How Will the Marine Emissions Trading Scheme Influence the Profit and CO_2 Emissions of a Containership

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Abstract. Greenhouse Gas (GHG) emissions from international shipping has become an increasing concern to the whole world. Although the shipping industry has not been included in the mandatory GHG emissions reduction list in the *Kyoto Protocol*, it should do something to cut down its emissions. This paper proposes a marine emissions trading scheme which mainly concerns CO_2 and studies its influence on the annual profit and CO_2 emissions of containerships based on speed reduction. Through a case study, we demonstrate that speed reduction is really an effective measure in cutting down ship GHG emission. Meanwhile, the auction rate of allowances has a great impact on the annual profit of a ship. Furthermore, the conducted scenario and sensitivity analysis confirm that in different shipping market situations, the ship always has a most profitable speed, no matter what the auction rate is.

Keywords: Marine Emissions Trading Scheme, Auction Rate, Speed Reduction, Profitability.

1 Introduction

Global climate change has already had observable effects on the environment. Early researchers generally suggested that the atmosphere had been warmed over the past century, and human activities were likely to be the most important driving factor to that change. Global emissions of CO_2 from international shipping are substantial and have a long history dating back to the industrial revolution [1]. It is estimated that in 2007 international shipping have emitted 870 million tons, or about 2.7% of the global emissions of CO_2 [2]. Currently, emissions from shipping are around 1000 million tons annually, nearly 130 million tons more comparing with 2007, and in the absence of action they are expected to be more than double by 2050 [3].

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1.1 Development of Greenhouse Gas (GHG) Emissions Reduction Programs for International Shipping

As GHG emissions call more attention from international society, the programs to cut down international shipping GHG emissions from the International Marine Organization (IMO) became a hot topic. In 1977, state parties of the International Convention for the Prevention of Pollution from Ships (MARPOL) adopted a new protocol on ship GHG emissions, which entitled MEPC to examine the feasibility of GHG emissions reduction proposal.

In the 42nd session of the MEPC in 1998, a project steering committee was founded to guide the research on ship GHG emissions. At the same time, this session entitled the IMO to make policies on shipping emissions reduction.

In the 59th session of the MEPC in July 2009, the IMO adopted "EEDI (Energy Efficiency Design Index) Calculation Provisional Guidance," "EEDI Voluntary Certification Interim Guidance," "Ship of Energy Efficiency Management Plan (SEEMP)" and "Guidelines to EEOI (Energy Efficiency Operational Indicator) Voluntary Use." Mandatory measures to reduce emissions of GHGs from international shipping were adopted by Parties to MARPOL Annex VI represented in the 62nd session of the MEPC.

In the 64th session of the MEPC in October 2012, the IMO improved further the draft guidance on treatment of innovative energy efficiency technologies and reviewed the interim guidelines for the calculation of the coefficient *fw* for decrease of ship speed in representative sea conditions for trial use.

1.2 Literature Review

Generally, there are three ways to reduce shipping emissions, i.e., technical, operational and market-based measures.

From the technical perspective, the options for ship operators to reduce fuel consumption of vessels can be broadly divided into five categories: engine and transmission technology, auxiliary power systems, propulsion systems, superstructure aerodynamics and hull shape [4]. In 2000, study of GHGs emissions from ships analyzed model tests from MARINTEK's database, which indicated that if the behavior of the hull in still water is optimized, there is a potential for energy savings in the range of 5-20% [5]. With respect to modernizing engines, using power turbines to recover energy from exhaust, or some other measures, such as energy efficiency in the power generation system, could be increased [6, 7]. Changing energy type could also be an efficient option to improve engine efficiency. Corbett and Winebrake [8] suggested that bunker oil refining efficiency influences CO_2 emissions significantly. Non-renewable energy (such as LNG, LPG, and nuclear power [9]) and renewable energy (such as wind power, solar energy, and biofuels) have been used to substitute the traditional bunker fuel in recent years. Furthermore, renewable sources could meet a greater share of the rapidly growing international shipping energy demand in the long term, while planning for 100% renewable energy for transport plays an import part in combination with equally important technologies and proposals [10] .

From the perspective of operational measures, policy makers, such as MEPC have designed EEOI and SEEMP to guide energy efficiency increase of vessels through optimizing ship operations. International ship operators also try to exploit potential operational improvements to achieve emissions reduction, e.g. fleet composition and speed reduction [2]. Psaraftis et al. [11] demonstrated that speed reduction is an effective emissions reduction measure for fast ships. Corbett et al. [12] highlighted that a speed reduction mandate targeted to achieve 20% CO_2 reduction in the container fleet costs between $20 and $200 per ton CO_2, depending on how the fleet responds to a speed reduction mandate. Based on the research of Corbett et al. [12], Crist [4] calculated the impact of speed reduction on 8500 TEU container vessels. The analysis of speed reductions from 10% to 50% showed that when the speed is reduced to a half, fuel consumption decreases by 87%. Furthermore, according to a study of Eide et al. [13] in 2009, cost effective GHG reductions for a fleet may be in the order of 30% for technical measures, and above 50% when including speed reductions.

From a market perspective, there are also some literatures on market-based measures to reduce international shipping CO_2 emissions [14-16]. However, there is a lack of research combining market-based measures with operational or technical measures. One important reason is that there have not existed any worldwide market-based measures to limit international shipping GHG by now. In order to propel the development of market-based measures, Miola et al. [17] analyzed limits and opportunities of current market-based measures through a discussion at the international level in 2012. Meanwhile, they estimated the cost-effectiveness of the main technical GHG reduction measures in order to give a magnitude of such costs within a market-based policies framework [17].

From the literature review above, we can see that research on the joint influence of market-based and the other two measures are not extensive. Even if there are a few, they mainly focused on GHG emissions reduction or cost effectiveness, disregarding the profitability of the ship. Moreover, rules of market-based measures are not decided by ship operators compared with technical and operational measures, thus it is worth to study some potential market-based measures to help ship operators choose the most profitable GHG reduction options in advance. This paper mainly focuses on proposing a potential market-based measure, especially an emissions trading scheme. Combined with slow steaming [18], which is an operational measure, this paper discusses the joint influence of these two measures on the profit and CO_2 emissions of a ship.

This article is organized as follows. Since the background of this article is introduced in Section 1, Section 2 briefly reviews emissions trading schemes and proposes a marine emissions trading scheme based on existing research. Section 3 develops a model to evaluate the influence of the marine emissions trading scheme on the annual profit and CO_2 emissions of a ship when it responses as speed reduction. Section 4 carries out a case study on a containership. Discussions of the results are given in Section 5. Conclusions and further research are drawn in Section 6.

2 Potential Marine Emissions Trading Scheme

Among the existing literature, there are mainly two market-based measures, respectively, emissions taxes and emissions trading [19-21]. Between these two measures, emissions taxes are not considered on a global scale as they have political characteristics. Furthermore, how much emissions taxes should be levied, who will manage the fund, etc., are also issues hindering their implementations.

Generally, in an emissions trading scheme, a central authority sets a cap on the amount of a pollutant that can be emitted. The cap is allocated or sold to involved firms in the form of emissions allowances. Firms can exchange allowances in the market. This allows the system to reduce emissions without significant government intervention. Since an emission trading scheme is more marketable than emissions taxes, this paper mainly tries to propose an international, potential marine emissions trading scheme.

Existing emissions trading schemes are mostly regional, such as the European Union Emissions Trading Scheme (EU ETS) and the New Zealand Emissions Trading Scheme (NZ ETS) [22]. Taking international shipping as a global industry, regional emissions trading schemes cannot take an ideal effect on cutting down its emissions. In order to solve this issue, a global marine emissions trading scheme should be put forward. However, there still exist some issues hindering its implementation. The key one is the allowance allocation method. In theory, the efficiency of an emissions trading scheme is independent on the choice of allocation criteria and the design of the initial allocation method [23, 24]. However, the allocation method determines the financial burden to international ship operators. This will be crucial for the acceptability of the marine emissions trading scheme.

Generally, five basic methods have been proposed to allocate allowances, namely grandfathering, benchmarking, auctioning, baseline, no allocation. Each allocation method gets some support or objections, while auctioning appears to be the most attractive option [14, 15, 24]. However, if international shipping carriers get all the allowances through auctions that would be a huge financial burden to them.

Considering the financial burden to ship operators and the GHG emissions reduction pressure to the international shipping sector, the initial allocation of allowances to the shipping sector could, in principle, be done by a combination of grandfathering and auctioning [14]. A hybrid system of these two allocation measures could provide a starting point for a slow transition from allocation free of charge to an auctioning system. Moreover, the obligation to surrender allowances for emissions growth shows parallels with both allocating free of charge and auctioning. One parallel lies in the fact that involved firms do not have to pay for emissions within a certain quantity for free. Once the free quantity is exceeded, they must auction allowances.

After the initial allocation of allowances has been determined, we take a final decision on the size of the cap and auction rate. In this paper, the equivalent cap for a liable entity in the marine emissions trading scheme could be 80% of its 2012 emissions and the ship itself considered as the liable entity [14].

Table 1. Marine emissions trading scheme, in detail

Liable Entity	Cap	Free Rate	Auction Rate
Ship	80% of its 2012 emissions	0.8	0.2
		0.6	0.4
		0.4	0.6
		0.2	0.8
		0	1

As the auction rate of allowance is hard to decide, this paper mainly refers to auction rates in EU ETS to propose a scenario analysis, which may consider some possible auction rates in the future marine emissions trading scheme. Table 1 summarizes the key factors of the marine emissions trading scheme here proposed.

3 Profitability of Containerships with Different Speed Reduction Rates under the Marine Emissions Trading Scheme

Although there are several kinds of ship delivering cargos between continents, this article mainly focuses on containerships. Containerships are usually operated on closed routes (also known as cycles, strings or loops) and follow a published schedule of sailings [25]. A route is a specified sequence of calling ports that each containership assigned to that route repeats on each voyage.

This paper assumes that all the parameters used to calculate ship annual revenue, cost and CO_2 emissions are constant under the period of this study. Given this assumption, a model is developed to calculate maximum annual profit speed of a containership and its corresponding profit and CO_2 emissions.

Definition of each parameter used in the model is summarized as follows.

- i: the origin port
- j: the destination port
- k: an individual containership serving the ij route
- F_{ijk}: the whole fuel consumption of ship k from i to j (tons)
- MF_k: main engine maximum daily fuel consumption (tons/day)
- AF_{ks}: auxiliary engine daily fuel consumption when ship is at sea (tons/day)
- AF_{kp}: auxiliary engine daily fuel consumption when ship stays in port (tons/day)
- S_{0k}: the design speed (maximum speed) at sea of containership k (knot)
- S_{ijk}: the operational speed at sea of containership k from i to j (knot)
- d_{ij}: the distance from i to j port (nautical miles)
- π_{ijk}: the profit from the origin i to the destination j per year (USD)
- R_{ij}: the freight rate of per TEU from the origin i to the destination j (USD)
- W_{ijk}: the number of TEUs per ship in one trip from i to j
- C_k: the fixed cost per day for containership k excepting auxiliary engine fuel cost (USD)
- P_M: the price of bunker fuel for main engine (USD/ton)
- P_A: the price of bunker fuel for auxiliary engine (USD/ton)
- D_{ijP}: total days ship stays in port from i to j,
- T_{ij}: the number of trips made by containership k between i to j per year

Based on these parameters, equation (1) represents an annual profit function for ship k from the origin i to the destination j [12],

$$\pi_{ijk} = \left(R_{ij} * W_{ijk} - C_{ijks} - C_{ijkp}\right) * T_{ij} \quad (1)$$

where C_{ijks} (cost at sea) and C_{ijkp} (cost in port), respectively, are

$$C_{ijks} = \left[C_k + P_M * MF_k * \left(\frac{S_{ijk}}{S_{0k}}\right)^3 + P_A * AF_{ks}\right] * \frac{d_{ij}}{24S_{ijk}} \quad (2)$$

$$C_{ijkp} = \left(C_k + P_A * AF_{kp}\right) * D_{ijP} \quad (3)$$

Our main purpose is to get the maximum annual profit speed, so we define S_{ijk} as the only variable in Equation (2) and recognize marginal profit equals zero. Therefore, the maximum annual profit speed function is:

$$S_{ijk} = \left[\frac{(P_A * AF_{ks} + C_k) * S_{0k}{}^3}{2 * P_M * MF_k}\right]^{\frac{1}{3}} \quad (4)$$

Applying Equation (4) to determine the optimal speed, we could investigate how the motivation for profit maximization of shipping carriers influences ship speed under the marine emissions trading scheme proposed above.

3.1 CO_2 Emissions

International containerships emit several kinds of exhaust gases, such as CO_X, NO_X and SO_X. Among these types of emissions, the quantity of CO_2 is the maximum and it is the one that influences global climate most. Therefore, this paper focuses on calculating the quantity of CO_2 from international containerships.

Marine fuels are a petroleum byproduct with carbon segment which converts to CO_2 after burning. Normally, fuel consumption is used to calculate the CO_2 emissions rate. The fuel consumption of a ship is the sum of fuel used by main and auxiliary engines and it is calculated by Equation (5).

$$F_{ijk} = \left\{\left[MF_k * \left(\frac{S_{ijk}}{S_{0k}}\right)^3 + AF_{ks}\right] * \frac{d_{ij}}{24S_{ijk}} + AF_{kp} * D_{ijP}\right\} \quad (5)$$

The fuel consumption of a ship is then multiplied by the fuel's carbon fraction (defined at 0.8645) and a conversion factor from carbon to CO_2 (equal to 44/12) in order to calculate CO_2 emissions in tons per trip [12]. The CO_2 emissions of each trip from i to j then is:

$$CO_{2_{ij}} = (0.8645) * \left(\frac{44}{12}\right) * F_{ijk} = 3.17 * F_{ijk} \quad (6)$$

Inserting Equation (5) into Equation (6), we obtain:

$$CO_{2_{ij}} = 3.17 * \left\{\left[MF_k * \left(\frac{S_{ijk}}{S_{0k}}\right)^3 + AF_{ks}\right] * \frac{d_{ij}}{24S_{ijk}} + AF_{kp} * D_{ijP}\right\} \quad (7)$$

3.2 Annual Profit of a Ship in the Marine Emissions Trading Scheme

As mentioned before, there are three basic measures to cut down exhaust emissions of containerships, respectively, technical, operational and market-based measures. Usually, technical measures need a long time to plan before their final implementation. For this reason, this paper mainly considers the combined influence of operational and market-based measures on the annual profit of a containership.

There are several types of specific operational measures to mitigate CO_2 emissions from containerships. Ship operators tend to prefer speed reduction when there is an emissions trading scheme [12]. Speed reduction is inexorably linked with fuel cost and ship profits. Based on the original maximum profit speed, we propose several ship speed reduction rates and calculate their corresponding annual profits and CO_2 emissions. Ship speed keeps stable in each round trip.

Based on Equation (7), we construct a model to calculate the annual emissions and profit of a ship when it responds with speed reduction. CO_2 emissions coming from a containership in a cycle route between i and j will be

$$CO_2 = 3.17 * \left(F_{ijk}{}' + F_{jik}{}' + AF_{kp} * D_P\right) \tag{8}$$

$$F_{ijks}{}' = \left[MF_k * \left(\frac{S_{ijk}*(1-x)}{S_{0k}}\right)^3 + AF_{ks}\right] * \frac{d_{ij}}{24S_{ijk}*(1-x)} \tag{9}$$

$$F_{jiks}{}' = \left[MF_k * \left(\frac{S_{jik}*(1-x)}{S_{0k}}\right)^3 + AF_{ks}\right] * \frac{d_{ji}}{24S_{jik}*(1-x)} \tag{10}$$

where x is the rate of speed reduction. S_{jik} is the operational speed at sea of containership k from j back to i. d_{ji} denotes the distance from j to i ports. D_P is the total days ship k stays in port in the cycle route between i and j. $F_{ijks}{}'$ and $F_{jiks}{}'$ are fuel consumptions at sea after speed modification.

Based on the marine emissions trading scheme proposed above, CO_2 emissions exceeding the free quantity should be auctioned, and those exceeding the cap of allowances should be purchased in the market. This paper assumes that ship operators will not reduce speed sharply to make profit on the saving allowances. Then annual profit of a containership after slow steaming under the scheme can be calculated as follows:

$$\pi_k = T_{ij} * \left\{R_{ij} * W_{ijk} + R_{ji} * W_{jik} - \left[C_{ijks}{}' + C_{jiks}{}' + C_{kp}\right] - C_{co2}\right\} \tag{11}$$

$$C_{ijks}{}' = \left[C_k + P_M * MF_k * \left(\frac{S_{ijk}*(1-x)}{S_{0k}}\right)^3 + P_A * AF_{ks}\right] * \frac{d_{ij}}{24S_{ijk}*(1-x)} \tag{12}$$

$$C_{jiks}{}' = \left[C_k + P_M * MF_k * \left(\frac{S_{jik}*(1-x)}{S_{0k}}\right)^3 + P_A * AF_{ks}\right] * \frac{d_{ji}}{24S_{jik}*(1-x)} \tag{13}$$

$$C_{kp} = \left(P_A * AF_{kp} + C_k\right) * D_P \tag{14}$$

$$C_{co_2} = \left\{P_a * \left[CO_{2(F)} - CO_2\right] * n + P_p * \left[CO_{2(C)} - CO_2\right] * m\right\} \tag{15}$$

where P_a denotes the auction price of CO_2 allowance. P_p denotes the purchase price of CO_2 allowance. $CO_{2(F)}$ denotes the free allowance a ship gets. $CO_{2(C)}$ denotes CO_2 allowance cap for a ship. C_{co_2} is CO_2 cost. π_k is the total annual profit of ship k. n and m are constants, which values are either 0 or 1.

When

$$CO_{2(F)} > CO_2$$

n=0, m=0, which means there is no CO_2 emissions cost. When

$$CO_{2(F)} < CO_2 < CO_{2(C)}$$

n=1, m=0, there is CO_2 auction cost, but no purchase cost. When

$$CO_2 > CO_{2(C)}$$

n=1, m=1, there are CO_2 auction and purchase costs.

4 Case Study

This paper takes an international liner route, i.e., Asia to North Europe, as an example to evaluate the influence of the marine emissions trading scheme on the annual profit of a ship. There are three reasons for the choice of this route. At first, it is one of the typical shipping lines for international containerships. Moreover, one end of this shipping line is Europe, which is active in the marine emissions trading scheme. Fig.1 shows the explicit information of the route.

Fig. 1. Shipping Route for the Case Study (Source: China Ocean Shipping (Group) Company)

We assume a containership operating in this line with a capacity of 8000 TEUs. Its design speed is 24.1 knots and the corresponding main engine fuel consumption is 11.9 tons/h. Hence, the main engine maximum daily fuel consumption (MF_k) is 285.6 tons. Its auxiliary engine fuel consumption is 2 tons/day at sea and 1 ton/day in port. In general, trips of the Asia to north Europe route are differentiated by westbound and eastbound. For the case study in this paper, westbound means a voyage from Shanghai to Felixstowe. On the contrary, eastbound is a trip from Felixstowe back to

Shanghai. The ship works 350 days each year. To each round trip, the ship stays in port for 11 days in total. Moreover, according to a survey from the ship operator, the average daily fixed cost (C_k) of this containership operating on the Asia-Europe route is 114667 USD and the average loading factor is 85%.

From Table 2 we can see that the volumes rate of container trade in 2013 between eastbound and westbound is nearly 0.5. Combining the average freight rate of a 40ft container for Asia-Europe route in 2013 (shown in Table 3), and average loading factor, we can evaluate the annual revenue of the ship.

Table 2. Forecast development of Asia to North Europe Container Trade Volumes in 2013 (Source: Container Market Review and Forecaster, Quarter 1/2013, Drewry Maritime Research)

Quarter	1Q	2Q	3Q	4Q	Total
Westbound (000 TEU)	2210	2231	2394	2185	9020
Eastbound (000 TEU)	1172	1122	1103	1160	4557

Table 3. Container Freight Rate Benchmarks (Spot Market) for Asia-Europe Route in 2013, all-in (USD per 40ft container) (Source: Sea & Air Shipper Insight, Drewry Maritime Research, April 2013 - Issue no. 04)

Time	Jan. 2013	Feb. 2013	Mar. 2013	Average
Westbound	2959	2575	2572	2702
Eastbound	1263	1230	1267	1253

Note: All-in rates include base rate, BAF, other surcharges and terminal handling charges at origin and destination.

In this paper, the bunker fuel prices are referred to Rotterdam bunkers price on May 3rd, 2013. Price of MDO[1] and 380 cst[2] is, respectively, 830 USD/ton and 576 USD/ton. Auction price and purchase price for CO_2 allowance in this paper is 25 USD/ton and 30 USD/ton, because analysts pointed out that only when the CO_2 allowances price is 20 to 30 EUR/ton it can promote entities search measures to cut down GHG emissions [26].

Applying Equation (4) to this case, we calculate the profit-maximizing speed of the ship. As profit-maximizing speed only relates to ship's engine and fuel prices, profit-maximizing speed in westbound and eastbound of the ship are both 17 knots when there is no emissions costs. If the ship operated in this speed in 2012, its corresponding CO_2 emissions should be 95275.3 tons.

When the Marine Emissions Trading Scheme proposed in this paper put into effect, the CO_2 emissions allowances for this ship will be 76220.24 tons, 80% of 2012. In addition, annual profit and CO_2 emissions of the ship with different speed reduction rates are shown in Tables 4 and 5.

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1 Fuel for auxiliary engine.

2 Fuel for main engine.

5 Discussion

Table 5 demonstrates that speed reduction is a useful measure in cutting down CO_2 emissions of a ship. Fig. 2 illustrates two phenomena. Firstly, with the rise of CO_2 allowances auction rate, the annual profit of the ship is descending quickly when the ship speed is fixed. Due to this phenomenon, auction for CO_2 allowances could be a financial burden to ship carriers. Secondly, between all the auction rates proposed in this paper, when loading the factor is 85%, ship speed reductions of 5%, based on its original profit-maximizing speed, should be the most profitable choice for a ship operator comparing with other speed reduction rates.

Table 4. Annual profit (USD) of the ship with different speed reduction rates in five allowance auction rates

Auction Rate	Speed Reduction Rate			
	0	5%	10%	15%
0.2	1495739.2	1645158.9	1362113.4	1021391.1
0.4	1114638.0	1264057.8	981012.2	259188.6
0.6	733536.8	882956.66	599911.0	-121912.6
0.8	352435.6	501855.3	218809.8	-503013.8
1	-28665.6	120754.1	-162291.4	-884115.0

Table 5. Annual CO_2 emissions (tons) of the ship in different speed reduction rates

Speed Reduction Rate	0	5%	10%	15%
Annual CO_2 emissions	95275.3	82744.8	71251.2	60853.3

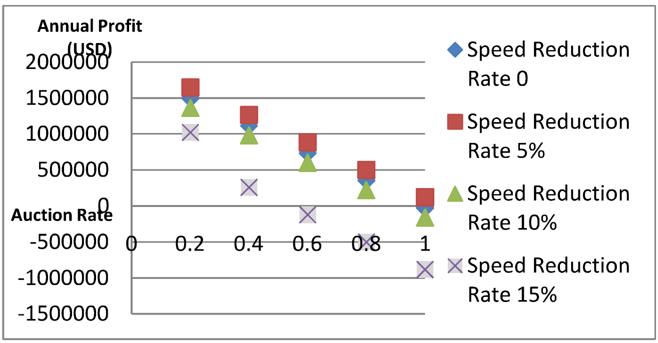

Fig. 2. Trends of the annual profit of the ship with different speed reduction rates when the auction rate increases

Annual profit of a ship is not only influenced by CO_2 allowances auction rate, but also by the shipping market. Generally, the shipping market has a great impact on the profit of a ship, which might influence the implementation of this scheme. This article studies the acceptability of this trading scheme from the perspective of profit.

In the international shipping market, loading factor and freight rate are key influential factors of ship profit, which fluctuates with market. However, in most cases, the loading factor denotes the situation of the shipping market better than the freight rate since modifications of the freight rate are aroused by fluctuation of the loading factor. Hence, this paper tries to find out how the marine emissions trading scheme influences ship profit when the loading factor is different and to discuss its acceptability.

As this article has calculated the annual profit of the case ship when its loading factor is 85%, in the subsequent context, we continue to study its annual profit based on other four loading factors as comparison. Like for the 85% loading factor, the ship has the most profitable speeds in each of the other four loading factors studied, no matter what the auction rate is.

Table 6. Profitability of different loading factors under the Marine Emissions Trading Scheme

	Loading factor				
	95%	90%	85%	80%	75%
Speed reduction rate	0%	5%	5%	5%	10%
Maximum Annual profit (USD)	8556193.8	5030691.8	1645159.0	-1740373.9	-5107001.2
Auction rate	0.2	0.2	0.2	0.2	0.2
Minimum Annual profit (USD)	7031789.0	3506287.0	120754.1	-3264778.7	-6631406.0
Auction rate	1	1	1	1	1

Table 6 shows obviously that with rising loading factor, ship operators prefer higher speeds to gain more profits, ignoring CO_2 emissions. As to the acceptability of this scheme, loading factors from 85% to 95% finally result profits to the ship which demonstrate it could be accepted in theory. Of course, from the profit perspective, lower auction rates are more acceptable by ship operators. However, when shipping market is declining, such as loading factor is 80% or even less, the scheme will cause negative profits to the ship, which increases the difficulty of its implementation. Therefore, in a depressing market, in order to increase the incentives of ship operators to adopt this scheme, it can be implemented with revenue recycling or some policies.

6 Conclusions and Further Research

This paper proposes a potential marine emissions trading scheme with a focus on CO_2 emissions to research its influence on the annual profit and CO_2 emissions of a containership when ship speed reduces correspondingly.

The initial allocation measure in the marine emissions trading scheme is a combination of grandfathering and auctioning, which considers not only the financial burden to ship operators, but also emissions reduction pressure to the whole industry. Based on scenario analysis and referred to EU ETS, this paper proposes five possible auction rates. A case study based on a containership running the Asia-Europe route with 8000 TEUs capacity is conducted to test the influence of the marine emissions trading scheme on the annual profit and CO_2 emissions of a containership with the response of speed reduction. The results of this case study demonstrate that speed reduction is an effective measure in cutting down GHG emissions of a ship. In addition, the auction rate of allowances has a strong impact on the annual profit of a ship which drops sharply as the auction rate increases. Furthermore, from the profit perspective, ship operators' choice on speed reduction and their incentive to adopt the scheme turn out to be related with the situation of the shipping market. Hence, the auctioning rate among the cap of emissions for a ship may refer to the international shipping industry or be supported by policies such as revenue recycling.

In order to verify the feasibility of this scheme, in the further research multiple containerships and other typical routes should be considered. As far as acceptability of this scheme, this paper discusses it mainly from the profit perspective. More attention should be paid on social welfare, a combination of other technical or operational measures to further study the implementation of the marine emissions trading scheme.

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