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A Comprehensive Review of Research on Carbon Tax and Carbon Emissions Trading Policies in Shipping Industry

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Abstract: Carbon tax and carbon emissions trading are currently the two principal policy instruments for achieving carbon emission reduction. Since January 1, 2024, the shipping industry has been formally incorporated into the European Union Emissions Trading System (EU ETS). This paper integrates the development mechanisms and current status of various policies, and provides a systematic review in combination with the existing literature, with the aim of offering a reference for the future development of shipping carbon emissions system.

Keywords: Shipping, Carbon tax; Carbon emissions trading system.

1. Introduction

The shipping industry is an essential component of the transportation sector. According to data from the International Maritime Organization (IMO), international shipping accounted for approximately 3% of global carbon dioxide emissions in 2023. Without further measures, this share is projected to rise to 18% by 2050. To address greenhouse gas emissions from the shipping industry, IMO member states reached agreement in July 2023 on the following targets:(1) Establish interim emission-reduction milestones: by 2030, reduce total greenhouse gas emissions by 20% compared with the 2008 level, while striving for a 30% reduction;(2) Set a medium-term reduction target: by 2040, reduce total greenhouse gas emissions by 70% compared with the 2008 level, while striving for an 80% reduction;(3) Achieve net-zero greenhouse gas emissions by or around 2050.

2. Development in Carbon Emission Reduction Policies in Shipping Industry

(1) Carbon tax

Carbon tax is levied on carbon dioxide emissions generated by the combustion of various fuels. The tax amount is calculated based on fuel consumption or carbon emissions multiplied by a fixed tax rate. It can be imposed either at the production stage of fossil fuels, which facilitates tax administration but weakens the transmission of price signals and may reduce the effectiveness of emission reduction, or at the consumption stage of fossil fuels, which better reflects tax fairness but entails greater administrative difficulty. In this way, a carbon tax is intended to incentivize firms to reduce carbon dioxide emissions.

The prototype of the carbon tax is the Pigouvian tax. Its underlying logic is that a divergence between private costs and social costs leads to a privately optimal outcome that is socially suboptimal. The tax is set equal to the external damage caused by a firm in producing each additional unit of output; in other words, the tax is equal to the marginal external cost. Therefore, the government can use taxation to correct the private costs faced by economic agents and internalize environmental pollution that would otherwise remain an externality, thereby achieving the objective of pollution control.

Under the dual pressures of global warming and the international community, the Marine Environment Protection Committee (MEPC) has accelerated its preparations in recent years, and three mainstream carbon tax mechanisms have been brought into the scope of negotiations.

The first is the International Greenhouse Gas Fund (GHG Fund) mechanism, which has been successively supported by countries such as South Korea and Liberia. Under this mechanism, a carbon tax is levied on marine fuel consumed by all international ships of 400 gross tonnage and above. The tax revenue is used to purchase carbon emission allowances outside the shipping sector to offset excess emissions within the sector, as well as to support the research and development of related shipping technologies.

The second is the Port State Levy (PSL) model, under which a fuel surcharge is imposed based on a vessel's operations on specific voyages, with the carbon tax being directly collected by the port state at which the vessel calls.

The third is the Rebate Mechanism (RM), which serves as a supplementary arrangement for carbon tax mechanisms applicable to the shipping industries of developing countries. Its principle is similar to that of the GHG Fund. The implementation process includes such steps as ship emission reporting, payment of carbon taxes to banks, and supervision by relevant ports. Its core feature is that developing countries are granted unconditional tax rebates in proportion to the value of their imported goods.

In summary, the GHG Fund is currently the most widely favored among the major carbon tax proposals. Its tax rate is determined based on emission reduction targets, projected emission levels, and the carbon allowance price under the Clean Development Mechanism (CDM). The tax revenue is centrally managed by the International Greenhouse Gas Emissions Fund, and the funds are mainly used for allowance purchases, market management and operational expenditures, and the IMO's technological research and development.

(2) Carbon Emissions Trading

The Carbon Emissions Trading System (ETS) is a market-based mechanism designed to reduce greenhouse gas emissions.

Under this system, the relevant authorities set an overall cap on greenhouse gas emissions in accordance with air pollution control requirements, and then establish corresponding sector-specific targets for different industries. Based on these targets, a certain number of emission allowances are allocated to firms or organizations. If a firm’s emissions exceed its initially allocated free allowances, it must purchase additional carbon emission permits; conversely, if its emissions fall below the allocated level, it may sell its surplus allowances to other liable entities that need them to comply with the prescribed limits.

The MRV system forms the foundation for the implementation of an emissions trading system. MRV consists of three processes: Monitoring, Reporting, and Verification. Through the MRV framework, government authorities supervise and review the aggregated data submitted by all participants within their respective industries or regions, thereby securing stakeholder recognition of the data and enhancing the credibility of the carbon trading system. It provides an essential guarantee for the stable operation of the carbon market and also serves as an important basis for corporate low-carbon transformation and regional low-carbon macro-level policymaking.

Once a sound MRV system has been established, the government adjusts the overall cap as well as the allowances allocated to individual companies and organizations in light of actual conditions, so as to ensure fairness, transparency, and effective enforcement of the rules. The ultimate goal is to shape a rational competitive landscape among firms and promote a green development trajectory through the interaction of market supply and demand and price fluctuations under the ETS framework.

The European Union Emissions Trading System (EU ETS) is the earliest established, most mature, and most influential carbon market in the world, and it was officially launched in 2005. On February 8, 2023, the Committee of Permanent Representatives of the Council of the European Union, and on February 9, 2023, the European Parliament’s Committee on the Environment, Public Health and Food Safety, respectively approved the final compromise text of the ETS revision proposal, which stipulates the following:

The EU ETS has applied, since 2024, to cargo ships and passenger ships of 5,000 gross tonnage (GT) and above, and will apply, from 2027 onward, to offshore vessels of 5,000 GT and above.

For voyages between ports under the jurisdiction of EU member states, 100% of the vessel’s reported emissions must be calculated and reported.

For voyages departing from a port under the jurisdiction of an EU member state and arriving at a port outside EU jurisdiction (for example, Rotterdam to Shanghai), or departing from a port outside EU jurisdiction and arriving at a port under the jurisdiction of an EU member state, 50% of the vessel’s reported emissions must be calculated and reported.

(3) Theoretical Comparison Between Carbon Tax and Carbon Emissions Trading Policies

In terms of carbon pricing, a carbon tax is based on a fixed tax rate established by government authorities, which generally remains unchanged over a certain period of time. By contrast, allowances under an emissions trading system are traded in the market, and their prices fluctuate continuously in response to market conditions.

In terms of emission control, a carbon tax does not directly impose a cap on carbon emissions. Instead, it seeks to reduce emissions by placing tax pressure on firms, thereby encouraging them to adjust production and lower emissions. Since its impact on emissions is achieved indirectly through prices, its mitigation effect is subject to uncertainty. Moreover, as the scope of taxation is generally confined within national borders, it cannot by itself address the problem of global emission reduction. In contrast, an emissions trading system sets an explicit cap on industry-wide emissions and achieves market equilibrium through the allocation and trading of allowances, making its emission reduction effect more predictable.

In terms of policy implementation, a carbon tax, as a form of government taxation, is relatively stable and allows firms to make more predictable emission-reduction arrangements, while also generating fiscal revenue for the government. However, the introduction and adjustment of carbon tax policies usually require strict legislative or administrative procedures, which reduces policy flexibility. By comparison, emissions trading policies are generally more flexible in their formulation, issuance, and adjustment. Nevertheless, their financial nature implies greater participation by capital and financial institutions, and the smooth implementation of such policies depends heavily on the regulatory system’s capacity to manage financial risks.

3. Literature Review

Seen from the perspective of local markets:

In 2009, Cao Jing, in Pursuing a Low-Carbon Development Path: The Design of China’s Carbon Tax Policy and CGE Model Analysis, constructed a dynamic CGE model and found that under two “revenue-neutral” scenarios, a carbon tax would have only a limited impact on the economy while producing significant greenhouse gas emission reduction effects [1]. However, this study focused on China’s unilateral domestic policy and did not take into account the influence of the international emissions reduction environment.

In 2013, Li Jing and Li Ruiyu, in A Study on the Impacts of Carbon Tax on China’s Shipping Industry and Countermeasures, conducted a representative analysis of inland and coastal vessels and found that container ships were the most affected by carbon tax in terms of costs. They suggested that China’s shipping industry should be granted appropriate preferential treatment under a carbon tax policy [2]. However, their study did not examine the operating conditions of ocean-going vessels.

In 2016, Zhao Yue, in A Study on the Impact of EU Maritime Carbon Tax on China’s Liner Shipping Industry, used the Monte Carlo method to analyze the effects of variables such as the price elasticity of container demand, freight rates, and carbon tax prices on the economic performance of liner shipping. The study showed that improvements in energy-saving and emission-reduction technologies could effectively reduce both carbon emissions and the economic losses of the liner shipping industry [3]. Although the paper provided analysis and recommendations from the perspective of the shipping industry, it did not address corresponding policy responses in China.

Also in 2016, Yang Jingyu, in Low-Carbon Economic Analysis and Green Performance Evaluation of River-Sea Direct Shipping Vessel Types Based on Carbon Trading, developed a low-carbon revenue model for river-sea direct container ships. By using the marginal abatement cost curve, the study demonstrated that the emission-reduction benefits of green technologies for vessel design schemes are not simply linearly additive [4]. Focusing on three dimensions—environmental coordination, economic rationality, and technological advancement—the paper proposed a new approach to green evaluation systems.

In 2018, Zhang Li, in Maritime Carbon Tax and the Green Development Path of China's Shipping Industry, qualitatively analyzed the impact of carbon tax on the management costs of the shipping industry and pointed out that China's shipping industry could not avoid the maritime carbon tax standards established by the European Union if it was to move toward a low-carbon and green development path [5]. However, the study did not quantify actual operating costs.

In 2019, Zhu Shoucheng, in A Study on the Impact of Carbon Emissions Trading Mechanism on China's International Shipping Industry, used the SWOT method to analyze the domestic and international development environment and concluded that it was feasible to incorporate China's shipping industry into the current Shanghai carbon market [6]. However, the study did not consider the issue of internal carbon trading arising from the autonomy of shipping enterprises themselves.

Also in 2019, Sui Zhichao, in The Impacts of Carbon Tax and Carbon Emissions Trading Mechanisms on Liner Fleet Operations, established a bi-level programming model for carbon tax and carbon emissions trading mechanisms in China's liner shipping industry. They found that as the carbon tax increased, the total carbon trading volume first declined and then rose [7]. This study proposed a new model for balancing the government's carbon reduction targets with firms' economic benefits.

In 2020, Hu Yi, Wei Xiaoyan, and Shen Minghui, in Is Carbon Tax More Suitable than Carbon Trading for Developing Countries, examined the applicability and effectiveness of carbon tax and carbon trading under different scenarios in developing and developed countries. They concluded that both policies are effective in both types of countries, but no mutually reinforcing effect exists between them [8].

In 2023, Ye Tiantian, in A Policy Study on the Coordination of Carbon Trading and Carbon Tax in China, qualitatively analyzed the synergistic effects of carbon trading and carbon tax policies in several European countries and argued that China should clearly promote the coordinated implementation of carbon trading and carbon tax [9]. However, the study did not incorporate industry-specific analysis into its scope.

Also in 2023, Zhao Wenchao and Hao Haixia, in The Underlying Logic and Practical Considerations for Levying a Carbon Tax in China, analyzed the operating mechanisms and implementation difficulties of carbon tax and carbon trading from both domestic and international perspectives. They pointed out that a full life-cycle carbon emission monitoring system is the core of policy design [10].

In 2023, Zhang Yuting, in A Study on the Impact of Carbon Tax Levy on China's Industrial Economy, constructed a Cobb–Douglas production function and found that carbon tax can effectively promote the development of the tertiary industry and facilitate the optimization and upgrading of China's industrial structure [11]. The study proposed a regionally differentiated carbon tax model, but it did not carry out further research on representative industrial subdivisions.

Seen from the perspective of global range:

In 2015, Kun Wang, in Modeling the Impacts of Alternative Emission Trading Schemes on International Shipping, developed demand models for container shipping and bulk shipping, and found that both the Open ETS and the Maritime ETS (METS) would lead to reduced sailing speeds, lower shipping volumes, and decreased fuel consumption. The study also showed that dry bulk shipping would suffer greater economic impacts than container shipping [12]. However, it did not consider the possibility that the former might offset transport losses by selling a larger amount of carbon allowances.

In 2019, Yewen Gu and Stein W. Wallace, in Can an Emission Trading Scheme Really Reduce CO2 Emissions in the Short Term? Evidence from a Maritime Fleet Composition and Deployment Model, established an optimization model for fleet composition under the METS framework and concluded that, in the short term, the implementation of METS would not lead to emission reductions [13]. However, the study was conducted under a low fuel price scenario and therefore may not be applicable to market conditions characterized by rising fuel prices.

In 2021, Shuaian Wang, in Implications of the EU's Inclusion of Maritime Transport in the Emissions Trading System for Shipping Companies, constructed a relationship framework between total cost and total sailing distance under the ETS from the perspectives of green shipping technology investment and fleet deployment. The study found that the Suez Canal route would become more attractive than the Cape of Good Hope route [14]. This research thus suggested the possibility of breaking away from traditional routes by calling at non-EU ports.

In 2022, Gaudin, in An Assessment of Carbon Pricing Effects on International Shipping, developed a profit optimization model for fleet operations and incorporated macroeconomic parameters. The study found that both carbon tax and carbon emissions trading would reduce trade speed and global carbon emissions, and that the emissions trading mechanism could limit increases in trade costs [15]. However, the research focused on the short term and did not consider the possibility of long-term fleet transformation and expansion.

Also in 2022, Yongzhong Wu, in Impacts of Shipping Carbon Tax on Dry Bulk Shipping Costs and Maritime Trades—The Case of China, developed a carbon emission model for China's shipping sector based on dry bulk trade volumes. The study showed that, in response to carbon tax costs, China's dry bulk trade would increasingly rely on neighboring countries, that is, by shortening transport distances to reduce emissions [16]. This study regarded slow steaming as an inevitable short-term decision for ships.

In 2023, Yongzheng Jerry Chua and Irfan Soudagar, in Impact Analysis of Environmental Policies on Shipping Fleet Planning under Demand Uncertainty, established a fleet planning model under the ETS framework and found that an open system similar to the EU ETS would have no significant impact on fleet deployment decisions by liner shipping companies and would not lead to a substantial reduction in emissions [17]. However, the study assumed a relatively low carbon price and did not consider the impact of higher carbon prices on firms' transport capacity.

4. Conclusion

It is foreseeable that the maritime industry may face higher greenhouse gas emission costs in the future as a result of increasingly stringent regulatory measures. Under the current circumstances, shipping companies should take advantage of the transitional leniency period of the EU ETS by actively formulating ship energy efficiency management plans, improving operational performance, and advancing low-carbon transformation. At the same time, making early arrangements for the adoption of green and clean fuels and for vessel upgrading can help companies gain a first-mover advantage. As older vessels may be forced to reduce sailing speeds in the future due to the burden of bearing the full cost of carbon emissions, firms that establish greener fleets with generally higher operating speeds may be able to increase effective transport capacity and ultimately expand their market share in the cargo market.

Judging from the global development trend of emissions trading systems in 2026, the implementation of carbon trading has gradually expanded from developed countries to developing countries, the volume of emissions covered by carbon markets has increased significantly, and carbon prices have shown an overall upward trend. Drawing on international experience, China should strengthen the construction of its MRV system to ensure the accuracy of data in its carbon trading system, thereby laying a solid foundation for the future inclusion of the shipping industry in the ETS framework. In addition, efforts should be made to improve the energy efficiency of ships and further encourage vessel upgrading and transformation. If a carbon tax policy is introduced concurrently in the future, supporting policy measures will also be needed to offset the impact of the high costs of carbon taxation on business operations.

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