Considering the double asymmetric emission reduction strategy of finance and information between port and shipping cooperation under carbon tax

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Abstract: Vertical cooperation is a key decision for port and shipping supply chain members to achieve energy saving and emission reduction goals. In this study, a three-stage Stackelberg model is constructed by considering a green emission reduction investment strategy in a two-level port and shipping supply chain consisting of a port and two shipping companies with financial asymmetry and asymmetric information under carbon tax regulation, and introducing factors such as carbon tax regulation and variable costs. Among them, the port maintains a long-term information-sharing partnership with the financially weak shipping company, which competes with the financially strong shipping company for Cournot, and the port provides loading and unloading services for both shipping companies. The study shows:(1) The port's abatement investment coefficient and information sharing discount simultaneously affect the level of abatement. (2) Emission reduction investment coefficient and information sharing cooperation discount are important influencing factors for the port to benefit from vertical cooperation (3) When port and shipping companies focus more on developing a certain cooperation strategy, or the cooperation intensity of both capital investment and information cooperation is more balanced, the port is more likely to benefit from investing in shipping companies with weak capital.

Keywords: Port and shipping vertical cooperation, information sharing, green emission reduction investment, financial asymmetry, shipping carbon tax

1 INTRODUCTION

In the form of increasing global energy scarcity and gradually shrinking environmental capacity, governments have introduced a series of low-carbon policies to control excessive carbon emissions from port and shipping industry. The carbon tax policy was proposed by the European Union in 2012 and is planned to implement on shipping emissions. Against the background of increasingly stringent environmental policy constraints such as carbon tax [1], the government has put forward higher requirements for low-carbon behavior in port and shipping operations. For this reason ports and shipping companies have to take countermeasures. On the one hand, in order to realize the economic and environmental returns in carbon emission reduction, shipping companies have increased their efforts to actively invest in green energy saving and emission reduction technologies by purchasing LNG vessels, scrapping and renewing old vessels, converting oil to gas, and switching to light oil [4]. Lu Zhen et al. [11] introduced the problems restricting China's current shipping emission reduction from the perspective of

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shipping green technology, and put forward management suggestions. Wang et al. [9] combined the decision-making of the government, ports and shipping companies to solve the optimization problem of government subsidy to LNG ships under the condition of maximizing social benefits. The above articles rarely consider the financial situation of port and shipping enterprises to reduce emissions. Especially when it comes to green investment of many large LNG ships, it is difficult for small and medium-sized enterprises to realize their business decision-making and emission reduction investment.

On the other hand, in addition to the horizontal cooperation form of alliance, the uncertainty of the general policy environment and the competitive situation of the industry has prompted the shipping supply chain to extend upstream and downstream and seek the opportunity of vertical cooperation in shipping to improve the core competitiveness [10]. In recent years, as port and shipping cooperation methods have been pushed out, more port enterprises have taken the initiative to participate in the acquisition of shipping companies, such as Shanghai Port Group holding 9.9% of OOCL. There are fewer studies in this area, among which Song [8] found that the Pareto gain of the whole shipping supply chain can be improved by port investment at the cost of extracting more surplus from shippers. Metzger [7] applied financing methods such as fuzzy revenue to illustrate the choice of shared balances for green emission reduction technologies from the perspective of green technology financing, addressing the financing problem and shipping emission reduction measures between the research gap. Although sustainability investments have been widely considered in other related industries [2], less consideration has been given to corporate financial asymmetries in the case of financial flow cooperation between ports and shipping.

In addition, port and maritime cooperation has expanded from traditional port business to port information technology cooperation. Data prove that port supply chain information sharing mechanism can shorten delivery time by 10%-20% and bring 30% cost savings in case turning [5]. For this area, although it has been commonly practiced in the port and shipping industry, there is less related literature. Lai [3] considered risk behavior and information sharing on the basis of sustainable investment in maritime supply chains and found that port information sharing helps to improve the profitability and sustainability investment of both ports and shipping. Zheng [12] focused on the demand information sharing for welfare maximizing port authorities and profit maximizing ports. The study found that when the externality of information sharing on welfare exceeds a certain unit, both competing ports can benefit from cooperation in information sharing. However, ports' green investments in shipping companies need to take into account realistic factors. On the one hand, the target shipping companies often have financial asymmetry, and investors will measure the financial status and financial strength of the target companies. In addition to this, ports seeking vertical cooperation opportunities may have a span of time and cooperation methods, and studies have shown that corporate investments will prefer to consider companies that have experience or are in the process of cooperation, even if it is a basic information cooperation sharing (Wan 2020). In contrast, ports prefer to apply information sharing cooperation to port-owned shipping companies with the same information sharing system and related interests. These shipping companies are often backed by ports and have relatively small market size. In addition, ports cultivate their own shipping companies to compete with large companies, and in order to avoid the situation that other shipping companies are dominant, they often choose to favor their own shipping companies in terms of information and policies through information sharing cooperation, which makes it more practical to consider information cooperation sharing.

Based on this, this paper needs to address and analyze the decision problem of the port's emission reduction level and investment strategy when the port makes green emission reduction investment for one shipping company with double asymmetry of financial information. For this purpose, under the carbon tax policy, this paper considers a secondary shipping supply chain consisting of one port and two shipping companies. The port provides port operation services to two financially asymmetric shipping companies, and the shipping companies participate in duopoly competition among themselves. The financially weak shipping company cooperates with the port in surviving information sharing. In addition, the port makes green energy saving and emission reduction investments for the shipping companies (e.g., purchase of LNG vessels, etc.), and the shipping companies cooperate in the form of returning part of the investment return after the investment is completed. The model framework can be seen as the port will provide loading and unloading operation services to two shipping companies with different financial status, and make green energy saving and emission reduction investment and information sharing for them to help shipping companies reduce carbon emissions. The contributions of this study are summarized as follows. When considering the shipping vertical cooperation strategy, the impact of two cooperation strategies, information sharing cooperation and green emission reduction investment, on the port's revenue and emission reduction level is considered; unlike previous literature on low carbon supply chain financing, the port provides green emission reduction investment decisions for shipping companies with both financial and information asymmetry, which is more innovative and realistic.

2 MODEL CONSTRUCTION

2.1 Model Description

The reverse demand function of the two shipping companies is characterized as follows: $p = d - q_1 - q_2$. Both shipping companies M_1, M_2 are required to pay a carbon tax at the end of port service. However, there is a financial asymmetry between the two shipping companies. Shipping companies M_1 are relatively well-funded and have enough working capital to carry out loading and unloading operations in ports for a long time, but they do not have the capital to invest in carbon emission reduction green technology (such as investing in multiple LNG ships). Shipping companies M_2 are relatively undercapitalized, subject to more severe capital constraints, and do not have enough capital to invest in green technology projects other than traditional port operations services. Although the shipping company M_2 is weak in capital, it is backed by the port and has a long-term information sharing cooperation relationship. The shipping company only needs to pay the information sharing cost and management fee, and can obtain the port loading and unloading service at a partial discount when it attaches to the port. Port assistance for M_1 and M_2 to ease financial constraints is conducive to improving the overall efficiency of port and shipping supply chain, and to achieving ship tie-up business. Therefore, the port can provide green emission reduction investment service for M_1 or M_2 to reduce its initial emission level and return the investment profit to the port after the investment activities. Generally speaking, a port will choose an investment strategy for a shipping company due to its limited financial situation. Therefore, this paper considers two scenarios, discusses the green energy saving and emission reduction investment strategy provided by the port for shipping enterprises with different financial situations, and analyzes the value of the green energy saving and emission reduction investment strategy for the two shipping companies.

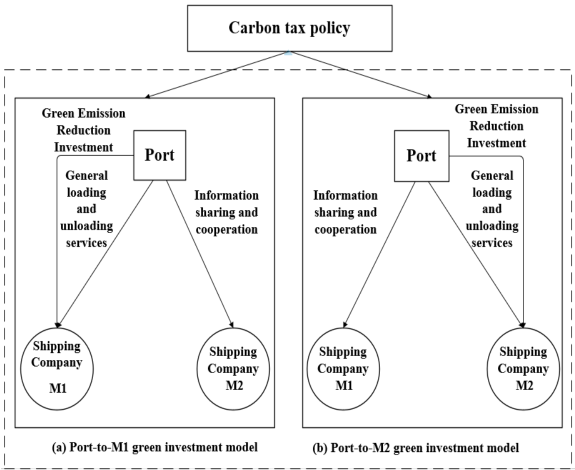

Figure1. the financial and information asymmetric emission reduction strategy model

2.2 Basic Assumptions and Parameter Settings

2.2.1 Basic Assumptions and Parameters setting

In order to facilitate analysis without loss of generality, the following assumptions are made for the model. It is assumed that both ports and shipping companies are rational decision makers pursuing profit maximization. Since the situation when shipping companies call at ports is considered, it is assumed that the capacity of ports is large enough and the handling capacity of ports is not affected by congestion and other factors; It is assumed that only one shipping company can make emission reduction investment under realistic conditions such as port constraints and its own finance; It is assumed that the carbon tax policy is implemented and the policy mainly charges the carbon emission of shipping companies during their port affiliation, that is, shipping companies need to pay carbon emission tax on the emissions generated when ships enter the emission control area and during the affiliation period. To simplify the modeling, assume that the operating cost of the port is 0; It is assumed that shipping companies have a long-term information cooperation relationship with ports, and ports do not need to pay extra costs for information cooperation; Assume that the discount income of information sharing cooperation is greater than the value of information sharing cost and total management expense paid by shipping companies at the end of the information sharing cooperation period, i.e. $c_e q_2 \geq m$;Referring to the research method of Ma [6] it is assumed that there is a quadratic positive correlation between emission reduction investment funds and emission reduction level.

Table1. Symbol description of this text.

Parameter	
p_i^j	E_j market price per TEU for handling at Port under Scenario (USD/unit)
d	Potential market Demand for handling Services (Unit)
β	Initial carbon emissions per TEU of port handling (kg/unit)
s	Unit price of carbon tax imposed by the Government on carbon emissions per TEU of stevedoring operations (USD/unit)
r	Port handling service discount for information sharing cooperation of shipping enterprises [0,1]
m	Value of information sharing cost and total management fee paid by shipping company at the end of information sharing cooperation period (USD/unit)
v	Cost coefficient of emission reduction investment [0,1]
λ	Return of investment profit to port by shipping company after completion of investment (USD/unit)
c_e	Unit variable cost of implementing green emission reduction investment services [0,1]
Decision variable	
t_i	Decision variable Shipping Enterprise i's target emissions (kg/unit)
w^{Ej}	Loading/unloading price per TEU under scenario E_j (USD/unit)
q_i^{Ej}	Quantity handled by Shipping Company i under Scenario E_j (Unit)

2.3 Model Scenario Analysis

2.3.1 Scenario E_1 of green energy saving and emission reduction investment strategy

The port chooses to provide green energy saving and emission reduction investment for M_1 with abundant funds, and maintain information sharing and cooperation with M_2. A three-stage Stackelberg game is played, and the decision order of the model is: in the first stage, the port bears the total investment cost of reducing the customer's M_1 emission level. Therefore, the port first determines a new target emission level t_1 for customer M_1, $(\beta - t_1)$ refers to the carbon emission reduction efforts taken by the port, and the total cost of emission reduction is $\frac{v}{2}(\beta - t_1)^2$. In the second stage, after the investment service of green emission reduction, the port and two shipping companies will carry out routine operation services, and the port will determine the loading and unloading operation prices w^{E1} of M_1 and M_2. Because of M_2' s information sharing cooperation, M_2 will obtain port services at a discounted price and pay the information sharing cost and management fee. Next, the two shipping companies decide their respective order quantities and. According to the regulations of carbon tax, M_1 and M_2 should pay carbon tax $st_1q_1^{E1}$ and $s\beta q_2^{E1}$ respectively. According to the investment service of green energy saving and emission reduction, shipping enterprise M_1 will share the investment income value with the port. In addition, there may be variable costs borne by M_1. Variable cost refers to the cost of reducing the transportation efficiency of the shipping company. The newly invested green emission reduction service may lead to a running-in period between the shipping company and the previous transportation mode, thus reducing the loading and unloading efficiency of the shipping company. In this scenario, there are variable costs $c_e q_1^{E1}$ borne by shipping company M_1. In this situation, the benefits of M_1 and M_2 are as follows:

$$\pi_1^{E2}(q_1^{E2}) = (d - q_1^{E2} - q_2^{E2})q_1^{E2} - w^{E2}q_1^{E2} - st_1q_1^{E2} - \lambda - c_e q_1^{E2} \tag{1}$$

$$\pi_2^{E1}(q_2^{E1}) = (d - q_1^{E1} - q_2^{E1})q_2^{E1} - w^{E1}rq_2^{E1} - m - s\beta q_2^{E1} \tag{2}$$

The port's revenue is primarily made up of operational services provided to shipping companies and shared carbon tax savings from making green energy efficiency and emission reduction investments, with profits as shown below:

$$\pi_s^{E1}(t_1, w^{E1}) = w^{E1}q_1^{E1} + m + w^{E1}rq_2^{E1} + \lambda - \frac{v}{2}(\beta - t_1)^2 \tag{3}$$

Derivation of (1)(2),the equilibrium decisions of the 3 supply chain members can be obtained by using backward induction, It is easy to test that $\pi_1^{E1}\left(q_1^{E1}\right)$ and $\pi_2^{E1}\left(q_2^{E1}\right)$ are concave functions with respect to q_1^{E1} and q_2^{E1}, respectively.

$$\pi_1^{E2}\left(q_1^{E2}\right) = d - c_e - 2q_1 - q_2 - w - st_1 \tag{4}$$

$$\pi_2^{E2}\left(q_2^{E2}\right) = d - q_1^{E2} - 2q_2^{E2} - rw^{E2} - s\beta \tag{5}$$

Solve both first-order conditions simultaneously and find the order quantity of the shipping company according to (4)(5), respectively.

$$q_1^{E2} = \frac{1}{3}\left(-2c_e + d + \beta s + (-2 + r)w - 2st_1\right) \tag{6}$$

$$q_2^{E2} = \frac{1}{3}\left(c_e + d - 2\beta s + w - 2rw + st_1\right) \tag{7}$$

Substituting the two ordering quantities into equation (3) separately, we can check the second-order condition $\frac{\partial^2 \pi_S^{E2}}{\left(\partial w^{E2}\right)^2} = \frac{2\left(r^2 - 3r - 2\right)}{3}$ of a with respect to w^{E2} as $\pi_S^{E1}\left(t_1, w^{E2}\right)$ concave function of off w^{E2} in. Solving for the first-order derivative of the two ordering quantities after substituting them into Eq. (3) with respect to w^{E2}, we find：

$$w^{E2} = -\frac{c_e - 2d + \beta s + 4c_e r - 2dr + st_1 - 2\beta rs + 4rst_1}{-4r^2 + 10r + 2} \tag{8}$$

Substituting the port handling price and two port operations into equation (3), we check the second-order condition $\pi_S^{E2}\left(t_1, w^{E2}\right)$ of t_1 find that $\frac{\partial^2 \pi_S^{E2}}{\left(\partial t_1\right)^2} = \frac{16r^2 s^2 + 24vr^2 + 8rs^2 - 60vr + s^2 - 12v}{12\left(-2r^2 + 5r + 1\right)}$, therefore, when $v > \frac{s^2(4r+1)^2}{-24r^2 + 60r + 12}$, we get the first-order result of $\pi_S^{E2}\left(t_1\right)$ about t_1, we get the optimal port handling price t_1^*, and substituting t_1^* into w^{E2}、q_1^{E2} and q_2^{E2}, we get the optimal handling operations q_1^{E2*}, q_2^{E2*} decided by two ports M_1 and M_2 respectively.

The target carbon emission level of t_1^*, and the profits of ports are calculated as follows：

$$t_1^* = -\frac{\begin{array}{c} c_e s - 2ds + 12\beta v + \beta s^2 + 2\beta rs^2 + 16c_e r^2 s - \\ 8dr^2 s - 24\beta r^2 v - 8\beta r^2 s^2 + 8c_e rs - 10drs + 60\beta rv \end{array}}{16r^2 s^2 + 24vr^2 + 8rs^2 - 60vr + s^2 - 12v} \tag{9}$$

$$\pi_s^{E1*} = \lambda + m - \frac{\left(c_e + 4c_e r - 2(1+r)(d - \beta s)\right)^2 v}{2\left(s + 4rs\right)^2 + 24\left(-1 + r\left(-5 + 2r\right)\right)v} \tag{10}$$

2.3.2 Scenarios E_2 of green energy saving and emission reduction investment strategy

M_2 in addition to providing information sharing services, the port also chooses to provide a green energy efficiency and emission reduction investment strategy to reduce its emission level. In the first stage, the port first establishes a new target emission level for shipping company M_2 at a total investment cost, $\frac{v}{2}\left(\beta - t_2\right)^2$, $\left(\beta - t_2\right)$ is the effort made by the port to reach the new emission level t_2. In the second stage, since M_2 cooperates on an information-sharing basis, M_2 is required to pay the port a service fee with a discount $w^{E2} r q_2^{E2} + m$, as well as share the value of the investment return based on the green energy efficiency and emission reduction investment strategy. M_1 and M_2 are required to pay a carbon tax $s\beta q_2^{E2}$ and $st_2 q_2^{E2}$. In addition, M_2 will bear variable costs $c_e q_2^{E2}$. the profits of M_1, M_2 and the port are expressed as:

$$\pi_1^{E2}\left(q_1^{E2}\right) = \left(d - q_1^{E2} - q_2^{E2}\right) q_1^{E2} - w^{E2} q_1^{E2} - s\beta q_1^{E2} \tag{11}$$

$$\pi_2^{E2}\left(q_2^{E2}\right) = \left(d - q_2^{E2} - q_1^{E2}\right) q_2^{E2} - \left(w^{E2} r q_2^{E2} + m\right) - st_2 q_2^{E2} - \lambda - c_e q_2^{E2} \tag{12}$$

$$\pi_S^{E2}\left(t_2, w^{E2}\right) = w^{E2} q_1^{E2} + m + w^{E2} r q_2^{E2} + \lambda - \frac{v}{2}\left(\beta - t_2\right)^2 \tag{13}$$

Similar to the solution methods of t_1^*, π_s^{E1*}, we will not repeat them for the time being, The optimal target carbon emission level of t_2^*, and the profits of ports are calculated as follows

$$t_2^* = \frac{\left(-1+2r\right)s\left(c_e + d - 2c_e r + dr + \beta\left(-2+r\right)s\right) - 12\beta\left(1+\left(-1+r\right)r\right)v}{\left(1-2r\right)^2 s^2 - 12\left(1+\left(-1+r\right)r\right)v} \tag{14}$$

$$\pi_s^{E2*} = -\frac{\left(c_e\left(-1+2r\right)-\left(1+r\right)\left(d-\beta s\right)\right)v\left(s^2\left(c_e\left(-1+2r\right)^3 + d\left(-1+r\left(3-4\left(-3+r\right)r\right)\right)+\beta\left(1-2r\right)^2\left(1+r\right)s\right) - 12\left(c_e\left(-1+2r\right)\left(1+\left(-1+r\right)r\right)-d\left(1+\left(-6+r\right)r^2\right)+\beta\left(1+r^3\right)s\right)v\right)}{2\left(\left(1-2r\right)^2 s^2 - 12\left(1+\left(-1+r\right)r\right)v\right)^2} + \lambda + m \tag{15}$$

3 RESULTS ANALYSIS

3.1 Comparative analysis

This section will discuss the influence of investment coefficient of port emission reduction and information cooperation discount on new target emissions under different strategies.

Proposition 1. When $0 < v < \frac{(1+r)(1+4r)s^2}{12\left(1+2r\left[2+(-2+r)r\right]\right)}$ and $0.5 > r > 0$ are satisfied, $t_2^* < t_1^*$; When $0 < v < \frac{(1+r)(1+4r)s^2}{12\left(1+2r\left[2+(-2+r)r\right]\right)}$ and $1 > r > 0.5$ are satisfied, $t_2^* > t_1^*$. When $1 > v > \frac{(1+r)(1+4r)s^2}{12\left(1+2r\left[2+(-2+r)r\right]\right)}$ and $0.5 > r > 0$ are satisfied, $t_2^* > t_1^*$; When $1 > v > \frac{(1+r)(1+4r)s^2}{12\left(1+2r\left[2+(-2+r)r\right]\right)}$ and $1 > r > 0.5$ are satisfied, $t_2^* < t_1^*$.

Proposition 1 suggests that the optimal new target emissions will be heavily influenced by the information sharing cooperation discount for the port's emission reduction investment factor and If with in the lower range, then ports set more forgiving new target emission levels for M_1 than for M_2. In other words, ports are more willing to set tougher carbon emission standards for the financially weaker M_2 when they invest in a lower factor. The reason is that less service discounts also signify a weaker basis for cooperation with M_2. With lower emission reduction investment factors, the port is forced to focus on improving its low-carbon advantage in order to improve its competitiveness when its own financial position and information are not superior. Conversely, the same port emission reduction investment factor scenario, when the well-financed M_1 receives investment and adopts a more stringent carbon emission standard is an important decision to enhance its competitiveness in the industry. However, when in the higher range, shipping companies will make the opposite decision for the new target emission level. When the information cooperation discount is low, ports are more willing to choose the financially strong shipping company M_1 to set lower emissions. This is because the initial economic advantage of M_1 at this time can meet the daily operational needs, and the high investment capital is more likely to achieve a rapid increase in low carbon levels. In addition, when the information cooperation discount is higher, the port is more willing to set lower carbon emissions for the financially weak shipping company M_2. In this way, the port can not only get the information cooperation discount in shipping enterprise M_2 and save carbon tax, but also the higher investment coefficient can improve the financial difficulty of shipping enterprise M_2 and focus on the main strength to improve the green level.

3.2 Numerical analysis

As the model can not directly observe the impact of subsidies on the profits of regional ports and emission reduction, a numerical analysis is carried out here. Assuming $\lambda=2, d=50, c_e=1, m=1, b=0.3, s=1.5$,the investment coefficient of emission reduction and the cooperation discount of information sharing are 0-1 in turn, and the parameters are brought into the corresponding formula to analyze the port profits under the three modes of port emission reduction investment. Under each mode, the investment coefficient of emission reduction and the discount of information cooperation and sharing on the port income are shown in the following figure:

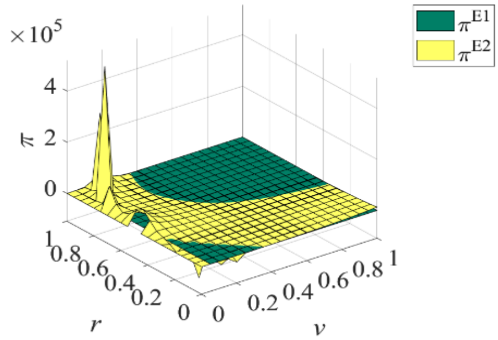

Figure 2. Impact of investment coefficient and information cooperation sharing discount.

Looking at figure 2, we can see that there are two situations in which ports make higher profits from M_1 with abundant investment funds. First, when the investment coefficient is lower （v<0.35） and the discount on information cooperation and sharing is lower （r<0.35）, and when the investment coefficient is higher （0.35<v<1） and the discount on information cooperation and sharing is lower （r>0.46）, the investment return is more robust in these two cases. This is because in the first case, the lower information sharing cooperation discount brings less improvement to the competitiveness of shipping companies M_2, while the well-funded M_1 is more likely to benefit from the emission reduction investment without affecting the freight volume. On the one hand, the port benefits from the emission reduction investment in M_1. In the second case, when two different cooperation strategies are adopted separately for shipping companies with greater intensity, the shipping companies have their own advantages in terms of emission reduction level and handling demand respectively, thus promoting the port to benefit from the smooth development of the shipping market. The higher profit of the port from M_2 mainly occurs when only one of the information cooperation and sharing discounts and investment emission reduction coefficients are at a low or high level, and when both are at the middle level. In other words, when the port pays more attention to enhance the strength of a certain cooperation strategy or the two cooperation strategies support cooperation is more balanced, it is easier to benefit from the investment M_2. Figure 2 also shows that M_2, which has a weak port investment capital, can obtain a higher return value when the reduction factor is low (v=0.15) and the information sharing cooperation discount is higher（r>0.9）. This is due to the fact that the port's own revenue is affected by the large investment in shipping companies, while the information sharing cooperation costs less for the port, and in the short term, it drives M_2 to gain a higher competitive advantage to benefit from the port in freight orders. It is noteworthy that when the port invests in M_2 with a low emission reduction factor（v=0.15）and a low information sharing cooperation discount （r<0.2）, the port will experience a significant loss in revenue, while investing in M_1 will provide a robust return for the port. This is due to the low degree of stimulation of M_2 emission reduction and enhancement of freight volume by the very low emission reduction factor and information sharing cooperation, which have limited effect on enhancing the overall competitiveness of M_2, far short of the portion of port concessions, thus causing a loss for the port.

4 Conclusions

Considering the double asymmetry of financial asymmetry and information cooperation and sharing, this paper constructs a three-stage Stackelberg model of vertical cooperation and emission reduction of shipping enterprises under carbon tax regulation, and finds that:

(1) the investment coefficient of port emission reduction and the discount of port handling service for information sharing and cooperation have different effects on enhancing the level of emission reduction of the new target.

(2) Ports need to choose different investment strategies based on their own emission reduction investment coefficients and discount rates for information sharing cooperation in order to benefit from vertical cooperation in port and shipping.

(3) There are two scenarios in which ports can profit more from investing in well-funded m1, firstly, when the investment coefficient is low and the information sharing discount is low, and secondly, when the investment coefficient is high and the information sharing discount is high, and in these two scenarios the investment returns are more robust for well-funded ones. When port and shipping enterprises focus more on developing a certain cooperation strategy, or when the cooperation strength of both capital investment and information cooperation is more balanced, ports are more likely to benefit from the investment.

REFERENCES

[1] Gianoli A, Bravo F. (2020). Carbon tax, carbon leakage and the theory of induced innovation in the decarbonisation of industrial processes: the case of the port of rotterda. J. Sustainability. 12(18): 7667.

[2] Jiang R, Zhao L, Guo L. (2022). A Stackelberg game model with tax for regional air pollution control. J. Journal of Management Analytics. 2022: 1-21.

[3] Lai X, Tao Y, Wang F. (2019). Sustainability investment in maritime supply chain with risk behavior and information sharing. J. International Journal of Production Economics. 218: 16-29.

[4] Lan J, Li B. (2022). Research on Green Emission Reduction of Shipping Industry from the Perspective of Energy Transformation. J. Logistics Technology. (16), 73 -77.
[5] Liu J, Wang J. (2019). Carrier alliance incentive analysis and coordination in a maritime transport chain based on service competition. J. Transportation Research Part E: Logistics and Transportation Review. 128, 333-355.
[6] Ma P, Wang H, Shang J. (2013). Contract design for two-stage supply chain coordination: Integrating manufacturer-quality and retailer-marketing efforts. J. International Journal of Production Economics.146, 745-755.
[7] Metzger D. (2019). Fuzzy real options and shared savings: Investment appraisal for green shipping technologies. J. Transportation Research Part D: Transport and Environment. 77, 1-10.
[8] Song Z, Tang W, Zhao R. (2018). Cooperation mode for a liner company with heterogeneous ports: Business cooperation vs. port investment. J. Transportation Research Part E: Logistics and Transportation Review. 118, 513-533.
[9] Wang S, Qi J, Laporte G. (2022). Governmental subsidy plan modeling and optimization for liquefied natural gas as fuel for maritime transportation. J. Transportation Research Part B: Methodological. 155, 304-321.
[10] Yang L, Cai Y, Wei Y, et al. (2019). Choice of technology for emission control in port areas: A supply chain perspective. J. JOURNAL OF CLEANER PRODUCTION. 240, 118105.
[11] Zhen L, Zhu G, Wang X. (2020). Review on Green Port and Shipping Management. J. Systems Engineering Theory and Practice. 40(8), 14.
[12] Zheng S, Ge Y E, Fu X, et al. (2020). Demand information sharing in port concession arrangements. J. Transportation Research Part B: Methodological. 138, 118-143.