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Decarbonization of international shipping industry and its impact on China from the perspective of economic analysis

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DECARBONIZATION OF INTERNATIONAL SHIPPING INDUSTRY AND ITS IMPACT ON CHINA FROM THE PERSPECTIVE OF ECONOMIC ANALYSIS

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Decarbonization of international shipping industry and its impact on China from the perspective of economic analysis**

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Low-carbon sustainable development of international shipping industry is the primary goal of international shipping industry in the 21st century. IMO' s GHG emission reduction measures are mainly from three aspects: technical measures, operational measures and market-based measures.

Through the analysis of the GHG emissions under international shipping industry background, policy requirements, the thesis conducts the economic analysis of the international shipping industry decarbonization, mainly including: carbon levy, ETS, alternative fuel/new energy, and the their running mechanism, function. Based on the research, the advantages and disadvantages of China's shipping industry (mainly including economy, policy guarantee, science and technology reserve. etc.) are analyzed, and constructive solutions are proposed.

KEYWORDS: DECARBONIZATION ； MARKED-BASED MEASURES ； CARBON LEVY；ETS

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LIST OF ABBREVIATIONS

CCS	China Classification Society
CO_2	Carbon dioxide
DCS	Data Collection System
EEDI	Energy Efficiency Design Index
ETS	Emission Trading System
EU	European Union
EU-ETS	European Union Emission Trading System
GHG	Greenhouse Gas
GHG FUND	Greenhouse Gas Fund
ICS	International Chamber of Shipping
IMO	International Maritime Organization
IPCC	International Panel on Climate Change
ISWG-GHG	Intersessional Working Group on Reduction of GHG Emission from Ships
MBMs	Market-Based Measures
MEPC	Marine Environment Protection Committee
METS	Maritime Emission Trading System
MRV	Monitoring\Reporting\ Verification
UNFCCC	United Nations Framework Convention on Climate

	Change
UNEP	The United Nations Environment Programme
WMO	World Meteorological Organization

CHAPTER 1 INTRODUCTION

1.1 Background of the study

As the largest industry in the world, the shipping industry accounts for 80% of global trade. (Balcombe et al., 2019) The shipping industry plays an important role in promoting global trade and economy. At the same time, it also generates greenhouse gases (GHGs) emissions from ships that cannot be ignored. According to the fourth IMO GHG study 2020, unless effective mitigation measures are taken, CO_2 emissions will increase by 250% by 2050 compared to 2008. (IMO, 2021)

In order to cope with global climate change, the Paris Agreement in 2015 made an overall arrangement for global GHG emission reduction, but did not establish targets for lowering GHG emissions in the shipping industry. Until April 2018, in order to promote the shipping industry to reduce CO_2 emissions as soon as possible, the International Maritime Organization (IMO) formulated a preliminary GHG emission reduction strategy for the international shipping industry, and made general arrangements for the shipping industry to respond to global climate change, as a response to the 2015 Paris Agreement. IMO' s first preliminary shipping GHG reduction strategy sets clear targets to reduce shipping emissions intensity by 40% by 2030 and 70% by 2050 (50% reduction in total emissions), based on 2008 emissions, and sets short -, medium -and long-term measures to achieve these targets.

Nevertheless, in August 2020, the IMO launched the fourth GHG study, which evaluated the current status of CO_2 emissions from the shipping sector. By 2050, CO_2 emissions from the shipping industry are expected to be 30% higher than in 2008 and 50% higher than in 2018, the study said. (IMO, 2021)

According to a report by Simpson Spence & Young, global shipping emissions totaled 833 million tons of CO_2 in 2021, up 4.9% year on year, up from 800 million tons in 2019 and accounting for 3% of the world's total emissions.

The increased speed of some vessel types along longer trade routes and increased congestion at ports were estimated to push up total emissions in 2021. After the outbreak of the global economy r recovered, high demand for consumer goods, enhanced emissions of distribution in different areas of the shipping industry, the largest LNG transportation fleet emissions have increased, followed by the emission of container vessels and bulk carriers. With the global demand for oil recovery, the world tanker fleet of CO_2 emissions also have increased.

The high level of data does not meet expectations, so the emission reduction task of the shipping industry needs more concern. At the same time, more efficient and useful emission reduction methods and measures have also become the direction that people should consider.

At the Maritime Environment Protection Committee (MEPC77) meeting in November 2021, member States discussed a number of proposals for further medium-term measures to reduce GHG emissions. These include Market-Based Measures (MBMs) to address GHG emissions from shipping, as well as proposals for the establishment of an International Maritime Research and Development Committee (IMRB).

The rapid growth of CO_2 emissions from shipping has long been a heat topic in the international community. The issue of shipping CO_2 emissions has been wandering away from the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol and the Paris Protocol. Finally, the parties reached an agreement on technical and operational emission reduction measures for

ships, and made relevant provisions mandatory through laws and texts. However, the shipping industry has adopted market-based measures to reduce emissions, and the parties are more divided. Among the market mechanism schemes included in the IMO negotiations, Maritime Emissions Trading System (METS), Carbon Levy and other market-based measures have become hot spots of controversy. The European Union (EU) has also said publicly that it will include shipping in its carbon trading system if there is no progress on a market mechanism.

Despite the heated debate about the green energy transition of shipping and the gradual strengthening of global shipping regulation, global shipping emissions continue to increase, which has become an "uncomfortable fact" for IMO.

At present, the entire shipping industry is going through a transition to a low- and zero-carbon future. It is worth considering how to use an economic path to help the industry achieve carbon reduction targets in this process.

At the same time, in order to respond positively to global warming, China solemnly declared at the 75 Session of the United Nations General Assembly on September 22, 2020 that CO_2 emissions would strive to reach a peak before 2030 and achieve carbon neutrality before 2060. (Zhao Hongtu, 2022)As the largest developing country in the world, China's annual carbon emissions from the use of fossil fuels are still very high.

Based on the above situation, relevant scientific theories at home and abroad are used to study the implementation effect of China's shipping industry after entering the carbon trading market, that is, to study the emission reduction capacity of carbon trade and its economic impact on the shipping industry. It is of great practical significance for the government and enterprises to adopt relevant policies and management strategies, which can provide reference for the international

negotiations of China's shipping industry.

It can also serve as a reminder to shipping lines and shipowners to think about shipping investments over the next 10 years. Still, it will encourage people to actively grasp information and attach importance to the latest development of international energy-saving and emission reduction technologies. Comparing the economic advantages of existing alternative energy sources will presumably help understand carbon levy and ETS, and promote the government to provide subsidies or other financial policies to promote the decarbonization process of the shipping industry.

1.2 Aim of the study

Low-carbon sustainable development of international shipping industry is the primary goal of international shipping industry in the 21st century. IMO' s GHG emission reduction measures are mainly from three aspects: technical emission reduction (including hull optimization, propeller selection, use of shore power, alternative fuels/new energy), operational emission reduction (including reducing ship speed and improving loading and unloading efficiency) and market-based measures.

This article through the analysis of the GHG emissions under international shipping industry background, policy requirements, the thesis conducts the economic analysis of the international shipping industry decarbonization, mainly including: carbon levy, ETS, alternative fuel/new energy, and the their running mechanism, function. Based on the research, the advantages and disadvantages of China's shipping industry (mainly including economy, policy guarantee, science and technology reserve. etc.) are analyzed, and constructive solutions are proposed.

Based on the research, the advantages and disadvantages of China's shipping industry (mainly including science and technology reserve, economy, policy guarantee, etc.) are analyzed, and constructive solutions are proposed.

CHAPTER 2 INTRODUCTION TO CURRENT SITUATION AND MEASURES OF DECARBONIZATION OF INTERNATIONAL SHIPPING INDUSTRY

2.1 The impacts of climate change

The GHG produced by human activities has had a significant impact on the global climate and environment. It causes global warming, rising sea levels, more extreme weather, and even reduced crop yields. As long ago as 1896, Swedish scientist Svan Ahrrenius pointed out that CO_2 emissions could cause global warming. It was only after 1980 that this scientific fact began to be widely recognized by more and more people. The warming melts snow and ice, as shown by the rapid reduction of Arctic sea ice; the record minimum of Arctic ice extent in September was set in 2007 and again in 2012, with 2019 matching 2007 as the second minimum(Xie, 2020).

In 1988, the United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) set up the Intergovernmental Panel on Climate Change (IPCC). The IPCC publishes comprehensive scientific assessment reports every 6 to 7 years, and the Fifth Assessment Report on Climate Change, released in 2014, provided the main scientific support for the development of the Paris Agreement. On 9 August 2021, the IPCC released its climate change assessment report "Climate Change 2021: The Physical Science Base". In the decade from 2011 to 2020, global surface temperatures were 1.09℃ higher than in 1850-1900, making it the warmest decade since 1850. In parallel, the WMO 's state of the global climate 2020, released in April 2021, showed that the global average temperature in 2020

was 1.2℃ above the pre-industrial level (the 1850-1900 average). While the land is warming more than the global average, the Arctic is warming more than twice as much. (ICS, 2022)

The 2021 IPCC report also predicted that global warming in the 21st century would exceed 1.5℃, or even 2℃, unless emissions of $CO_2$and other GHG would be drastically reduced in the coming decades. As temperatures rise, heat waves will increase. Warm seasons will lengthen, cold seasons will shorten, and extreme high temperatures will affect agricultural production and human health. They want to reduce GHG emissions, especially CO_2 emissions.

The IPCC' s Sixth Assessment Report (AR6) warns that global action on climate change mitigation and adaptation is urgent and that any delay will close the window of opportunity for a future that is no longer livable or sustainable.(Bo, 2022) AR6 report estimates future climate change risks in the near future (2021-2040). In the medium to long term, as global warming intensifies, the risk of climate change will increase.

2.2 Actions against climate change

The UNFCCC was adopted on 9 May 1992. and was adopted at the United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro, Brazil, on 4 June 1992. The UNFCCC is the world's first international convention to comprehensively control emissions of GHG such as CO_2 in order to combat the adverse effects of global warming on human economy and society. It is also a basic framework for international cooperation on global climate change.

In order to strengthen the implementation of the UNFCCC, the international community has been engaged in continuous negotiations to refine and implement the

convention. In 1997, the Third Conference of the Parties to the UNFCC adopted the Kyoto Protocol as a supplement to the convention to limit GHG emissions by developed countries in order to curb global warming. It proposed 3 flexible market mechanisms, namely carbon pollution trading, joint implementation and clean development(Morgan & Patomäki, 2021). The Kyoto Protocol entered into force on February 16, 2005.

In 2015, the Paris Agreement made arrangements for the post-2020 international mechanism to address climate change. It is whether the three flexible mechanisms involve in the carbon emissions trading between different countries, and they are an important mechanism for international cooperation on climate change, which is to realize the link giving countries on GHG emissions investment costs of flexibility, so as to realize the effectiveness of the global climate change on the issue of cost allocation. However, considering that investment in CO_2 sequestration products has a long income cycle, which requires not only capital input but also technology input, the direct sale of CO_2 emission quota is obviously more in line with the capital attribute of short-term vitality. Some developed countries prefer to sell CO_2 credits directly to developing countries rather than build synergies with these shelves. For example, most of the CO_2 emissions of Chinese enterprises exceed the standard, so many domestic enterprises tend to buy foreign quotas, thus forming a disguised export of capital.

2.3 Definition and characteristics of decarbonization of shipping industry

2.3.1 Definition of decarbonization of the shipping industry

In order to cope with climate change, reduce the CO_2 emissions from ships, promote the shipping industry to achieve green transformation and accelerate the development

of green and low-carbon shipping has become an important part of the international shipping industry at the new period.

The international shipping industry is at the leading position in global CO_2emission reduction. Under the influence of its CO_2 emission reduction strategy, regional market mechanism such as the EU and "zero emission alliance", "decarbonization" has become a hot topic in the international shipping industry.

Decarbonization refers to the green, low-carbon and high-quality development of shipping and the continuous promotion of "zero-carbon" shipping development. At present, the world's shipping industry is undergoing profound changes, speeding up the development of green and low-carbon shipping has become a major issue in the new century. Therefore, there is an urgent need for systematic research on energy conservation, noise reduction, energy conservation and new materials.(Tie, 2017).

2.3.2 Characteristics of decarbonization of the shipping industry

First, low cost of construction and maintenance. Compared with other modes of transportation, the upfront investment and infrastructure investment for CO_2 reduction of ships are smaller. Compared with land transportation, seaborne transportation is more suitable for energy conservation and emission reduction due to its large volume, small footprint and low energy consumption. At the same time, the speed of loading and unloading of ships is accelerated, which can improve the sailing efficiency of ships and reduce transport costs; For the wharf, it can improve the capacity of the wharf, thus improving the throughput and income of the wharf. In addition, new energy fuels can be used to reduce environmental pollution and noise pollution.

Second, the important influence of scientific and technological innovation. There

cannot be a single approach to achieving emissions reduction targets, but a set of complementary initiatives and new technologies must be adopted. Research and development of low-carbon energy is the key to the development of the shipbuilding industry and the reduction of CO_2emissions. After the demand for low-carbon energy in the shipping industry levels off, it will drive investment in new energy in developing and low- and middle-income countries, thereby overcoming the technical barriers to "decarbonized" ships.

Third, high shipping economic benefits. At present, the international shipping market continues to be depressed, the total shipping capacity is surplus, the competition among shipping companies is increasingly fierce, and the implementation of carbon levy will also increase the cost of shipping. However, in the long run, the green development of shipping enterprises can not only save operating costs, but also enable them to carry out scientific management. The key to improving the competitiveness of low-carbon transportation is to make low-carbon transportation more convenient, more economical and faster. At the same time, shipping enterprises are one of the core forces to realize the transformation of development mode and accelerate the development of modern transportation industry.

2.4 The nature and market function of the shipping industry

2.4.1The nature and characteristics of the shipping industry

Seaborne transport has slow transport speed and large carrying capacity, reducing transport costs. However, it is usually not possible to achieve "door to door", that is, to change between means of transport, by sea alone. Therefore, from the development and change of the existing transportation mode, obviously in the era of knowledge economy, the reform of shipping transportation mode and the convenient

development of "water-land transshipment" will have a significant impact on the future transportation mode. Container ships, for example, have created an efficient method of transportation for the convenience of multimodal transportation organization and station change. This also applies to the transport of bulk goods. Therefore, even in terms of remodel and convenient organization of multi-modal transport, shipping in this century will continue to develop in this way. This needs to change the mode of transportation, in order to achieve high quality, high efficiency.

2.4.2 Market functions of the shipping industry

As an important form of international trade, shipping has become an important means of transportation in the world. Despite its slow speed and high risk, it has advantages such as large capacity, volume, low freight and strong adaptability, as well as the global special geographical environment. The emergence and development of container transport, not only makes the transport of goods more intensive, rationalization, but also saves the packaging materials and transportation costs, reduces the damage of goods, goods poor, to ensure the quality of products, shortens the transport time, reduce the transport costs. In some countries with advanced maritime transport, their foreign exchange transport income has become the main pillar of their economy.

International shipping connects all countries and regions in the world. Shipping is the link of technology, economy and trade. Shipping is a form of combining producers, operators and consumers, and turning production and consumption activities into global activities through transportation. Shipping promotes not only the development of international trade, but also the global economy. The construction of ports and the opening of air routes enable trade and logistics, develop capacity, promote global economic development and improve people's livelihood. Worldwide, shipping is the

world's most important means of transportation, accounting for two thirds of world trade.

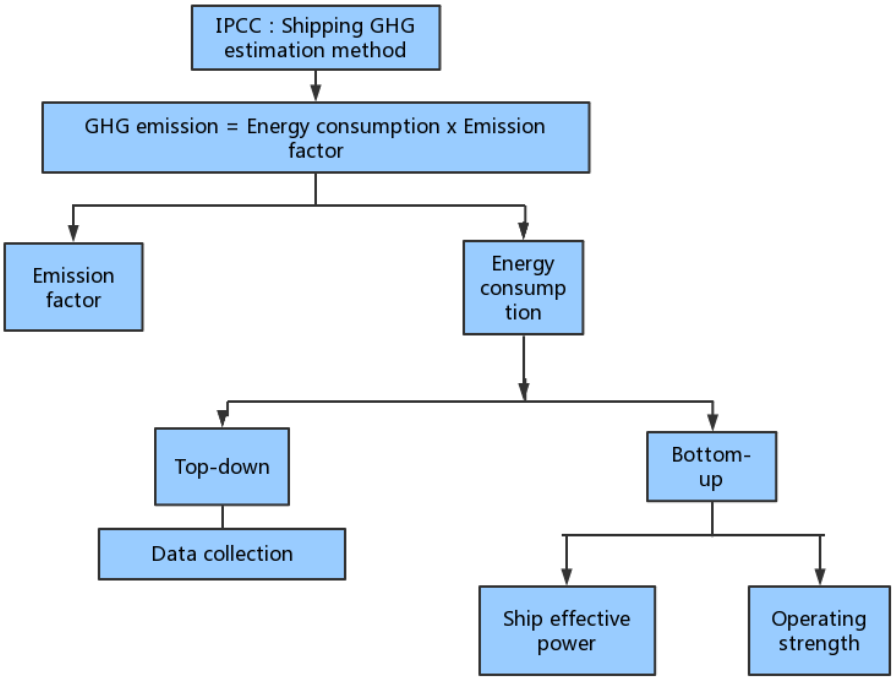
2.5 Overview of GHG emission reduction in international shipping industry

For a long period of time, compared with road, air and rail transportation, shipping has become the most important mode of transportation in international trade with its low freight price and low energy consumption. With the rapid development of shipping industry, its total GHG emissions are on the rise.

With the rapid development of shipping trade, the emission reduction work of shipping industry has also entered the track of rapid development. As discussion of ship energy efficiency grows, the shipping industry is beginning to recognize that CO_2 emissions from many existing ships worldwide must be balanced.

The global shipping industry consumes approximately 10,000 trillion BTS of thermal fuel annually, releasing 1 billion tons of CO_2 and 3% of GHG, as well as 15% of the world's major pollutants. Numerous scientific studies show that human activities, especially the excessive use of carbon-containing fossil fuels, are exacerbating the global GHG effect. The IPCC, as the world's most authoritative international organization on climate issues, is mainly responsible for assessing the potential impacts of global climate change on nature, human society and economy from a scientific perspective, and formulating feasible countermeasures to adapt to and mitigate climate change.In IPCC 1996 and 2006 guidelines, there are two main methods for calculating total GHG emissions.(Figure 1)One is "top-down" and the other is "bottom-up". IMO' s first report adopted a "top-down" approach, while IMO's second and third GHG reports in 2009 and 2014 adopted a "bottom-up" approach.(Shouchen, 2019)

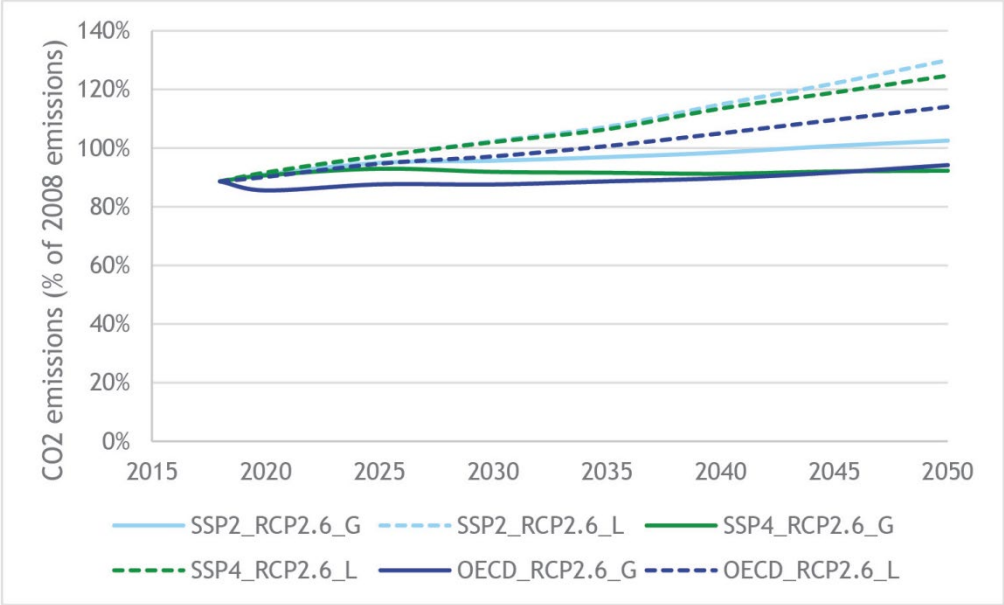
Figure 1 IPCC：Shipping GHG estimation method



Source：From (Shouchen, 2019)

Overall, shipping's share of global CO_2 emissions is modest, currently between 2% and 4%. Given the increasing demand for shipping as world trade develops, this will directly lead to a surge in industrial carbon emissions. If no effective mitigation measures are taken, the CO_2 emissions from the international shipping industry will reach more than 2.5 billion tons by 2050, accounting for 18% of global emissions.(Bouman et al., 2017) IMO has developed an initial carbon reduction strategy for this purpose, while the EU' s policy focuses on using market mechanisms and promoting industry cooperation on zero emissions through a "Zero Emissions alliance" to promote new alternative fuels. Emissions are projected to increase from about 90% of 2008 emissions in 2018 to 90-130% of 2008 emissions by 2050 for a range of plausible long-term economic and energy scenarios (Figure 2).(IMO, 2021)

Figure 2 Projections of maritime ship emissions as a percentage of 2008 emissions



Source：From (IMO, 2021)

2.5.1Preliminary strategy of GHG emission reduction in international shipping industry and its impact on shipping industry cost in recent ten years

IMO' s initial mitigation strategy includes short -, medium - and long-term mitigation measures. However, the document itself is not legally binding, so any vision, goals or measures must be incorporated into IMO' s mandatory document system. This means that its goals and measures at the present stage are not fully mature, there are many uncertainties, which have a profound impact on the shipping industry in the future. In terms of policy, the two sides will conduct further discussions on the preliminary strategy based on empirical analysis and research, and formulate the final strategy in 2023. During this time, IMO will use fuel consumption data to gather information to ensure that strategic decisions made in 2023 are scientific and sound.

According to information released by IMO, EEDI and CII have played an important role in IMO' s emission reduction plans, as shown by a brief summary of the actions taken by the IMO to reduce emissions between 2022 and 2050.（Figure 3）

Figure 3 A brief summary of the actions taken by the IMO to reduce emissions between 2022 and 2050.

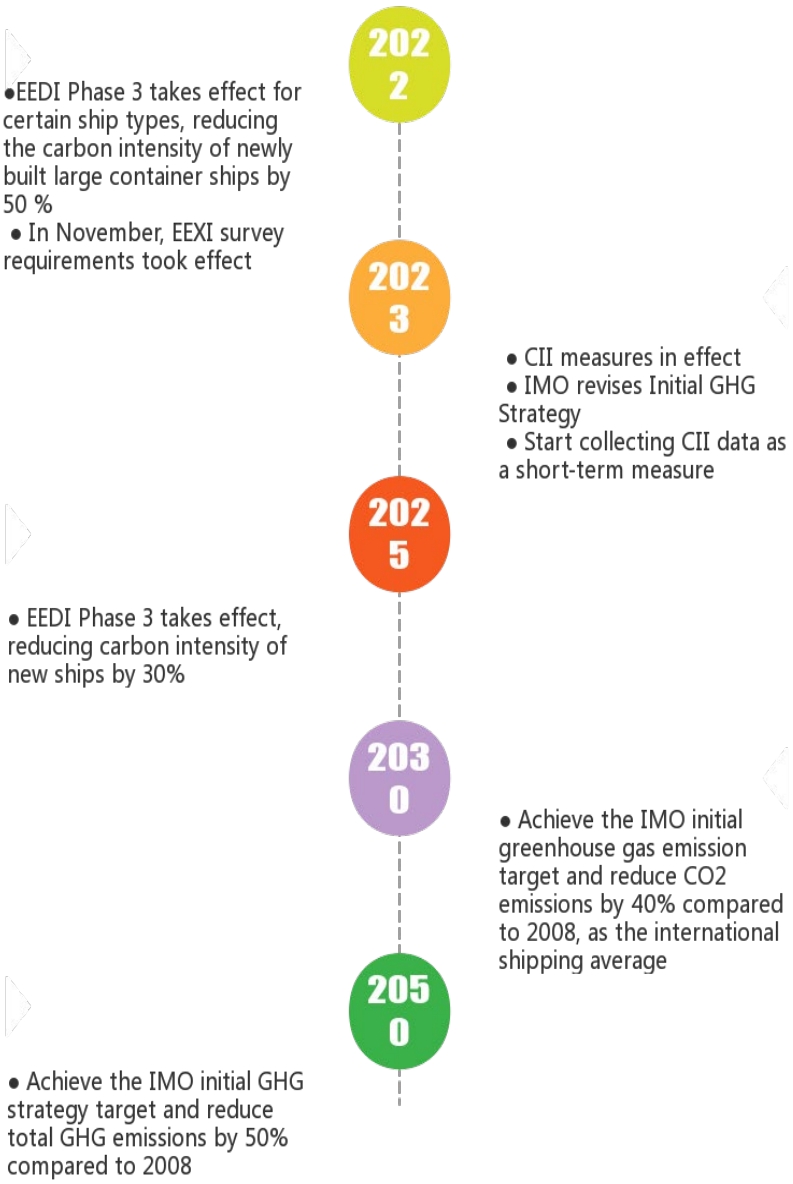


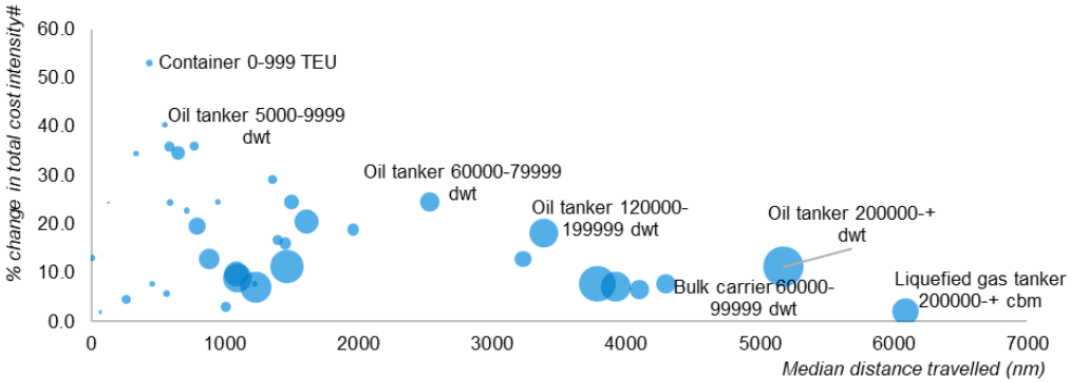
Figure 4 DNV typical ship categories for the HIGH-GHG reduction scenario and results converted to AIS data

DNV ship category	DNV study		AIS data (only laden or partially laden journeys)						
	% Increase in CII	N° of ships in 2019	N° of ships deployed in 2019	N° of direct journeys	Median distance travelled (nm)	Median duration of journey (days)	Median speed (knot)	Average DWT	Average age
Deep sea – bulk carrier	9.3	8,895	7,938	46,082	3,833	17.5	9.7	85,639	9.7
Short sea – bulk carrier	16.0	1,968	1,614	15,082	1,450	8.9	9.5	27,383	17.7
Deep sea – tanker	19.9	5,648	4,722	38,237	1,649	9.9	9.7	79,934	10.3
Short sea – tanker	37.6	3,104	1,992	38,003	631	3.4	9.4	10,772	11.5
Deep sea – container	14.9	3,086	2,898	111,560	827	3.1	13.8	75,393	11.4
Short sea – container	41.1	2,212	1,717	97,225	516	1.9	12.6	15,255	14.1
Liquified Gas	10.3	1,924	1,496	22,620	1,050	5.5	10.6	31,171	11.6
Other	16.2	9,880	5,043	120,432	586	2.5	11.8	12,218	15.6
Total	**16.0**	**36,717**	**27,420**	**489,241**	**762**	**3.2**	**11.3**	**40,740**	**12.9**

Source: UNCTAD compiled from DNV and Marine Traffic data.

Figure 4 is the output data received from DNV in connections with the 2030 HIGH-GHG reduction scenario, shows that ships most affected by the IMO short-term measure in terms of cost intensity are container ships and tanker vessels operating in short sea shipping. (UNCTAD, 2021)Total cost intensity increases by 41.1% and 37.6% for containers and tankers deployed in short-sea shipping, respectively, under the HIGH-GHG reduction scenario.

Figure 5 Percentage change in cost intensity by ship segment, average size*and median distance travelled



Source: UNCTAD compiled from DNV and MarineTraffic data. *: Size of the bubbles stands for the average ship size per DWT. #: % change in total cost intensity in HIGH-GHG reduction scenario compared to the Current Regulations scenario in 2030.

Figure 6 Ship cost changes under the 2030 HIGH-GHG reduction scenario (Bulk carriers of 200,000 dwt and above)

Scenario in 2030		Speed reduction (% relative to design speed)	Number of ships	Cruising hours	Number of voyages	Transport work capacity (dwt-mile)	Transportation work (tonne-mile)
Current Regulations	Total	14.7%	627	3,435,753	8,973	10,220,941,397,109	6,559,927,950,432
	per ship			5,480	14.3	16,301,341,941	10,462,405,025
HIGH-GHG reduction	Total	25.1%	713	3,924,673	9,012	10,223,919,686,546	6,561,839,453,822
	per ship			5,504	12.6	14,339,298,298	9,203,140,889
Change	Total	10.5 percentage point	13.7%	14.2%	0.4%	0.0%	0.0%
	per ship			0.5%	-11.7%	-12.0%	-12.0%

Scenario in 2030		CO2 emissions (tonnes)	Carbon intensity (gCO2/ dwt-mile)	Annual CAPEX (millions of USD)	Base OPEX (millions of USD)	Fuel expenditure (millions of USD)	Total cost (millions of USD)	Total cost intensity (USD/ tonne-mile)
Current Regulations	Total	20,749,982	2.03	1,320	1,637	2,435	5,393	0.082
	per ship	33,094		2.10	2.61	3.88	8.60	
HIGH-GHG reduction	Total	17,519,454	1.71	1,511	1,830	2,471	5,812	0.089
	per ship	24,571		2.12	2.57	3.47	8.15	
Change	Total	-15.6%	-15.6%	14.5%	11.8%	1.4%	7.8%	7.7%
	per ship	-25.8%		0.6%	-1.7%	-10.8%	-5.2%	

Source: UNCTAD calculations, based on data provided by DNV.

Similar patterns are shown in Figure 5and Figure 6. Compared with large ships sailing long distances, the total cost intensity of small ships sailing short distances increases more. As can be seen from Table 2 the more stringent the short-term GHG emission reduction measures are, the more ships will be demanded. There will be a very marginal change (i.e., a 0.6% increase) in capital expenditure per ship in the 2030 HIGH-GHG reduction scenario compared to the 2030 Current Regulations scenario. However, the capital expenditure for the same transport work will increase

as more ships will be required to transport the same cargo volume in view of the speed reduction.

2.5.2 Current situation of decarbonization of the international shipping industry

International shipping has a competitive advantage in the cost of transporting goods over long distances, with shipping companies accounting for 90% of total global trade. In recent years, due to the increase in the number of ships, most of the large international shipping ships have been in the waters above the high seas, passing through the waters of different countries and regions. Therefore, various relevant agencies have made joint efforts to regulate the GHG emissions of the industry and formulate relevant regulations.

In Europe, about 13% of CO_2 emissions from the transport sector come from shipping companies. In 2011 White Paper on transport development, the European Commission proposed a 60% reduction by 2050. In December 2019, the EU signed the European Green Pact, which aims to make Europe a global leader in "climate neutrality" by 2050 and improve the competitiveness of its industries. The EU has long been committed to market mechanisms to control industrial GHG emissions, and has become the world's largest carbon trading market.

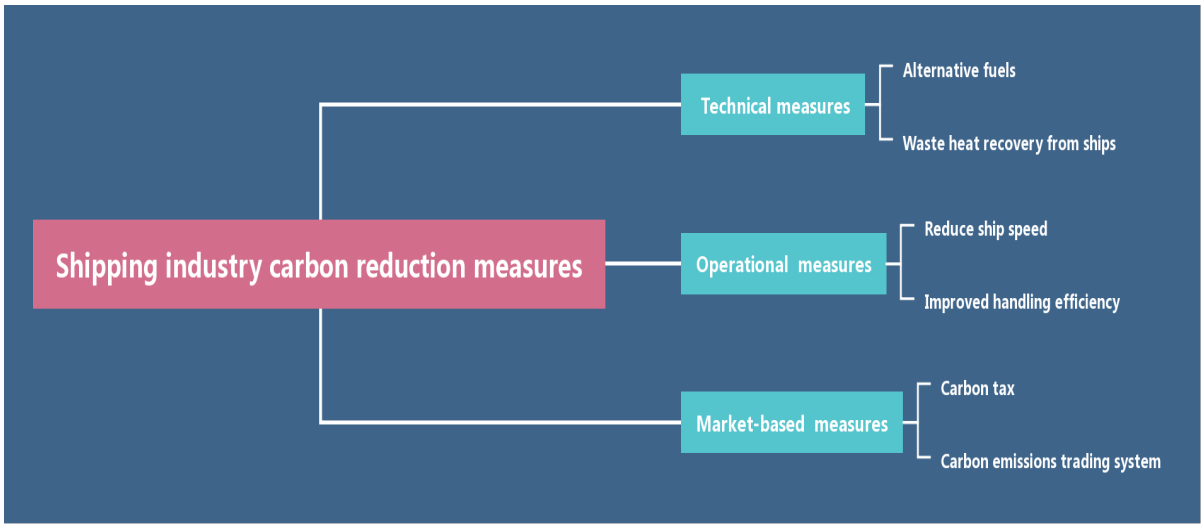
The Zero Emissions Alliance was established at the United Nations Climate Action Conference in September 2019. It is a platform co-hosted by the International Maritime Forum, the World Economic Forum and Friends of Ocean Action. The alliance, which includes large companies in shipping, energy, infrastructure and finance, now has more than 150 members (Peng, 2021). The alliance believes that in order to achieve the IMO 's 2050 target of reducing annual GHG emissions from seaborne transport by more than 50% compared with 2008 levels, the deployment of commercially viable zero-emission vessels will be required from 2030, with rapid

growth in the next 30 and 40 years. The alliance's overarching goal is to have commercially viable zero-emission ships on the market by 2030. To achieve this, the alliance has developed a four-stage strategy: The first stage (2019-2020) is to create and expand the alliance's base; The second stage (2021-2023) : formulate solutions and develop an enabling environment; The third stage (2024-2027) is to test the environments; The fourth phase, 2028-2030, prepares the market for zero-emission vessels.

2.5.3 Major measures to reduce emissions in the international shipping industry

IMO aims to reduce emissions in the international shipping industry from three aspects（Figure 7）:

Figure 7 Shipping industry carbon reduction measures



a) Technical measures

It mainly focuses on optimization of hull, propulsion device and propeller, improvement of main engine efficiency, recovery of ship waste heat and use of new energy. GHG emission reduction is mainly to reduce the use of fossil fuels, directly reduce the production of CO_2, such as the use of biofuels, fuel hydrogen, electricity, wind, solar energy and other alternative or auxiliary energy, or through technological progress and strengthening management to improve energy efficiency.(Sijia, 2020)Technological progress also includes energy-saving optimization design of ship, engine and propeller integration, rational configuration of propulsion diesel engine and power plant, and efforts to reduce ship resistance and improve propulsion efficiency; In order to directly reduce the fuel consumption of diesel engine, a new combustion system, an improved fuel injection system and a higher maximum combustion pressure are adopted to optimize the supercharging system, improve scavenging pressure, optimize the combustion chamber, and adopt a new combustion system to improve the fuel injection system and increase the maximum combustion pressure. And through the main engine shaft generator, series propeller, waste heat recovery and other energy-saving technologies to improve the overall thermal efficiency of the ship.

b) Operational measures

Commercial optimisation includes development of tools that provide a better understanding of technical and operational limitations from a commercial standpoint (Armstrong, 2013). Operational emission reduction measures include: reasonable ship scheduling; Economic navigation and meteorological

navigation; Adopt slow down navigation and energy saving speed; Use of high quality fuel oil (Haiou, 2017). It includes a CO_2 intensity index (CII) rating for ships, which will be verified each calendar year after the rules come into force, and an annual CII rating based on the ship's operating efficiency ranking among the global fleet for that year. Under the current draft amendments, poorly performing ships will not directly lead to punitive consequences for the time being, but will need to have a corrective plan and be included in the Ship Energy Efficiency Management Plan (SEEMP). Consistent with the IMO fuel data collection mechanism and existing ship technology energy efficiency requirements, the operational energy efficiency requirements and classification mechanism for existing ships only apply to EEDI vessels of 5,000 gross tons and above.

c) Market-based measures

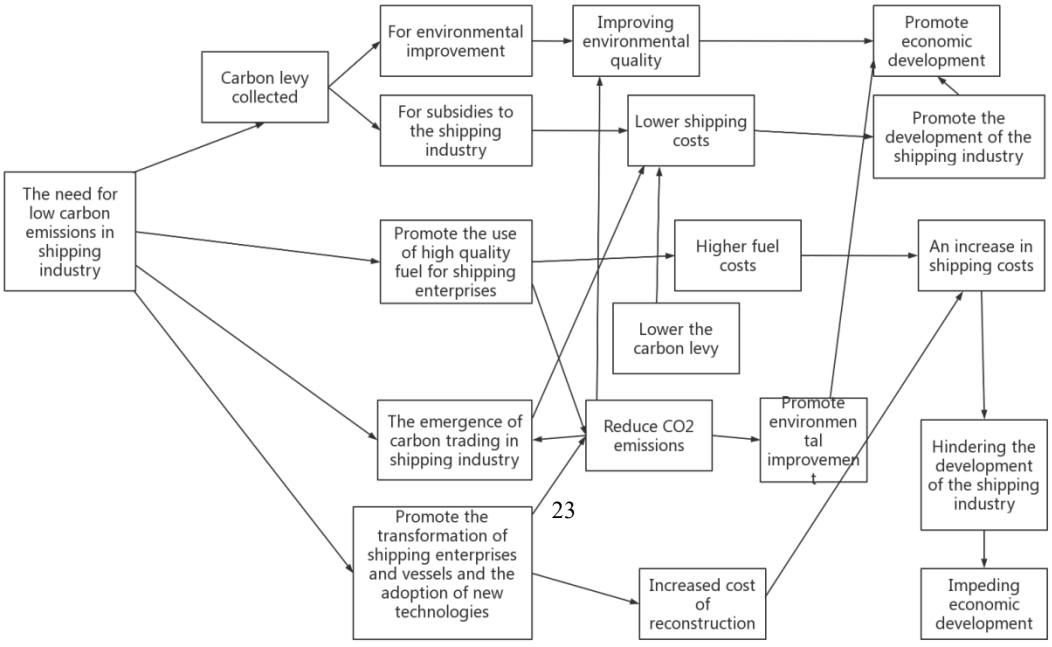
It includes a carbon levy, ETS, GHG emissions fund, and other market-based incentives and penalties.For now, as in other industries, there is no magic bullet for decarbonisation. Halving CO_2 emissions is likely to require a range of options, including new fuel sources, improved technical or operational efficiency, and demand reduction. Biofuels are seen as promising carbon-neutral fuels that can reach global markets relatively quickly because they do not require large investments in Marine engines or infrastructure(Jiatai, 2021). Liquefied natural gas (LNG) is the main alternative to liquefied fossil fuels and can reduce the impact on air quality and direct CO_2 emissions, although methane emissions have been shown to reduce GHG benefits. Other alternative fuels include biofuels, methanol, hydrogen, electric propulsion and

even nuclear fuel, but each provides varying degrees of decarbonization and produces different economic costs and air quality-related pollutants.

CHAPTER 3 ECONOMIC PATH ANALYSIS OF DECARBONIZATION OF INTERNATIONAL SHIPPING INDUSTRY

The rapid growth of CO_2 emissions from ships has been a hot issue in the international community(Wan et al., 2018). However, the issue of CO_2 reduction in the shipping industry has been excluded from the legal text of international climate negotiations. This does not mean that the shipping industry is out of the frame of climate negotiations. Since 1997, the IMO has been engaged in lengthy negotiations with all parties on the issue of CO_2 reduction for shipping. Technical and operational measures of ships have been agreed and enforced through legal texts. However, there are significant differences between parties on what market-based mitigation measures (MBMs) should be in place for the shipping industry. In the market mechanism scheme included in the IMO negotiations, Emissions Trading System (ETS), IMO Climate Fund, and some shipping energy and trade proposals have become hot spots of controversy. In MBMs， various factors of the shipping low-carbon system are linked with each other, mainly through the control of cost to promote the control of environmental pollution.（Figure 6）

Figure 8　MBMs：Low carbon of shipping relational factors



Source：From (Haiou, 2017)

National policies to control GHG emissions generally fall into three categories: command-and-control, economic incentives, and persuasion. Among them, economic stimulus means because of good flexibility, continuous improvement of good by all countries.(Bouman et al., 2017) In the economic stimulus means, the most important is the CO_2 pricing mechanism. In line with the principle of "polluters pay", people who want to emit GHG such as CO_2 should first obtain the right to emit CO_2 and then pay for the right, which is called CO_2 pricing.

CO_2 pricing schemes generally fall into two categories. One is a government-mandated approach, which is to levy a carbon levy. The other is through market means, namely the establishment of carbon emission trading system. The ETS means that the government determines the final emission level and the CO_2 price is determined by the market, so the CO_2 price is uncertain.

It is because of this distinction that the two methods have different characteristics. The introduction of carbon levy is more suitable for the control of small and micro emissions, while the ETS is suitable for the control of large emissions of enterprises or industries. The two policies can be used together. From the perspective of economy, both carbon levy and ETS are policy means to solve the externalities of public goods, but there are certain differences in principle and mechanism.

3.1 Overview of carbon levy

3.2.1 The background of carbon levy

A carbon levy means that the government sets the price of CO_2emission and the market decides the total amount of CO_2 emitted.(The World Bank, 2022)Because of the uncertainty of the market, the ultimate amount of CO_2 emissions cannot be

accurately estimated.

Marine carbon levy was first proposed by the EU. It is a tax levied on the proportion of CO_2 content of fuel oil emitted by ships to reduce fuel consumption and CO_2 emissions from ships.

In 2013, the EU proposed a regulatory plan for CO_2 emissions in the shipping industry, which is to monitor, report and verify carbon emissions of ships berthing at EU ports (referred to as MRV system), namely, carbon levy. The maritime carbon levy will apply to all ships with a gross tonnage of 5,000 or more entering, leaving and passing through the ports of the EU member states, and will apply to all maritime activities within the jurisdiction of the EU, regardless of whether theCO_2 emissions take place within the EU.

The EU' s unilateral approach to impose the carbon levy on shipping has been controversial(Chang, 2016). The controversy mainly revolves around the question of whether the responsibility of carbon levy proposed by the EU is fair. Most countries believe that CO_2 emissions from shipping should comply with the basic legal framework of the UNFCCC and its Kyoto Protocol, as well as the principles of "common but differentiated responsibilities" and equity. When it comes to CO_2 emissions, however, the EU says developing and developed countries should be equally responsible.

However, for the world shipping industry, the EU' s carbon levy on navigation will directly eliminate ships that do not meet the CO_2 emission standards, so that some small shipping companies that own these ships will exit the shipping market. The shipping industry has had to shuffle. The main reason is that shipping industry is a high-investment and high-risk industry, and the investment cost of shipping companies is very high. It is difficult for small shipping companies to survive if they

are affected by the carbon levy on navigation. Especially since 2019, due to the impact of the epidemic, shipping market prospects have been uncertain, shipping capacity supply and demand are relatively unbalanced, epidemic prevention and control costs and seafarers' labor costs have soared, and shipping company has already faced considerable pressure. If the EU continues to impose carbon levy policy, it will further increase shipping costs for companies.

The EU' s compulsory carbon levy on navigation has also been opposed by shipping countries and resisted by shipping companies around the world. As a matter of fact, the IMO and other organizations have gradually made restrictions and regulations on maritime pollution and GHG emissions in accordance with the actual development of the international maritime industry. From the MARPOL Convention to the implementation of then GHG emissions monitoring and verification of maritime transport in 2013, (Measurable, Reportable, Verifiable, MRV), from the international community to the global shipping industry pollution control and CO_2 emission reduction work, the issue has been put into legal documents and practical actions.

3.1.2 view on carbon levy from the perspective of the international shipping industry

Nominally, the EU' s carbon levy aims to reduce CO_2 emissions and change the current global pollution caused by shipping. However, fuel oil and other fossil energy used by ships will not only emit CO_2, but also produce a large number of other pollutants, including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_X), sulfur dioxide (SO_2), particulate matter (PM) and other atmospheric pollutants. The EU carbon levy is limited to emissions of CO_2 and other gases, but there is no reasonable limit on the emission of SO_2, the main pollutant that causes acid rain. It is far less comprehensive than the relevant regulations of IMO and other

world organizations.

A carbon levy is merely a pass-through of CO_2 trading, without actually reducing emissions. The EU' s carbon levy on navigation is "treating the symptoms rather than the root cause", which cannot fundamentally solve the adverse impact of CO_2 emissions on the environment. In the projects formulated by the EU, the differential treatment among countries is not fully considered. Carbon levy will have a great impact on countries with incomplete shipping development, but the EU has not formulated corresponding protection and support mechanism to protect the shipping industry of developing countries.

Carbon levy enables the EU to have legitimate reasons to collect taxes from shipping companies of various countries. Its rules are formulated by the EU and it decides whether to collect taxes on ships docking at EU ports, so the EU occupies a considerable initiative. If implemented successfully, the profits could be substantial.On 21 December 2021, the EU said it expects carbon levy and other revenues to reach 17 billion euros.

The EU' s implementation of this carbon levy not only brings direct economic benefits, but also brings comprehensive political benefits and voice to the EU. At the same time, promote the export and promotion of EU green energy technology to the world. The imposition of carbon levy on shipping can stimulate the consumption and use of green and low-carbon materials and related products in various countries, while the EU leads many countries in emerging green and low-carbon materials and environmentally friendly energy technologies.If other countries want to comply with the CO_2 emission standards set by the EU, they need to control the CO_2 emissions of their ships, so they need to retrofit their ships with green technologies. The EU can provide support in terms of green technologies and materials, and can therefore rely

on other countries to import advanced technology and materials to foster new growth areas. The EU' s carbon levy on shipping, in the form of a tax, appears on the surface to be contributing to global environmental improvement and should not be questioned by other countries. But as the manager of the collected funds, it is likely to use the money for energy conservation and emission reduction tasks of its shipping companies in various countries, or for technical support. Thus, the operating costs of shipping companies within the EU are indirectly reduced, and the development competitiveness of other shipping companies is reduced in disguise, therefore the EU shipping industry is in a more favorable competitive position.

3.1.3 International Shipping: Carbon levy on navigation and operating costs

Carbon levy is price-driven, akin to pigouvian taxes. According to British economist Arthur Pigou, it is a corrective tax that internalizes externalities by imposing a tax on producers that produce negative externalities or subsidising producers that produce positive externalities. For example, levy should be imposed on polluting paper mills and steel mills, and subsidies should be given to industries with externalities, such as education. When externalities exist, it is difficult to ensure the optimal allocation of resources by perfect competition market. In this case, private and social costs are no longer in line, and the economy as a whole exhibits inefficiencies.

a) The impact of carbon levy on ship operating costs

Ship operating cost is the total expenditure of shipping enterprises on ship operating expenses, which is mainly composed of fixed cost and variable cost. Fixed costs include crew wages, spare parts and materials, etc. Variable costs include fuel, port charges and other expenses. The carbon levy is a charge on the CO_2 produced by ships because of fuel consumption, so we count it in the

cost of ships' fuel. Assuming that one voyage of a ship is taken as the calculation unit, the model formula of the impact of carbon levy on ship operating cost is as follows:

$$P = \frac{C \cdot CT \cdot A}{TC} \cdot 100\% = \frac{C \cdot CT \cdot A}{C \cdot P + OC} \cdot 100\% \qquad 3.1.3.a\text{-}1$$

P： percentage of impact of carbon levy on operating cost, %;

C: Fuel consumption of ship voyage, ton;

CT: Carbon levy rate, USD/ton CO_2;

TC: Total operating cost of ship voyage, USD;

A: CO_2 emission factor, (diesel 3.160 4 tons of CO_2/ ton, fuel oil 3.236 6 tons of CO_2/ ton)

P: Fuel price, USD/ton;

OC: Ship voyage cost except fuel cost, USD.

Table 1 Hypothetical Scenarios of carbon levy in international shipping industry

	item	Hypothetical Scenarios
1	Tax link	Consumption link levy
2	expropriation	All international vessels of 400 gross tonnage and above
3	taxation basis	Adopt CO_2 emission as tax basis
4	CO_2emission accounting method	Estimation of fuel consumption, fossil fuel consumption and CO_2The emission coefficients are multiplied
5	Levy	The provisional tax rate adopts the carbon levy rate of "25 USD/ton ~ 400 USD/ton" favored by the IMO.

6	refund of tax and levy	Consider taxes for international shipping GHG fund, the fund For emission reduction projects in developing countries and for the IMO technical cooperation program

Combine formulas （3.1.3.a-1 ）and Table 1, we selected ocean-going ships for analysis. According to the latest international oil price in June 2022, the diesel price is USD 1120 /MT per ton, and the fuel oil price is USD 1180 /MT per ton. Combined with some fuel consumption data of a single ship voyage, the fuel cost of a ship voyage accounts for about 41.24% of the total operating cost. The current carbon levy rate favored by the IMO ranges from $25 to $400 per ton. (ICS, 2022)Then the total operating cost of the ship will increase by about 4%~5%.

b) Changes in unit shipping rates under carbon levy

The American Bureau of Shipping (ABS) released its low-carbon Shipping Vision 2030 and 2050, which provides a comprehensive analysis of the energy sources that the shipping industry may use in the future. Among them, the carbon intensity target calculated using data from the IMO GHG forth study and the United Nations Conference on Trade and Development (UNCTAD) is:

In 2008 it was 22 grams of CO_2 per ton mile

In 2015, it was 15.2 grams of CO_2 per ton mile

The 2030 target is 13.2 grams of CO_2 per ton mile

The 2050 target is 6.6 grams of CO_2 per ton mile

After conversion, the CO_2 emission per unit transport volume of shipping in the corresponding year is as follows:

13.67 g CO_2 / ton-km in 2008

9.44g CO_2 / ton-km in 2015

8.20g CO_2 / ton-km in 2030

4.10 g CO_2 / ton-km in 2050

According to the latest CO_2emission trading price of 36 yuan/ton in Beijing, it can be concluded from the China Carbon Emission Trading network that the shipping industry needs to pay for the CO_2 emissions in different years:

0.49 yuan/ton/km in 2008

In 2015, it was 0.34 yuan/ton/km

In 2030, it will be 0.30 yuan/ton/km

In 2050, it is 0.15 yuan/ton/km

If calculated according to the price of the Sino-US route, the freight rate of the 40-foot container between West America and Shanghai is $8,163. Based on the data of 20 tons per case, 6.55 exchange rate and 10,350 kilometers, the freight rate is 0.26 yuan/ton-km. If according to the price of 4000 US dollars, the unit freight of sea transportation is 0.13 yuan/ton/km. As can be seen, CO_2emission prices are higher than shipping costs. In this sense, a carbon levy is too heavy for the shipping industry to bear.

3.1.4 Impacts on the shipping industry

On the one hand, carbon levy will increase the total operating cost of shipping enterprises, thus reducing the competitiveness of shipping enterprises(Xu Huan, Liu Wei, 2013). On the one hand: From 2018, ships of more than 5,000 gross tonnage will be subject to a standard carbon levy when entering, leaving and passing through ports in the EU region. For shipping enterprises, compared with before the policy implementation, this part of carbon levy is the most direct cost increased. The

imposition of carbon levy on shipping will increase the total operating cost of shipping enterprises by 4% ~ 5%, which will directly worsen the financial situation of the already large loss of shipping industry and reduce the competitiveness of shipping enterprises. On the other hand, it will increase the cost of managing carbon levy policies. The company not only needs to set up full-time staff to track and investigate the carbon levy and related policies, and provide legal advice, but also needs to establish a CO_2 emissions declaration system for ships. The increase of these management costs, for small-scale shipping enterprises, is worse. The EU mainly collects carbon levy for shipping through EU-ETS system and MRV system. The detection, report and verification of CO_2 and emissions from ships will increase the management cost of shipping enterprises, mainly including: the preliminary preparation cost of understanding, communicating with and consulting with relevant departments about the rules and implementation plan of carbon levy; According to ETS system requirements, shipping enterprises need to bear the registration fees and transaction costs; According to the requirements of MRV system, it is necessary to establish the CO_2 emission declaration system of ships, allocate data statistics management personnel, calculate the time cost of CO_2 emission, compile CO_2 emission report, check cost and legal consultation cost, etc. AEA Technology estimates that the resulting additional management costs for all ships over 5, 000 gross tonnes operating on EU routes will be 77 million euros.

Because the current EU carbon levy applies to ships of more than 5,000 gross tons, shipping companies are limited in their choice of ships.(Li, 2018) First, fuel costs are apportioned to operating costs, which is not conducive to the long-term development of shipping companies. Second, the problem of fuel consumption caused by small ships is outside the scope of the current EU market control, resulting in a relatively unfair competition situation. The EU carbon levy policy will guide the shipping

industry policies of many countries, and these countries will formulate policies to encourage shipping enterprises to reduce carbon emissions.

The regulatory policy of shipping decarbonization has not been fully formed. Before it is formed, uncertainty will continue to generate commercial risks. Although industry leaders agree that early progress is not entirely dependent on the global regulatory framework. However, without new regulatory policies, the price difference between green and conventional fuels will continue for decades, which will certainly hinder shipping decarbonization. Therefore, a carbon levy framework is needed to bridge the price gap between fossil fuels and zero-carbon fuels. But in fact, few countries can manage carbon levy, and each country has a competitive relationship with each other, so it is bound to be very difficult to agree on a global regulatory measure of carbon levy.(Haoyue, 2020)

3.2 Overview of ETS

3.2.1 The definition of ETS

The Carbon Emission Trading System (ETS), also known as the carbon market, is an effective policy to stimulate the reduction of GHG emissions. The Kyoto Protocol, approved in 1997, sees the market mechanism as a new way to resolve the problem of lowering GHG emissions. The principle of carbon trading is that one party obtains GHG emission reduction amount from the other party in the form of payment, and the buyer can utilize the amount of emission reduction to mitigate the GHG impact to reach its emission reduction target. (Qian, 2021)

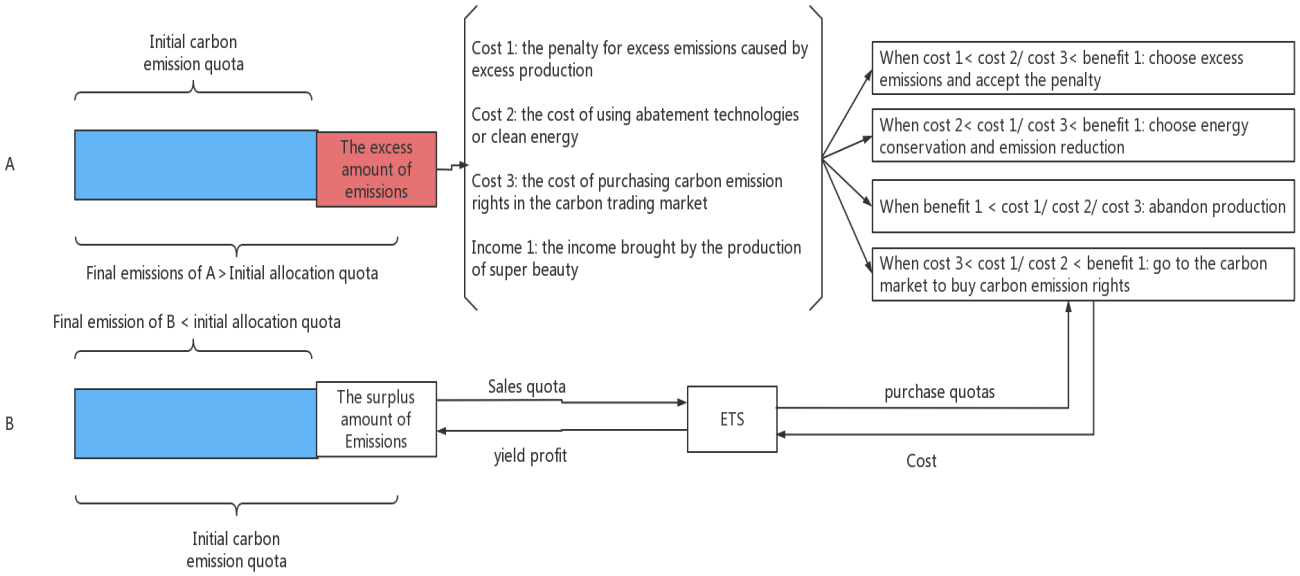
Cap-and-trade schemes originated in the US in the 1980s and 1990s as a model for decreasing pollution. Today, cap-and-trade schemes are generally used to lower

GHGs in various key industries. (Haoyue, 2020)

The core of ETS is to "cost" the environment, to use market forces to convert the environment into paid use of production factors, and to exchange the precious asset of carbon emission right as a commodity in the market.

As for the operation mechanism of the carbon market, first of all, the government determines the overall emission reduction target and adopts a quota system. The initial carbon emission rights are first assigned to the enterprises included in the trading system in the primary market, and the enterprises can exchange these carbon emission rights freely in the secondary market.

Figure 9 General trading process of ETS



Besides, enterprises with comparatively low emission reduction costs and economic incentives will take the lead in emission reduction, and sell the excess carbon emission rights to enterprises with relatively high emission reduction costs and gain

additional income. Enterprises with high emission reduction costs can lower the cost of carbon emission compliance by acquiring carbon emission permits.

3.2.3 Economics of ETS in shipping industry

As a widely accepted environmental and economic policy, ETS plays a positive role in reducing GHG emissions, protecting ecological environment and realizing sustainable development of human beings. In order to better push economic subjects to consciously implement the environmental policy and policy makers effectively implement the environmental policy, it is essential to carry out economic interpretation to grasp the essence of the environmental economic policy more properly.

a） Essential attribute: commercialization

To deal with the negative impact of ship greenhouse gas emissions on economic growth, the commercialization of CO_2 can promote people's attention to it. Carbon emission right trading in shipping industry takes the right to use carbon emission right as a commodity, and allows different subjects to buy and sell it through market-oriented means, so as to realize the effective allocation of resources and achieve the goal of pollution control. Obviously, once the carbon emission right has the commodity attribute, the compensability becomes the basic problem that the economic subject needs to consider when acquiring or transferring the commodity. Consequently,

commercialization is the essential attribute of carbon emission trading. (Song Liying, 2015)

b） Solution logic: Internalize the Externalities

When an economic agent engages in activities that alter the interests of other economic agents and does not pay additional fees for such effects, that is the externality dilemma, which leads to the failure of market equilibrium. By internalizing externalities, that is, by command-and-control regulation or market-based policies, taxes are levied on goods that have negative externalities and subsidies are given to goods that have positive externalities. Consequently, economic entities will determine how much carbon emission rights to attain or transfer in the market according to the costs and benefits of their emissions, hence promoting the development of the carbon emission rights trading market.

c） Efficiency principle: market mechanism

ETS right is based on the commoditization of carbon emission right, aiming at the efficient use and fair distribution of carbon emission right, and by means of marketization, centering on the price mechanism, ensuring that economic subjects are guided by the matching of costs and benefits to achieve the optimal allocation of carbon emission right. In a word, ETS is an ecological economic policy enforced to prevent the conflict between man, nature and society. The commercialization attribute facilitates the industry to pay more attention to the optimal allocation of carbon emission rights, and the

internalization logic of externalities helps the economic subjects attach great importance to the matching of ecological costs and ecological benefits. Market mechanism can make economic subjects pay more attention to improve the utilization efficiency and distribution fairness of carbon emission rights.

d） Cost and benefit effects

After the implementation of ETS, carbon emission has become a part of the production cost of products, and the marginal cost of products has correspondingly increased. This is mostly due tothe cost of attaining carbon emission right directly enhancing the production cost of products. Besides, the implementation of ETS has exacerbated the rise in energy prices for the shipping industry. In order to cope with the challenges brought by the increase of production costs, producers will indirectly transfer additional costs to the end users of products under the guidance of profit, that is, they will incorporate the marginal cost of products into the formulation of product prices. (Song Liying, 2015)

The ISWG-GHG 12 was held from 16 to 20 May. In line with the IMO work plan on the development of medium-term GHGs mitigation measures, the meeting discussed some specific recommendations for medium-term measures and associated impact assessments After very constructive discussions, the Working Group agreed to further develop a basket of medium-term measures, including elements such as carbon pricing (for example, through a market-based measure) and to report on progress made in reviewing procedures for assessing the impact of alternative greenhouse gas mitigation

measures on countries This preliminary impact assessment examines the potential impact of a tax on countries with a quota ranging from us $25 per tonne of CO_2 to US $400 per tonne of CO_2. The impact on industry and the country is analysed in the preliminary impact assessment. This measure is likely to have a net negative economic impact.(Norway, 2022)

Table 2 Total cost intensity per decade of the "decarbonization by 2050" path and two sensitive scenarios (CENTS/ton mile)

Sensitivity scenario	2030		2040		2050	
	Absolute(USD cents/ tonne mile)	Relative to "Current regulations "	Absolute (USD cents/ tonne mile)	Relative to "Current regulations"	Absolute (USD cents/ tonne mile)	Relative to "Current regulations"
"Decarbonization by 2050" (reference)	0.59	+58%	0.59	+85%	0.52	+75%
Higher seabornetrade growth	0.60	+66%	0.55	+80%	0.48	+68%
Higher price ofcarbon-neutral fuels	0.66	+73%	0.67	+108%	0.59	+100%

Source：From (ISWG-GHG 12-3-14, 2022)

Table 2 shows that higher price of carbon-neutral fuels has the greatest impact on future shipping costs (Norway, 2022). At the same time, a scenario simulation analysis is carried out. Sensitivity scenarios for changes in expected growth in seaborne trade demand and the price of carbon-neutral fuels were run as sensitivity scenarios for the estimated total cost intensity (in US dollars per ton mile) in the decarbonization path to 2050.

3.2.4 Impacts of carbon emissions trading system for shipping industry

a）Benefits of EU-ETS application to international shipping

ETS has strict emissions standards and sets an overall emission cap that all polluters need to work together to achieve, and to assign each company a quota of emissions, coupled with severe pollution penalties, ensuring that emitters can help achieve this overall goal. EU-ETS has been successfully implemented in a number of industries such as energy, oil refining, steel, cement and paper. After several years of implementation, the effectiveness of the carbon quota allocation system and carbon trading platform has been fully verified. Therefore, the extension of EU-ETS to the shipping industry will further promote the implementation of ship emission reduction.

EU-ETS allows emissions trading within and across sectors, including offsets, which provides greater flexibility to achieve policy goals. Since the price of carbon credits is set by the market, achieving emissions reductions through EU-ETS may be the most economical way for some companies that are temporarily struggling to adapt.

For individual carbon emitters, in order to meet the prescribed carbon emission reduction target, they can purchase emission credits through funds, or adopt low-carbon or zero-carbon alternative fuels or adopt innovative technologies to reduce carbon emissions. Considering economic benefits, individual carbon emitters may switch to alternative fuels or adopt innovative technologies to achieve emission reduction requirements in order to reduce their costs. This has injected vitality into emission reduction innovation.

b）Potential problems of EU-ETS application to international shipping

The price of carbon credits traded in the EU-ETS depends on supply and demand in the EU carbon market. The trading price of carbon credits in the EU-ETS is affected by the surplus of credits, resulting in a relatively low price. Some shipping companies, especially when the price of carbon credits is low, will prioritise buying extra credits to meet the requirements rather than investing in improving the energy efficiency of new and existing ships. In this way, enterprises will directly reduce their willingness to invest in reducing carbon emissions and will not take advantage of long-term low-carbon economic development.

Especially for small and medium-sized enterprises, the number of ships under management is small. Compared with large shipping companies, these companies have fewer opportunities to participate in carbon trading, and the proportion of management costs is relatively high, with obvious competitive disadvantages. Some of the larger shipping companies also have to bear

more of the transaction costs through carbon allowances and market trades. For shippers, due to the increase in operating costs of shipping companies, freight rates will rise correspondingly, which will lead to the change of short-distance sea transportation to road transportation and multimodal rail transportation. For consumers, the increase in product prices leads to a decrease in people's demand for these expensive goods and services, which results in an increase in alternative goods.

3.3 Other Marked-based Measures

Follow the heart of the UNFCCC and IMO against decarbonization. The amount of the fund is directly linked to fuel efficiency. The fund is funded from the fuel surcharges paid by ships. The recommendations in the SWG-GHG 10/5/2 document also include the establishment of an IMO Climate Fund (ICF) to use the funds raised to accelerate the use and deployment of zero-carbon technologies and fuels, with special consideration to the needs of developing countries, especially the least developed countries and small island developing States.(ICS, 2022)

The comprehensive energy efficiency incentive mechanism is a combination of Japan's leverage incentive system and the ship energy efficiency system of the World Maritime Conference. It is similar to the International Emission Reduction Fund, but the difference is that the comprehensive energy efficiency incentive mechanism does not charge ships that do not meet the standards. Funds obtained from the comprehensive energy efficiency incentive mechanism are used for research and development of emission reduction technologies and related projects in the shipping

industry.

The compensation mechanism (Table 5) mainly focuses on the compensation of developing countries for the economic cost of emission reduction. Developing countries can obtain compensation by collecting credit loans, while developed countries can obtain credit based on the amount of financing through the market mechanism without compensation. The funds raised support technological innovation in developing countries and the shipping industry.

Personally, the International Shipping Emission Reduction Fund is relatively feasible, because it can be refined to include the advantages of other market measures, and this fund can support the emission reduction work of developing countries. I will not elaborate too much here.

Table 3 Other Marked-based Measures

Other MBMs			
	Project	Proposer	Is it limited to the shipping industry
1	GHG reduction fund	Denmark, Cyprus, Marshall Islands, Nigeria, etc	No
2	Comprehensive energy efficiency incentive mechanism	Japan, ICS	Yes
3	compensation system	World Conservation Union	No

CHAPTER 4 EFFECTS OF CARBON LEVY AND ETS ON CHINA'S SHIPPING INDUSTRY

Carbon levy and ETS are the emission reduction measures adopted by various countries in the world. However, the implementation of carbon emission trading and carbon emission trading system will greatly affect the economic development and structural balance. The purpose of the carbon levy is to reduce GHG emissions and encourage investment and development of low-carbon technologies. If the carbon market allocated the right to emit carbon to companies through competitive bidding, it would generate more revenue for the government, like a carbon levy, which could be used for more green development projects. Developed countries are actively pursuing "carbon tariffs", while China is the largest developing country and consequently the largest production base in the world. Facing a carbon levy is pretty tough, but it's a serious fight. In essence, carbon levy is an "environmental protection", which directly affects the export of China's high-carbon industry and reduces the quality of our products. (Xianchen, 2012) However, in the long run, carbon levy can promote shipping technology innovation and industrial upgrading, accelerate the transformation of overseas enterprises, and be conducive to environmental protection. China should actively adjust the shipping structure and promote the optimization and development of shipping, take an active part in the formulation of relevant international regulations and standards, expand domestic demand, reduce dependence on foreign trade, establish sound environmental protection policies and systems, and provide sound financial support for the development of low-carbon industry.

4.1 Impact on China's shipping industry

China's international shipping industry ranks only behind land transport in CO_2 emissions, slightly higher than the international shipping industry. In terms of carbon emissions from the shipping industry, China is divided into two categories: domestic and international. Among them, China has more than 5,200 ships over 1,000 tons, ranking first in the world. This shows that CO_2 emissions from the shipbuilding industry are a problem that cannot be ignored. China's international shipping industry ranks only behind land transport in CO_2 emissions, slightly higher than the international shipping industry. Although carbon levy and carbon markets sound similar, they are fundamentally different. A carbon levy is a government-led strategy in which an authority sets a fixed standard for GHGs emissions and charges companies for each unit of emissions they produce. A carbon market would allow government agencies to set annual emissions expectations, set emissions limits, and let the market determine the price of their emissions. Therefore, in a carbon market, the price of GHGs will fluctuate, but overall emissions will be easier to control. (Le, 2022)

The rise in operating costs caused by the "Carbon levy" is bound to make this situation worse, thus laying a hidden danger for improving the competitiveness of China's shipbuilding industry. In addition to China Ocean Shipping（Group）Company, China Shipping and a few other large shipping companies, most of the other shipping companies are small, and because of the small scale of the company, it is difficult to deal with the complex and changeable market environment. If the "Carbon levy" adversely affects these small shipping companies, they will inevitably face adverse consequences. Such a large small and medium-sized shipping industry will make China's shipping industry unable to compete effectively in the face of the "Carbon

levy", thus affecting the overall international competitiveness.

The shipping industry ushered in the era of low carbon. With domestic ship prices falling to the cost line, the situation in the international shipping market is getting worse. Additionally, as the global economic recovery is slow, the ship fuel price is high, and the operating cost of shipping enterprises continues to rise. In the case of serious imbalance between supply and demand of transportation resources, it may suffocate many shipping enterprises that can hardly resist risks. The shipping industry's carbon market measures include slowing ships (setting maximum speed, charging for speeding vessels) and so on, some of which are based on fuel (for example, adding ships to fuel taxes).

A carbon levy is important for countries with high carbon emissions. For example, countries such as China and Russia, where heavy industry accounts for a large proportion of heavy industry, will greatly increase the export cost of their products, thus reducing their competitiveness in the European market. The carbon levy also indirectly improves the industrial competitiveness of EU countries, with foreign capital previously diverted to China returning to Europe due to "carbon leakage".

In the face of the development of carbon levy and ETS for marine transportation, the export price of products in China's related industries rises sharply, which reduces the export competitiveness and increases the production cost of products. Some companies will also increase their import of raw materials. In addition, as countries around the world become more and more clear about carbon tariffs, the EU will review them by 2026 to seek its own interests and say. Presumably the size of the levy will be gradually increased.

Facing the carbon levy adopted by developed countries, it is urgent to accelerate the transformation of high-carbon industries and increase their production costs. Of

course, there are pros and cons. The regulation of carbon emission will accelerate the replacement of new ships, and the demand of carbon emission will also promote the development of some special ship types. The carbon emission will have a great impact on the assets of ships in the future. Therefore, more energy and equipment will be favored by more markets. Emission rating and classification will also be an important basis for the future trading of new and used ships.

4.2 Countermeasures for the current situation

At present, China's carbon trading market is still in its infancy, and its future development needs to start from the following aspects: First, the scope of the market should be expanded from a single industry to other major emission industries; Second, the introduction of carbon market investment institutions should be accelerated; Third, the improvement of the company's carbon governance level should be strengthened and a carbon governance system should be built; Fourth, product innovation in China's carbon trading market should be stressed; Fifth, the market operation of primary and distribution market should be promoted; Sixth, cooperation with other markets are supposed to be explored. Therefore, the future focus should be on carbon asset management.

4.2.1Countermeasures of the Government

For the appropriate tax breaks, carbon levy will bring great influence for the shipping industry. In order to improve the competitiveness of the shipping market, levy breaks and other levy adjustments to improve the competitiveness of the shipping. Ship registered in China should pay business levy, income levy, and proposed to the shipping industry such as the transport royalities of preferential tax policy; or we can

refer to the practice of Japan and reasonably adjust the existing carbon emission levy to avoid double taxation.

Certain subsidies to shipping companies should be provided. Fuel costs account for a large proportion of total operating expenses. As mentioned above, after the introduction of carbon levy, the operating cost of ships has increased significantly. Therefore, appropriate subsidies should be given to the shipbuilding industry in order to make it more competitive in domestic integrated transportation. After the implementation of the carbon levy, a certain proportion of the carbon levy can be used for energy conservation and emission reduction, and encourage enterprises to research and develop new energy-saving technologies to encourage the development of new and renewable energy. Equipment update, energy saving.

Actively explore the establishment of a carbon emission trading system for the shipping industry, establish carbon emission quotas for the industry, include carbon emissions from shipbuilding into the ETS and carry out carbon trading. (Weiwei, 2018)In theory.the ETS is just as cost-effective as a carbon levy, except that a carbon levy is based on a price, while the total amount of emissions is determined by the market: emissions from carbon trading depend on the external environment and external regulatory costs, and the price of the transaction changes with the market. Carbon levy and ETS are two major economic means to control carbon emissions. Both have their own advantages and disadvantages, so the combination of the two will produce better results. In other words, ETS can start with a carbon levy, and at the same time, it can also set up a monitoring mechanism that is favorable to the

shipping industry to reduce CO_2 emissions

Help shipping companies use clean energy. The most basic way to reduce CO2 and carbon emissions from ships is to adjust China's energy consumption structure and change the current situation of using fuel oil as fuel. At present, the existing clean energy includes LNG wind energy, solar energy, sea (river) water energy, and shore electricity when ships berth. Policy guidance and financial support should be strengthened to promote clean energy in the shipbuilding industry.

4.2.2 Countermeasures of Shipping companies

The IMO EEXI and CII, which will take effect soon, require shipping companies to take emission reduction measures as mandatory measures, but most of the requirements remain in the document. Shipowners still have methods such as shaft/main engine power limits in place to meet EEXI requirements, and CII ratings do not materially affect ships in operation.

Establishing a set of low-carbon development strategies and carbon asset management strategies suitable for the company has become the basic requirement of excellent operation of shipping companies. The introduction of a market mechanism means that shipping companies (shipowners/ship operators) have to pay for ships that perform poorly in terms of energy efficiency. Of course, with regard to the low-carbon development of the fleet, leading large shipping companies have already begun to make efforts. After the carbon emission reduction measures based on market mechanism come into effect in the future, this type of investment will bring huge cost savings to shipping companies and even create additional income. Similar to leading trading companies choosing futures markets to preserve the value of bulk

traded commodities, future shipping companies may also need special strategic planning to maximize the benefits of low-carbon fleet investment and carbon market.

4.2.3 Countermeasures of scientific research institution

Research, development and application of new technology of ship energy conservation and emission reduction have been explored. The company actively develops new technology, new product development and promotion, including microbubble lubrication of ship surface, drag reduction, waste heat recovery of main engine exhaust, CRP pod, diesel electric hybrid propulsion, etc.; advanced ship lightweight technology, ship exhaust gas treatment technology, ship no (less) ballast technology, technology exchange, technology training and other aspects are discussed. Technical readiness should be strengthened to help identify ways to decarbonize ships. Plus, it is assumed that biodiesel will likely be replacing diesel, due to infrastructural and engine compatibility.(Miharivola Andriantsiferana, 2019) Scientific research institutions should increase the research on biofuels.

CHAPTER 5 CONCLUSION

Although there will be many difficulties in implementing these measures in the future, the shipping industry remains positive about these measures and believes that market mechanisms are not yet mature, a position that is consistent with the view of some international shipping organizations. We believe that if market mechanisms are to be adopted, the principle of "common but differentiated responsibilities" should be introduced. As more developed countries and international shipping organizations gradually accept the application of the principles of "common but differentiated liability" and "non-discrimination", it is expected that the inclusion of these two principles in the issue of GHG emissions from ships will be an important issue.

Green environmental protection and sustainable development are common topics facing the current world shipping industry. All countries have the responsibility and obligation to reduce pollution and emissions from shipping. However, the actual situation and national conditions of different countries are different, and common but differentiated responsibilities must be fulfilled within the framework of international unity, rather than unilateral actions of any one region or country.

Nevertheless, as green shipping, energy conservation and emission reduction will be the mainstream trend of the international shipping industry, countries need to actively respond to the EU maritime carbon levy policy. Countries should adhere to reasonable international policy mechanisms, seek extensive international cooperation, adhere to the basic legal framework of the UNFCCC and its Kyoto Protocol, and jointly promote the principle of "common but differentiated responsibilities".

This study mainly estimated the economic impact of carbon levy and carbon ETS on the shipping industry, but did not study and analyze the internal carbon trading situation of shipping enterprises. If the internal trading situation of major shipping companies is taken into account, further research and discussion are needed.

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