Game Analysis of Government and Shipping Company Considering Subsidies

Lihaokun Liu(✉) and Yanping Meng

Shanghai Maritime University, Shanghai, China
llhk099@163.com, ypmeng@shmtu.edu.cn

Abstract. In the context of the sulfur cap, the government's adoption of different subsidy models will have an impact on shipping service pricing decisions. The Stackelberg game model between the government and the shipping company is established. The government aims at maximizing social welfare, and the shipping company aims at maximizing profit and analyzes and compares the two modes of government subsidizing the shipping company or the shipper. The results show that the same demand can be obtained for low-sulfur fuel oil shipping services under both subsidy models. The difference is that government subsidies to shipping companies can directly increase corporate profits. On the one hand, the increase in profits means that the demand for low-sulfur fuel oil shipping services will increase, and on the other hand, it will also help shipping companies continue to provide more low-sulfur fuel oil shipping services.

Keywords: Stackelberg game · low-sulfur fuel · government subsidy

1 Introduction

To reduce the environmental pollution caused by ships sailing internationally, the International Maritime Organization (IMO) decided at the 70th Marine Environment Protection Committee (MEPC) meeting held in October 2016 that from 2020 onwards, the maximum sulfur content of exhaust gases emitted into the atmosphere has been reduced from 3.5% to 0.5% [1]. Through this regulation, the low sulfur standard of marine fuel oil has been extended to a global scope, which will not only increase the operating costs of shipping companies but also have a huge impact on the world economy and global trade. With the implementation of the IMO 2020 sulfur limit order, shipping companies mainly have the following three options to reduce emissions: (1) using compliant low-sulfur fuel oil; (2) installing exhaust gas scrubbing systems for continued use of high sulfur fuel oil; (3) running on liquefied natural gas (LNG) [2]. The advantages and disadvantages of the three options are shown in Table 1. Retrofitting scrubbers and switching to low-sulfur fuel oil is more attractive for existing ships than using LNG. In view of the compliance selection of shipping companies under the sulfur limit order, the current research mainly focuses on analyzing the impact of different factors on the emission reduction choices of shipping companies from the perspective of technology transformation and cost and

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Table 1. Comparison of advantages and disadvantages of three options

Options	Advantages	Disadvantages
Using low-sulfur fuel oil	Safe; better environmental protection effect; better adaptation to emission requirements	The resources are scarce and expensive; High fuel costs; machines are required for renovation
Installing exhaust gas scrubber	Safe; low fuel costs; short payback period	High installation costs; disposal of recycled harmful substances is necessary; high costs for service life and maintenance; the compliance requirements of different ports are quite different
Using LNG	Low price; environmentally friendly; clean	Expensive ship transformation; large volume and space; insufficient supply

lacks consideration of the impact of government subsidy policies on the decision-making of shipping companies and shippers.

According to the actual situation, this paper considers a shipping service market composed of shipping companies and shippers. It is assumed that the same shipping company provides two shipping services with different prices for shippers with green preferences to choose from. Ships with low-sulfur fuel oil and ships with additional desulfurization devices (continue to use high-sulfur fuel oil); consumer groups are shippers with green preferences. At the same time, considering that the government subsidizes low-sulfur fuel oil shipping service providers, namely shipping companies, or consumers who choose low-sulfur fuel oil shipping services, namely shippers, construct a three-party game composed of the government-shipping companies-shippers Model. The order of decision-making in this paper is as follows. In the first stage, the government, as the leader, aims at maximizing social welfare, determines the unit subsidy, and determines the market price of low-sulfur fuel oil shipping services and desulfurization device shipping services; shippers in the third stage determine their consumption intentions based on the principle of maximizing utility. The purpose is to solve the equilibrium price, equilibrium demand, and equilibrium profit of shipping companies' shipping services under the two different subsidy models, and to determine the optimal government subsidy aiming at maximizing total social welfare.

2 Problem Description and Model Assumptions

2.1 Problem Description

Under the stricter maritime regulations, the price difference between high-sulfur fuel oil and low-sulfur fuel oil has led to a significant increase in the operating costs of shipping companies. Many large shipping companies have expressed that they will increase fuel surcharges so that the increased costs will be distributed to shippers [1]. Therefore, in the process of maximizing social welfare, the government needs to introduce relevant policies to support this transformation. At present, the government's subsidy targets are the main suppliers of shipping services (shipping companies) and consumers (shippers). The government subsidizes suppliers, which can positively stimulate their emission reduction power, reduce the cost burden, and share market risks, thereby promoting the development of the green shipping industry [5]. Domestic and foreign countries and regions have encouraged ships at ports to switch to low-sulfur oil through subsidies or fee reductions [4]. At the same time, government subsidy policies can also affect shipper demand. Therefore, under the background of the sulfur limit order, the design of the government subsidy policy is also a major concern.

2.2 Model Parameters and Basic Assumptions

Assumption 1: Consumers (shippers) are different in their willingness to pay. We suppose that the consumer's willingness to buy a product is λ, which is uniformly distributed in the interval [0, 1]. Without loss of generality, the market size of the shipper is normalized to 1, and each consumer consumes at most one unit of the product.

Assumption 2: The willingness of each consumer (the shipper) to consume the desulfurization unit shipping service is less than the willingness of the low sulfur fuel oil shipping service.

For the two shipping services provided by the shipping company, the only difference between switching to low-sulfur fuel oil and adding a desulfurization device is that the former is more environmentally friendly [5]. Switching ships to run on low-sulfur fuel oil can bring additional green utility to consumers. The difference is represented by θ, which means that the consumer's green preference is θ; $0 < \theta < 1$. This indicates that consumers are willing to pay higher market prices for green services. Therefore, a consumer willing to pay λ for a desulfurization unit shipping service is also willing to pay $(1 + \theta)\lambda$ for a low-sulfur fuel oil shipping service.

Assumption 3: Due to the production process and other reasons, the cost of purchasing low-sulfur fuel oil by shipping companies is higher than that of high-sulfur fuel oil, that is, the operating cost of low-sulfur fuel oil shipping services is higher than that of desulfurization unit shipping services.

Cost is an important exogenous variable in this model. Considering the high production cost of low-sulfur fuel oil using innovative green technology kc, where k > 1 represents the cost factor of low-sulfur fuel oil shipping services relative to desulfurization unit shipping services.

Assumption 4: Low-sulfur fuel oil shipping services and desulfurization unit shipping services have different environmental impacts.

Use e_l and e_h to denote the unit environmental impact of low-sulfur fuel oil shipping services and desulfurization unit shipping services, respectively. Due to the green properties of low-sulfur fuel oil, it is reasonable to assume $e_l < e_h$. Then the environmental impacts of these two shipping services can be calculated as $E_l = e_l q_l$ and $E_h = e_h q_h$. Among them, q_l and q_h represent the demand for low-sulfur fuel oil shipping services and desulfurization unit shipping services, respectively. The overall environmental impact of the shipping market is: $E = E_l + E_h = e_l q_l + e_h q_h$. At the same time, $kc + e_l$ and

$c + e_h$ represent the unit social cost of low-sulfur fuel oil shipping service and desulfurization unit shipping service, respectively. In this paper, we assume $kc + e_l < c + e_h$. Because only if this condition is met, the government will encourage the development of low-sulfur fuel oil and adopt corresponding subsidy policies.

Assumption 5: The government provides a fixed number of subsidies to suppliers (shipping companies) providing shipping services for low-sulfur fuel oil or consumers (shippers) purchasing shipping services for low-sulfur fuel oil.

The subsidy, which is denoted by s, is a decision variable of the government. Also, due to government fiscal spending constraints, the subsidy should be lower than the operating cost of shipping services for low sulfur fuel oil ($s < kc$). The total subsidy provided by the government to consumers is $S = sq_l$. At the government level, subsidies are government costs.

Assumption 6: The shipping company decides its action after observing the government's subsidy program. This sequence is consistent with practice.

Assumption 7: Consumer surplus is defined as the total real utility of all consumers (shippers) participating in the shipping market. Let CS stands for consumer surplus, which can be represented by substituting the range of λ. Then, we have the following equation.

$$CS = \int_{\lambda_1}^{1} u_l(\lambda)d\lambda + \int_{\lambda_2}^{\lambda_1} u_h(\lambda)d\lambda + \int_{0}^{\lambda_2} 0d\lambda \tag{1}$$

Among them, the superscript represents the model of subsidizing the shipping company and the mode of subsidizing the shipper respectively; it is assumed that the supplier organizes the supply according to the market demand, that is, the shipping service volume is equal to the market demand.

The government's goal is to implement appropriate subsidies for the shipping industry based on social values and public interests to maximize social welfare. Therefore, to study the impact of subsidies on social welfare and the environment, in this paper we consider the social welfare consisting of shipping company profits, total consumer surplus, government costs, and environmental impacts. Because the primary objective of implementing subsidy incentive programs is to reduce environmental impacts, the negative environmental impacts of both shipping services are considered in the social welfare function; the total government spending to subsidize suppliers or consumers should also be included. Let SW represents the total social welfare, then the social welfare can be expressed as:

$$SW = \prod\nolimits_s + CS - S - E \tag{2}$$

3 Model Analysis of Government Subsidy for Shipping Company

In the subsidy model for shipping companies (referred to as subsidy mode a), the government selects the shipping company that provides shipping services as the subsidy object and gives unit subsidy s^a according to the shipping company's sales volume of low-sulfur fuel oil shipping services, and the government can decide the intensity of the subsidy, that is, s^a is the decision variable of the government.

At this point, the consumer (the shipper) will gain a net utility of $u_l = (1+\theta)\lambda - p_l$ by purchasing a low-sulfur fuel oil shipping service, a net utility of $u_h = \lambda - p_h$ by purchasing a desulfurization unit shipping service, and a net utility of 0 by remaining inactive. Consumers choose products based on maximizing utility.

Therefore, the shipper is more inclined to choose the desulfurization unit shipping service when the following conditions are met: $u_h > u_l$ and $u_h > 0$; $\lambda < \frac{p_l - p_h}{\theta}$ and $\lambda > p_h$. Set $\lambda_1 = \frac{p_l - p_h}{\theta}, \lambda_2 = p_h$. If the shipper's willingness to pay satisfies the expressions: $\lambda_2 < \lambda < \lambda_1, p_l > (1+\theta)p_h$, then the shipper will ship the desulfurization unit. The demand for the service is $q_h = \int_{\lambda_2}^{\lambda_1} f(\lambda)d\lambda = \frac{p_l - p_h}{\theta} - p_h$. Similarly, when the shipper's willingness to pay is $\lambda_1 < \lambda < 1$, the shipper's demand for low-sulfur fuel oil shipping services is $q_l = \int_{\lambda_1}^{1} f(\lambda)d\lambda = 1 - \frac{p_l - p_h}{\theta}$.

The problem of the two-stage Stackelberg game can be described as:

$$\begin{aligned} &\max SW^a = \prod\nolimits_s^a + CS^a - S^a - E^a \\ &s.t. \max \prod\nolimits_s^a = \left(p_l - kc + s^a\right)q_l + (p_h - c)q_h \end{aligned} \tag{3}$$

First, the reverse induction method is used to solve and analyze the profit optimization problem of the shipping company in the last stage, that is, to solve the optimal decision-making problem of the shipping company under the given government subsidy s^a. Then solve the optimization problem of the government in the first stage. The goal of the government is to maximize the total social welfare, and the subsidies are determined by the government endogenously.

The model deduction process of reference [3]. From this, the Hessian matrix can be obtained as:

$$H = \begin{pmatrix} -\frac{2}{\theta} & \frac{2}{\theta} \\ \frac{2}{\theta} & -\frac{2(1+\theta)}{\theta} \end{pmatrix}$$

It can be seen from this matrix that when $-\frac{2}{\theta} < 0$, $|H| > 0$. The Hessian matrix is less than zero, indicating that there is an optimal p_l^a, p_h^a to maximize the profit of the shipping company. The following can be obtained by solving the first-order equation equal to 0:

$$p_l^a = \frac{1 - s + \theta + kc}{2}, p_h^a = \frac{1+c}{2} \tag{4}$$

Substitute the optimal demand for low-sulfur fuel oil shipping services and desulfurization unit shipping services at this time as:

$$q_l^a = \frac{s + \theta - (k-1)c}{2\theta}, q_h^a = \frac{(k-1)c - s - c\theta}{2\theta} \tag{5}$$

Among them, there is a range $s_{\min} < s < s_{\max}$ for the government subsidy amount s, which is used to ensure that the demand for low-sulfur fuel oil shipping services and desulfurization unit shipping services are non-negative. From $q_l^a > 0$ to $s_{\min} =$

$(k-1)c-\theta$, the subsidy implemented by the government cannot be too low; from $q_h^a > 0$ to $s < (k-1)c - c\theta$, and $s < kc$ has been assumed; if $(k-1)c - c\theta < kc$, then $s_{\max} = (k-1)c - c\theta$. And we can obtain the following expression: $s_{\max} - s_{\min} = \theta(1-c) > 0$. Therefore, the range of available government subsidies is $(k-1)c - \theta = s_{\min} \leq s \leq s_{\max} = (k-1)c - c\theta$. At this time, the subsidy cannot only satisfy the coexistence of the two shipping services in the market but also ensure that the subsidy range is smaller than the unit cost of low-sulfur fuel oil shipping services. Under this condition, $\lambda_2 \leq \lambda_1 \leq 1$ holds. Note that when $\theta > (k-1)c$, the value of s can be negative. This means that if consumers are sufficiently environmentally conscious, they will pay extra to the government to purchase low-sulfur fuel oil shipping services, but this article focuses only on non-negative subsidy schemes.

Then the consumer surplus can be constructed as follows:

$$CS^a = \int_{\lambda_1}^{1} u_l(\lambda)d\lambda + \int_{\lambda_2}^{\lambda_1} u_h(\lambda)d\lambda + \int_{0}^{\lambda_2} 0d\lambda = \frac{(\theta + kc - s - c)(r + \theta - kc + c)}{8\theta^2} \tag{6}$$

Substituting the above optimal solution into the available subsidy mode a, we can obtain the optimal profit of the disembarking company:

$$\prod\nolimits_s^a = \frac{\theta + (s+\theta)^2 + 2sc + k^2c^2 + c^2(1+\theta) - 2kc(s+\theta+c)}{4\theta}$$

$$\prod\nolimits_l^a = \frac{(1 - s + \theta - kc)(s + \theta + c - kc)}{4\theta},$$

$$\prod\nolimits_h^a = \frac{(1-c)[kc - r - (1+\theta)c]}{4\theta} \tag{7}$$

Therefore, the optimal total environmental impact under subsidy mode a is:

$$E^a = \frac{s + \theta - (k-1)c}{2\theta} e_l + \frac{(k-1)c - s - c\theta}{2\theta} e_h \tag{8}$$

The total cost to the government is:

$$S^a = \frac{s[s + \theta - (k-1)c]}{2\theta} \tag{9}$$

Social welfare can be expressed as:

$$SW^a = \frac{4se_h - 2kc(s + 3\theta + 3c - 2e_l + 2e_h)}{8\theta} + \frac{2c[s - 2e_l + 2(1+\theta)e_h] + 3\theta - (r - 3\theta)(r+\theta) + 3k^2c^2 + 3(1+\theta)c^2 - 4(r+\theta)e_l}{8\theta} \tag{10}$$

Next, by taking the second-order partial derivative of social welfare with respect to subsidy, we can obtain:

$$\frac{\partial^2 SW^a}{\partial s^2} = -\frac{1}{4\theta} < 0 \tag{11}$$

Therefore, there is a unique optimal solution to maximize social welfare under subsidy mode a, and the optimal subsidy at this time can be obtained by solving the first-order derivation:

$$s^{a*} = \theta - (k-1)c - 2e_l + 2e_h.$$

4 Model Analysis of Government Subsidy to Shippers

In the subsidy model for shippers (referred to as subsidy mode b), the government will subsidize consumer shippers who choose shipping services and subsidize the shippers who purchase low-sulfur fuel oil shipping services s^b. The government's decision variable is s^b.

At this point, the consumer (the shipper) will gain a net utility of $u_l = (1+\theta)\lambda - p_l + s$ by purchasing a low-sulfur fuel oil shipping service, a net utility of $u_h = \lambda - p_h$ by purchasing a desulfurization unit shipping service, and a net utility of 0 by remaining inactive. Consumers choose products based on maximizing utility.

Therefore, the shipper's willingness to pay is more inclined to choose the desulfurization unit shipping service when $p_h < \lambda < \frac{p_l - p_h - s}{\theta}$ is satisfied, where $\lambda_1 = \frac{p_l - p_h - s}{\theta}$, $\lambda_2 = p_h$ is set, and the shipper's demand for the desulfurization unit shipping service can be expressed as: $q_h = \int_{\lambda_2}^{\lambda_1} f(\lambda) d\lambda = \frac{p_l - p_h - s}{\theta} - p_h$ at this time. Then the conditions that shippers tend to choose low sulfur fuel oil shipping services are $\lambda > \frac{p_l - p_h - s}{\theta}$ and $\lambda > \frac{p_l - s}{1+\theta}$, and $\frac{p_l - p_h - s}{\theta} > \frac{p_l - s}{1+\theta}$. Therefore, when the shipper's willingness to pay is $\lambda_1 < \lambda < 1$, the shipper's demand for low-sulfur fuel oil shipping services is $q_l = \int_{\lambda_1}^{1} f(\lambda) d\lambda = 1 - \frac{p_l - p_h - s}{\theta}$.

The problem of the two-stage Stackelberg game can be described as:

$$\begin{aligned} &\max SW^b = \prod\nolimits_s^b + CS^b - S^b - E^b \\ &s.t. \max \prod\nolimits_s^b = (p_l - kc)q_l + (p_h - c)q_h \end{aligned} \tag{12}$$

In the same way, referring to the third part of the model solution, it can be obtained that there is an optimal p_l^b, p_h^b to make the shipping company profit $\prod_s^b$ be the largest.

$$p_l^b = \frac{1+s+\theta+kc}{2}, p_h^b = \frac{1+c}{2} \tag{13}$$

Substitute the optimal demand for low-sulfur fuel oil shipping services. The desulfurization unit shipping services at this time are expressed as:

$$q_l^b = \frac{s+\theta-(k-1)c}{2\theta}, q_h^b = \frac{(k-1)c - s - c\theta}{2\theta} \tag{14}$$

Therefore, it is found that the optimal demand for low-sulfur fuel oil shipping services and desulfurization unit shipping services under subsidy mode b is the same as subsidy mode a. Therefore, for the same reason, the government subsidy amount s exists in the same range, which is

$$(k-1)c-\theta = s_{\min} \le s \le s_{\max} = (k-1)c - c\theta.$$

Under this condition, $\lambda_2 \le \lambda_1 \le 1$ holds.

Then the consumer surplus can be constructed as follows:

$$CS^b = \int_{\lambda_1}^{1} u_l(\lambda)d\lambda + \int_{\lambda_2}^{\lambda_1} u_h(\lambda)d\lambda + \int_0^{\lambda_2} 0d\lambda = \frac{(\theta+kc-s-c)(r+\theta-kc+c)}{8\theta^2}. \tag{15}$$

Substituting the above optimal solution into the available subsidy mode b, then we get the equation for the optimal profit of the disembarking company:

$$\prod\nolimits_s^b = \frac{\theta+(s+\theta)^2+2sc+k^2c^2+c^2(1+\theta)-2kc(s+\theta+c)}{4\theta}$$

$$\prod\nolimits_l^b = \frac{(1-s+\theta-kc)(s+\theta+c-kc)}{4\theta},$$

$$\prod\nolimits_h^b = \frac{(1-c)[kc-r-(1+\theta)c]}{4\theta} \tag{16}$$

Therefore, the optimal total environmental impact under subsidy mode b is:

$$E^b = \frac{s+\theta-(k-1)c}{2\theta}e_l + \frac{(k-1)c-s-c\theta}{2\theta}e_h \tag{17}$$

The total cost to the government is:

$$S^b = \frac{s[s+\theta-(k-1)c]}{2\theta} \tag{18}$$

Social welfare can be expressed as:

$$SW^b = \frac{4se_h - 2kc(s+3\theta+3c-2e_l+2e_h)}{8\theta} + \frac{2c\left[s-2e_l+2(1+\theta)e_h\right]+3\theta-(r-3\theta)(r+\theta)+3k^2c^2+3(1+\theta)c^2-4(r+\theta)e_l}{8\theta} \tag{19}$$

Next, by taking the second-order partial derivative of social welfare with respect to subsidy, we can obtain:

$$\frac{\partial^2 SW^b}{\partial s^2} = -\frac{1}{4\theta} < 0 \tag{20}$$

Therefore, there is a unique optimal solution to maximize social welfare under subsidy mode b, and the optimal subsidy at this time can be obtained by solving the first-order derivative equation: $s^{b*} = \theta - (k-1)c - 2e_l + 2e_h$.

5 Comparison of Two Subsidy Models

If mode a subsidizes the shipping service provider and mode b subsidizes the consumer shipper, the following conclusions can be drawn.

Proposition 1: Under the same subsidy level (i.e., $s > 0$), the optimal price of low-sulfur fuel oil shipping service in mode a is lower than mode b, while the optimal price of desulfurization unit shipping service is equal under the two subsidy modes. In mode a, the low-sulfur fuel oil shipping service price is proportional to the shipper's green preference θ and cost c, and is inversely proportional to s; the desulfurization unit shipping service price is only proportional to c and has nothing to do with other parameters. In model b, the low-sulfur fuel oil shipping service price is proportional to s, and the rest of the conclusions are the same as in subsidy model a.

Proposition 2: Under the same subsidy level, the optimal demand for low-sulfur fuel oil shipping services and desulfurization unit shipping services under mode a is equal to mode b. In subsidy mode a, the demand for low-sulfur fuel oil shipping services is proportional to the shipper's green preference θ, cost c, and subsidy s; while the demand for desulfurization unit shipping services is the opposite, which is related to θ, s, and c. The situation in mode b is the same as in mode a.

Proposition 3: Under the same subsidy level, the desulfurization unit shipping service profit and the total profit of the shipping company in mode a are equal to mode b, while the low-sulfur fuel oil shipping service profit is lower than mode b.

Proposition 4: Under the same subsidy level, the consumer surplus of mode a is equal to mode b.

Proposition 5: Under the same subsidy level, the optimal social welfare of mode a is equal to mode b. To maximize social welfare, the optimal government subsidy under both subsidy modes is $s^* = s_{\max} = (k-1)c - c\theta$.

Proposition 6: Under the same subsidy level, the environmental impact of mode a is equal to that of mode b. The environmental impacts under both subsidy modes are inversely proportional to government subsidies.

6 Conclusions

This paper uses the Stackelberg game model to model the two subsidy methods of government subsidies to shipping companies and shippers and obtains the scope of government subsidies on the premise of ensuring the coexistence of low-sulfur fuel oil shipping services and desulfurization unit shipping services. Based on balanced decision-making and optimal profit, the models of the two subsidy modes are compared and analyzed from six aspects: low-sulfur fuel oil shipping service pricing, demand, shipping company profits, consumer surplus, social welfare, and environmental impact. Through the research of this paper, we can draw the following conclusions.

The mode of subsidizing shipping companies can bring lower market prices for low-sulfur fuel oil shipping services. However, due to the existence of government subsidies, its low-price advantage is offset, so that the two subsidy modes achieve the same level of demand under the same subsidy level.

Under the current reality that the operating cost of low-sulfur fuel oil shipping service is higher than that of desulfurization unit shipping service, government subsidies are crucial to the development of the low-sulfur fuel oil industry. Therefore, in the two subsidy models, the subsidies given by the government should not be too low; otherwise, it will be difficult to drive the large-scale operation of low-sulfur fuel oil shipping services.

The market where shippers have a green preference for low-sulfur fuel oil shipping services can drive supplier shipping companies to start the supply of low-sulfur fuel oil shipping services at low subsidy levels, and can achieve higher shipping company profits and total social welfare. Therefore, combined with the national standard subsidy mechanism, on the premise of ensuring the number of shipping services for desulfurization units, financial subsidies should be implemented to the maximum extent to promote the prosperity and development of the low-sulfur fuel oil shipping market.

There is no difference in the overall profit level, environmental impact, consumer surplus, and social welfare of shipping companies between the two subsidy models. However, the mode of government subsidies to shipping companies directly increases the profits of shipping companies and is conducive to further reducing the market price of low-sulfur fuel oil shipping services, stimulating the consumer demand of shippers, and being more easily accepted by shipping companies. Therefore, to drive the supply and market development of low-sulfur fuel oil shipping services, the government should choose shipping companies as subsidy targets.

The conclusions drawn here have guiding significance for the government to make subsidy decisions. The purpose of government subsidies to shipping companies and shippers is to expand the market demand for low-sulfur fuel oil shipping services. Under the two subsidy modes, low-sulfur fuel oil shipping Services can get the same amount of demand. The difference is that after the government subsidizes the shipping company and the shipper, the total profit and environmental impact obtained by the shipping company are the same, but the subsidy to the shipping company can directly increase the profit of the company. The increase in profit means low-sulfur fuel oil shipping services. The increase in demand, on the other hand, is beneficial for shipping companies to continue to provide more low-sulfur fuel oil shipping services, to better meet the needs of consumers, and to increase consumer surplus, which further promotes low-sulfur fuel oil after the increase in consumer surplus.

To sum up, there is a virtuous circle of low-sulfur fuel oil shipping service profits and consumer surplus in government subsidies to shipping companies. The low-sulfur fuel oil industry can enter a stage of accelerated development in this cycle. Therefore, the government chooses to subsidize shipping companies, which can not only reduce the environmental impact, but also help shipping companies reduce the operating cost of low-sulfur fuel oil shipping services and help improve transportation capacity, and the greater the subsidy, the more obvious the effect. Future research directions include government subsidies for shipping companies and shippers at the same time, multi-stage shipping supply chain subsidies, and government subsidies decline. At the same time, the coexistence of multiple subsidy modes such as price discounts and point systems can also be introduced in the research. Through the research of this paper, it is hoped that the government will give some reference to the subsidies for shipping companies or shippers, and it is also hoped that it can provide theoretical reference for future research on related aspects.

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