i^H, D_j^H: Transshipment container throughput in terminal *i* and terminal *j*;

D_i, D_j: Total container throughput at terminal *i* and terminal *j*;

$\pi_i^T(p,x)$, $\pi_j^T(p,x)$: Expected profit function for terminal *i* and terminal *j*;

$\pi_i^G(p,x)$, $\pi_j^G(p,x)$: Expected profit function for city *i* and city *j*.

2.2 Basic Assumptions

Assumption 1. Terminal *i* and terminal *j* are homogeneous;

Assumption 2. The sensitivity of service prices is greater than the sensitivity of hinterland logistics levels;

Assumption 3. When both terminals adopt blockchain technology, there are no privacy costs.

2.3 Both Do Not Adopt Blockchain Technology: NN

Taking into account the location and homogeneity of ports, this paper adopts the Hotelling model to characterize the throughput of local import-export containers. Customers are evenly distributed in [0,1]. Let z be the point of indifference for customers, as shown in Equation(Error! Bookmark not defined.). Customers to the left of z will choose terminal i, while those to the right will choose terminal j. Solving Equation (Error! Bookmark not defined.), we obtain the D_i^O and D_j^O:

$$p_i - ax_i + tz = p_j - ax_j + t(1-z) \qquad \text{(Error! Bookmark not defined.)}$$

$$D_i^o = N\frac{p_j - p_i + ax_i - ax_j + t}{2t}, D_j^o = N\left(1 - \frac{p_j - p_i + ax_i - ax_j + t}{2t}\right) \qquad \text{(Error! Bookmark not defined.)}$$

A higher level of hinterland logistics will also attract customers to transport containers through the port. Therefore, this paper characterizes the throughput of transshipment containers based on the traditional linear demand model, considering factors such as port service prices and hinterland logistics levels. Therefore, we can determine the container throughput of the port, as Equation (Error! Bookmark not defined.).

$$D_i^H = M - \alpha p_i - \beta p_j + \gamma x_i - \eta x_j, \qquad D_j^H = M - \alpha p_j - \beta p_i + \gamma x_j - \eta x_i \text{(Error! Bookmark not defined.)}$$

$$D_m = D_m^O + D_m^H, \qquad m \in \{i, j\} \qquad \text{(Error! Bookmark not defined.)}$$

We assume that unit terminal operating cost is quadratic with respect to throughput.Therefore, the expected profit of the Terminal is shown as Equation (Error! Bookmark not defined.).According to the theory of diminishing returns, it is understood that the marginal investment cost of a city will increase with the level of hinterland logistics system. In this paper, it is assumed that the investment cost is a quadratic function of x_i, the expected profit of the city is shown as Equation (Error! Bookmark not defined.).

$$\pi_m^T(p,x) = p_m D_m - cD_m^2, \qquad m \in \{i, j\} \qquad \text{(Error! Bookmark not defined.)}$$

$$\pi_m^G(p,x) = w_m D_m - \phi_m x_m^2, \qquad m \in \{i, j\} \qquad \text{(Error! Bookmark not defined.)}$$

2.3.1 NN Model Analysis

The pricing decisions made by terminal operators are short-term decisions, while the decisions regarding the hinterland logistics level made by city governments are long-term decisions. Therefore, firstly, the local governments of the two port cities determine their hinterland logistics level, and then the terminal operators of the two ports determine their service prices.

By Equation (Error! Bookmark not defined.), deriving the equilibrium solution for port service prices given the level of inland logistics, we can obtain the best response functions for the service prices:

$$p_i = \frac{1+2kc}{2k(1+kc)}\left(lp_j + dx_i - ex_j + \frac{N}{2} + M\right),$$

$$p_j = \frac{1+2kc}{2k(1+kc)}\left(lp_i + dx_j - ex_i + \frac{N}{2} + M\right)$$

$$k = \frac{N}{2t} + \alpha, \ l = \frac{N}{2t} + \beta, \ d = \frac{aN}{2t} + \gamma, \ e = \frac{aN}{2t} + \eta \qquad \text{(Error! Bookmark not defined.)}$$

Due to the concave nature of Equation (Error! Bookmark not defined.), an equilibrium exists in price for container terminal. From Equations (Error! Bookmark not defined.), the equilibrium prices for container ports are obtained as Equations (Error! Bookmark not defined.). Substituting the equilibrium prices for container terminal into Equation (Error! Bookmark not defined.) and Equation (Error! Bookmark not defined.) respectively, the total equilibrium demands are shown as Equations (Error! Bookmark not defined.). Substituting the equilibrium prices for container terminal into Equation (Error! Bookmark not defined.), we obtain the profit functions for cities as Equations (Error! Bookmark not defined.).

$$p_i^{NN} = (-elA + 2kdB)x_i + (ldA - 2keB)x_j + (lA + 2kB)\left(\frac{N}{2} + M\right),$$
$$p_j^{NN} = (-elA + 2kdB)x_j + (ldA - 2keB)x_i + (lA + 2kB)\left(\frac{N}{2} + M\right),$$
$$A = \frac{(1+2kc)^2}{4k^2(1+kc)^2 - l^2(1+2kc)^2}, B = \frac{(1+2kc)(1+kc)}{4k^2(1+kc)^2 - l^2(1+2kc)^2} \quad \text{(Error! Bookmark not defined.)}$$
$$D_i^{NN} = -kp_i^{NN} + lp_j^{NN} + dx_i^{NN} - ex_j^{NN} + \frac{N}{2} + M,$$
$$D_j^{NN} = -kp_j^{NN} + lp_i^{NN} + dx_j^{NN} - ex_i^{NN} + \frac{N}{2} + M \quad \text{(Error! Bookmark not defined.)}$$
$$\pi_i^G = w_i D_i - \phi_i x_i^2 = w_i[-k(-elA + 2kdB) + l(ldA - 2keB) + d]x_i$$
$$+w_i[-k(ldA - 2keB) + l(-elA + 2kdB) - e]x_j + w_i[-k(lA + 2kB)$$
$$+w_i l(lA + 2kB) + 1](\frac{N}{2} + M) - \phi_i x_i^2,$$
$$\pi_j^G = w_j D_j - \phi_j x_j^2 = w_j[-k(-elA + 2kdB) + l(ldA - 2keB) + d]x_j$$
$$+w_j[-k(ldA - 2keB) + l(-elA + 2kdB) - e]x_i + w_j[-k(lA + 2kB)$$
$$+w_j l(lA + 2kB) + 1](\frac{N}{2} + M) - \phi_j x_j^2 \quad \text{(Error! Bookmark not defined.)}$$

Due to the concave nature of Equations (Error! Bookmark not defined.), an equilibrium exists in the level of inland logistics.Taking the first order derivatives of Equations (Error! Bookmark not defined.) to zero , an equilibrium solution for the level of logistics in the hinterland is show as Equation (Error! Bookmark not defined.):

$$x_m^{NN} = \frac{w_m[l(ke+ld)A - 2k(kd+el)B + d]}{2\phi_m}, m \in \{i, j\} \quad \text{(Error! Bookmark not defined.)}$$

2.4 Both Ports Adopt Blockchain Technology: BB

Using blockchain technology, the situation of information blockade between terminals has been improved, providing more opportunities and confidence for market participants, thus stimulating the potential demand in the market. Therefore, we assume that the potential demand in the market has increased from the original M to λM. The government will subsidize the operating costs of ports and the fixed costs of using blockchain separately. In addition, because blockchain technology improves information transparency, customers need to bear the risk of privacy leakage when choosing a terminal to be put on the chain. We assume that θ represents the privacy cost borne by customers when choosing a terminal to be put on the chain. We can calculate the port's container throughput and expected profit, as well as the expected profit function for terminal and city:

$$D_i^{o(BB)} = N\frac{p_j - p_i + ax_i - ax_j + t}{2t}, D_j^{o(BB)} = N\left(1 - \frac{p_j - p_i + ax_i - ax_j + t}{2t}\right) \text{(Error! Bookmark not defined.)}$$
$$D_i^{H(BB)} = \lambda M - \alpha p_i - \beta p_j + \gamma x_i - \eta x_j, D_j^{H(BB)} = \lambda M - \alpha p_i - \beta p_j + \gamma x_j - \eta x_i \text{(Error! Bookmark not defined.)}$$
$$D_m^{(BB)} = D_m^{o(BB)} + D_m^{H(BB)}, \quad m \in \{i, j\} \quad \text{(Error! Bookmark not defined.)}$$
$$\pi_i^{T(BB)}(p, x) = p_i D_i - cD_i^2 - c\delta D_j - f(1 - \zeta),$$
$$\pi_j^{T(BB)}(p, x) = p_j D_j - cD_j^2 - c\delta D_i - f(1 - \zeta) \quad \text{(Error! Bookmark not defined.)}$$
$$\pi_m^{G(BB)}(p, x) = w_m D_m - \phi_m x_m^2 - \zeta f, \quad m \in \{i, j\} \quad \text{(Error! Bookmark not defined.)}$$

2.4.1 BB Model Analysis

Solving Equations (Error! Bookmark not defined.), the equilibrium prices for container terminal are obtained as Equations (17):

Substituting the equilibrium price for container terminal into Equation (Error! Bookmark not defined.) and Equation (Error! Bookmark not defined.) respectively, we can derive the equilibrium demand for containers as Equation (Error! Bookmark not defined.) and the profit function of city as Equation (Error! Bookmark not defined.).

$$p_i^{BB} = (-elA + 2kdB)x_i + (ldA - 2keB)x_j + (lA + 2kB)\left(\frac{N}{2} + \lambda M\right) - \frac{2k^2cB\delta}{1+2kc},$$

$$p_j^{BB} = (-elA + 2kdB)x_j + (ldA - 2keB)x_i + (lA + 2kB)\left(\frac{N}{2} + \lambda M\right) - \frac{2k^2cB\delta}{1+2kc} \quad \text{(Error! Bookmark not defined.)}$$

$$D_i^{BB} = -kp_i^{BB} + lp_j^{BB} + dx_i^{BB} - ex_j^{BB} + \frac{N}{2} + \lambda M,$$

$$D_j^{BB} = -kp_j^{BB} + lp_i^{BB} + dx_j^{BB} - ex_i^{BB} + \frac{N}{2} + \lambda M \qquad \text{(Error! Bookmark not defined.)}$$

$$\pi_m^{G(BB)}(p,x) = w_m D_m^{BB} - \phi_m x_m^2 - \zeta f, \qquad m \in \{i,j\} \qquad \text{(Error! Bookmark not defined.)}$$

Taking the first order derivative of Equation (Error! Bookmark not defined.) to zero , an equilibrium solution for the level of logistics in the hinterland is show as Equation (Error! Bookmark not defined.):

$$x_m^{BB} = \frac{w_m[l(ke+ld)A - 2k(kd+el)B + d]}{2\phi_m}, \; m \in \{i,j\} \qquad \text{(Error! Bookmark not defined.)}$$

2.5 One Adopts Blockchain While The Other Does Not: BN/NB

As terminal *i* and terminal *j* are homogeneous, we only present the scenario where terminal *i* adopts blockchain while terminal *j* does not , named BN. The profit functions of the terminal and the government are shown as Equation (Error! Bookmark not defined.) and Equation (Error! Bookmark not defined.).

$$D_i^{o(BN)} = N\frac{p_j - p_i + ax_i - ax_j + t - \theta}{2t}, \; D_j^{o(BN)} = N\frac{p_i - p_j + ax_j - ax_i + t}{2t} \text{(Error! Bookmark not defined.)}$$

$$D_i^{H(BN)} = \lambda M - \alpha p_i - \beta p_j + \gamma x_i - \eta x_j, \qquad D_j^{H(BN)} = M - \alpha p_j - \beta p_i + \gamma x_j - \eta x_i \text{(Error! Bookmark not defined.)}$$

$$D_m^{BN} = D_m^{o(BN)} + D_m^{H(BN)}, \qquad m \in \{i,j\} \qquad \text{(Error! Bookmark not defined.)}$$

$$\pi_i^{T(BN)} = p_i D_i - cD_i^2 + c\delta D_i - f(1-\zeta), \qquad \pi_j^{T(BN)} = p_j D_j - cD_j^2 \text{(Error! Bookmark not defined.)}$$

$$\pi_i^{G(BN)}(p,x) = w_i D_i - \phi_i x_i^2 - \zeta f, \qquad \pi_j^{G(BN)}(p,x) = w_j D_j - \phi_j x_j^2 \text{(Error! Bookmark not defined.)}$$

2.5.1 BN Model Analysis

Then, deriving the equilibrium solutions for terminal service prices given the level of inland logistics, we can obtain the best response function for the service prices as follows.

$$p_i^{BN} = \frac{1+2kc}{2k(1+kc)}\left[lp_j + dx_i - ex_j + \frac{t-\theta}{t}\frac{N}{2} + \lambda M\right] - \frac{kc\delta}{2k(1+kc)},$$

$$p_j^{BN} = \frac{1+2kc}{2k(1+kc)}\left(lp_i + dx_j - ex_i + \frac{N}{2} + M\right) \qquad \text{(Error! Bookmark not defined.)}$$

$$p_i^{BN} = (-elA + 2kdB)x_i + (ldA - 2keB)x_i + \left(lA + \frac{t-\theta}{t}2kB\right)\frac{N}{2}$$
$$+(lA + 2kB\lambda)M - \frac{2k^2cB\delta}{1+2kc},$$
$$p_j^{BN} = (-elA + 2kdB)x_j + (ldA - 2keB)x_i + (\frac{t-\theta}{t}lA + 2kB)M - \frac{kclB\delta}{1+kc} \text{(Error! Bookmark not defined.)}$$

Substituting the equilibrium terminal service price into Equation (Error! Bookmark not defined.) and Equation (Error! Bookmark not defined.) respectively, the total demands are shown as Equations (Error! Bookmark not defined.), Substituting the equilibrium terminal service prices into Equation (Error! Bookmark not defined.) and Equation (Error! Bookmark not defined.) respectively, the profit functions are shown as Equations (Error! Bookmark not defined.):

$$D_i^{BN} = -kp_i^{BN} + lp_j^{BN} + dx_i - ex_j + \frac{t-\theta}{t}\frac{N}{2} + \lambda M,$$
$$D_j^{BN} = lp_i^{BN} - kp_j^{BN} + dx_j - ex_i + M + \frac{N}{2} \qquad \text{(Error! Bookmark not defined.)}$$
$$\pi_i^{G(BN)} = w_i D_i^{BN} - \phi_i {x_i^{BN}}^2 - \zeta f, \qquad \pi_j^{G(BN)} = w_j D_j^{BN} - \phi_j {x_j^{BN}}^2 \text{(Error! Bookmark not defined.)}$$

Taking the first order derivative of Equation (Error! Bookmark not defined.) to zero , an equilibrium solution for the level of logistics in the hinterland is show as Equations (Error! Bookmark not defined.):

$$x_i^{BN} = \frac{w_i[-k(-elA+2kB)+l(ldA-2keB)+d]}{2\phi_i},$$
$$x_j^{BN} = \frac{w_j[l(ldA-2keB)-k(2kdB-elA)+d]}{2\phi_j} \qquad \text{(Error! Bookmark not defined.)}$$

2.6 Adoption Strategies

Prisoner's dilemma is a classic problem in game theory, used to reflect the optimal choices of individuals. Based on the equilibrium profits derived above in four scenarios, we summarize the expected profit matrix for the ports as Table 2.

Table 2. Prisoner's dilemma.

terminal j / *terminal i*	*B*	*N*
B	$\pi_i^{T(BB)}, \pi_j^{T(BB)}$	$\pi_i^{T(BN)}, \pi_j^{T(NB)}$
N	$\pi_i^{T(NB)}, \pi_j^{T(BN)}$	$\pi_i^{T(NN)}, \pi_j^{T(NN)}$

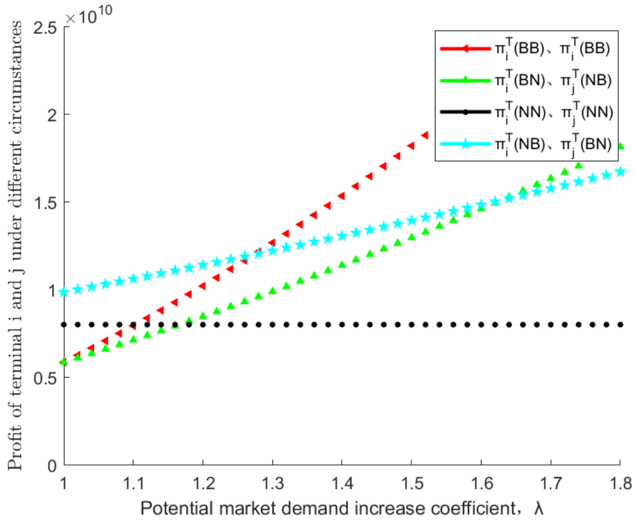

Fig. 1. The relationship between terminal profit and the increase factor of market potential.

We conducted numerical experiments according to the following parameter settings and presented the results in the Fig. 1..

$M = 8 \times 10^8$ TEU; $N = 1 \times 10^7$ TEU; $t = \$7 \times 10^3$/TEU; $c = \$10$/TEU ; $\theta = \$6000$/TEU ; $f = \$8 \times 10^9$; $\zeta = 0.5$; $\lambda = 4$; $\delta = 0.2$; $\omega_i = \omega_j = \$4000$/TEU ; $\phi_i = \$40/\text{TEU}^2$; $a = \$0.25$ per unit; $\alpha = 9 \times 10^6$ TEU per dollar; $\beta = 6.5 \times 10^6$TEU per dollar

$\gamma = 0.06$TEU per unit; $\eta = 0.03$ TEU per unit .

It is shown as Fig. 1., it is evident that the profit of a blockchain-enabled terminal is directly proportional to the potential market demand for container throughput. The profit of a blockchain-enabled terminal continues to increase. Therefore, container terminals should actively adopt blockchain technology to reap greater profits.

(a) When $\lambda \in (1, 1.1)$, $\pi_i^{T(NN)} > \pi_i^{T(BN)}, \pi_j^{T(NN)} > \pi_j^{T(NB)}$, NN is the Nash equilibrium for terminals competition. This indicates that when the value brought to terminals by adopting blockchain is low, terminals tend not to adopt blockchain.

(b) When $\lambda \in (1.18, 1.28)$, $\pi_i^{T(NB)} > \pi_i^{T(BB)}, \pi_j^{T(BN)} > \pi_j^{T(BB)}$. BN and NB are the Nash equilibrium for terminals competition. This indicates that when the information brought by blockchain technology is moderate, if one terminal adopts blockchain, the other terminal finds that the profit from not adopting blockchain is greater than that from adopting it, so it tends to not adopt blockchain.

(c) When $\lambda \in (1.28, 1.8)$, $\pi_i^{T(BB)} > \pi_i^{T(BN)}, \pi_j^{T(BB)} > \pi_j^{T(BN)}$. BB is the Nash equilibrium for terminals competition. This indicates that when the transparency of information brought by adopting blockchain is high, there is a positive increase in profits for both terminals, so both tend to adopt blockchain.

3 Conclusion

The paper establishes a two-stage game model to depict the competition between terminals and cities, and then analyzes the impact of blockchain on the decisions of terminals and local city governments. We use a backward induction method to derive the equilibrium solution for service prices, followed by obtaining the equilibrium solution for hinterland logistics levels. A prisoner's dilemma matrix is constructed to analyze the value of blockchain application, and different scenarios of terminal profits are plotted. The results indicate that the value of blockchain application depends on the level of information transparency it can provide. When the transparency of blockchain information is high, both terminals tend to jointly adopt blockchain to achieve optimal profits.

Acknowledgments. This research is supported by the National Natural Science Foundation of China (No.72171153).

References

[1] Zhou, Y., and Kim, K. H.: A game theoretic model and a coevolutionary solution procedure to determine the terminal handling charges for container terminals. Computers & Industrial Engineering, Vol.(144), pp. 106466 (2020)

[2] Asadabadi, A., Elise Miller-Hooks.: Co-opetition in enhancing global port network resiliency: A multi-leader, common-follower game theoretic approach. Transportation Research Part B: Methodological, Vol. 108, pp. 281-298 (2018)

[3] Gleser, M., Elbert, R., and Wu, H.: Port Competition through Hinterland Connectivity—A Case Study for Potential Hinterland Scope in North Rhine-Westphalia (NRW) Regarding an Environmental Policy Measure. Sustainability, Vol.15(3), pp.1980 (2023)

[4] Borger, B. D., Proost, S., D Ender, K. V.: Private Port Pricing and Public Investment in Port and Hinterland Capacity. Journal of Transport Economics & Policy. Vol. 42(9), pp. 527-561 (2008)

[5] Choi, T. M., Guo, S., Liu, N., and Shi, X.: Optimal pricing in on-demand-service-platform-operations with hired agents and risk-sensitive customers in the blockchain era. European Journal of Operational Research, Vol. 284(3), pp. 1031-1042 (2020)

[6] Wang, J., Liu, J., Wang, F., and Yue, X.: Blockchain technology for port logistics capability: Exclusive or sharing. Transportation Research Part B: Methodological. Vol:149, pp. 347-392 (2021)

[7] Jiaguo Liu., Huimin Zhang., and Lu Zhen.: Blockchain technology in maritime supply chains: applications, architecture and challenges. International Journal of Production Research. Vol. 61(11), pp. 3547-3563 (2023)

[8] Czachorowski, K., Solesvik, M., and Kondratenko, Y.: The application of blockchain technology in the maritime industry. Green IT engineering: Social, business and industrial applications, pp. 561-577 (2019)