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Analysis of international shipping emissions reduction policy and China's participation

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In addressing climate change, the shipping industry, which is regarded as one sector that cannot be ignored in controlling greenhouse gas emissions, has become a key area of concern for the international community to achieve emissions reduction targets. The International Maritime Organization—the body that regulates international shipping—as well as the European Union and other international entities have adopted a series of emissions reduction policies, beginning a new era of shipping emissions reduction. In view of the urgency and complexity of this issue, the future policy direction of shipping emissions reduction and whether or not existing policies can achieve the emissions reduction targets have become the focus of attention in the global shipping industry. In addition, China's dual identity as a shipping magnate and a developing country plays a crucial role in the development of shipping emissions reduction trends, and reducing shipping emissions is necessary for China to achieve the “double carbon” commitment. In view of the above, this study endeavours to compare the current major shipping emission reduction policies from the perspective of international law and the perspective of macro policies, and analyze the future direction of international shipping emissions reduction policy. At the same time, the study identify China as one of the key countries to influence future policy making and proposes the position and path for China's participation in international shipping emissions reduction, which provided valuable contributions for China to participate in accelerating energy transformation, exploring participation in the carbon emission market, and promoting international unified shipping policy.

KEYWORDS

shipping emission reduction, policy orientation, common but differentiated responsibilities, IMO, EU-ETS, China

1 Introduction

As the impact of climate change on the development of human society becomes more obvious, the international community is increasingly concerned about climate change and responses to it, and has called for strengthening global climate governance actions. The year 2021 was expected to be a “climate super year,” highlighting the international community's ambition to address these issues. To control carbon emissions, which are the main cause of

climate change, the international community has established the goal of net zero emissions, and China has pushed itself by making the “double carbon” commitment of reaching peak carbon by 2030 and carbon neutrality by 2060. The effect of international shipping emissions reduction is closely related to these global climate governance actions. International shipping is responsible for 80%–90% of global trade and is an important link to global economic interoperability, but increasing maritime activity is having a negative impact on the environment. According to International Maritime Organization (IMO) statistics, CO₂ emissions from shipping as a percentage of total global anthropogenic CO₂ emissions have climbed rapidly, from 1.8% in 1996 to 2.76% in 2007, and to 2.89% in 2018, reaching a staggering 1.056 billion tons. Shipping carbon emissions are projected to increase from about 90% of 2008 emissions in 2018 to 90%–130% of 2008 emissions by 2050, as estimated using a range of plausible long-term economic and energy scenarios (IMO, 2021). Therefore, if the status quo is maintained without further controls on shipping emissions, this challenge may become a major obstacle to sustainable development.

However, international shipping, due to its cross-border mobility and multi-jurisdictional nature, is difficult to include in the framework of national greenhouse gas (GHG) emissions accounting, so it has been included in the international legal framework of climate change by the United Nations (UN), and is discussed and studied under this topic to find solutions to control carbon emissions. At present, the IMO, national and regional organizations, and other industries in the maritime field have basically agreed on the general direction of emissions reduction and started a new journey to achieve these goals under the unified leadership of the IMO. However, current emission reduction trends and policies in each country reflect different national positions, which also dictate different timetables and roadmaps for the emission reduction process in each country. The emergence of unilateral measures, such as the European Union carbon emissions trading system (EU-ETS), has also challenged the IMO's authority, thus greatly increasing the uncertainty in the process of shipping emissions reduction. We believe that the ultimate goal of net zero emissions from shipping can only be achieved through the formulation and implementation of a unified policy on global shipping under the leadership of the IMO. Therefore, this article uses the method of legal interpretation to sort out current major international shipping emissions reduction policies, and analyzes three key factors affecting the formulation of future international uniform policies, namely, the urgency of shipping emissions reduction, the climate game between developed and developing countries, and the pushback pressure from the international community. Among them, the urgency of shipping emissions reduction is negatively related with the climate game, and positively related with the pushback pressure from the international community. We reasonably propose new trends in future international shipping emissions reduction, and provide policy-oriented suggestions for the low-carbon governance of the global shipping industry. We also identify China as one of the key countries to influence future policy making, and add new vitality to the Chinese solution to realize the low-carbon development of shipping under the “double carbon” goal. This study serves as a reference for policy makers in China to lead global green shipping development.

2 Evolution and development of international shipping emissions reduction policy

2.1 International legal framework on shipping emissions reduction

The development trajectory of international shipping emissions reduction and the international legal framework of climate change are not independent of one another, and the origin of the linkage between the two can be traced to the UN Framework Convention on Climate Change (UNFCCC). The Convention establishes the principle of common but differentiated responsibilities (the CBDR principle), a recognized principle of international law in the field of climate change, which has since become the cornerstone of the construction of the legal regime related to international shipping emissions. The international legal framework for shipping emissions reductions and climate change opens up a wider scope for cooperation in the Kyoto Protocol era (UN, 1998). The IMO and the UNFCCC have formally started cooperating on these issues, moving forward in parallel. The Kyoto Protocol further clarified and succeeded the CBDR principle, establishing a mandatory top-down emissions reduction model. Its Article 2.2 clarifies the IMO's status as the regulatory body responsible for reducing emissions from international shipping. In 2003, the IMO adopted Resolution A.963(23) (IMO, 2003), which clearly states that, it should cooperate with the Conference of the Parties to the UNFCCC, thus opening up a new era of IMO leading the way in reducing emissions from shipping under the guidance of the international legal framework for climate change, especially the CBDR principle. In December 2015, the landmark Paris Agreement (UN, 2015) was reached. It covers nearly 200 countries and regions and began a new era of global emissions reduction. The Paris Agreement gave new meaning to the CBDR principle and further reconciled the conflicting interests of developed and developing countries. It has established a top-down autonomous contribution model with country-owned contributions as the core, developing “common but differentiated responsibilities—respective capabilities—different national circumstances” model (Ji, 2019). The changes to the emissions reduction model have greatly mobilized the enthusiasm of national shipping emissions reduction advocates, prompted the number of international participating entities to increase rapidly, and accelerated the process of international shipping emissions reduction. After the signing of the Paris Agreement, various forms of international cooperation mechanisms have been developed, dealing with many aspects of addressing climate change, such as mitigation, adaptation, and capacity building, with particular attention paid to GHG emissions reduction. They also play an important role in achieving climate mitigation goals in the context of sustainable development (Jiang et al., 2022). New opportunities have also arisen for international cooperation in shipping emissions reduction; they emphasize that, while all parties should participate in these efforts on their own, developed countries should take the lead in achieving absolute emissions reduction targets, and provide financial and technological support to developing countries to increase their action, which provides new ideas for the promotion and implementation of unified policies in the future.

With the international consensus on climate change mitigation and the related legal framework, shipping emissions reduction is moving forward as a specific initiative of the international community, while international law on climate change, as an important part of the construction of the international governance system for shipping emissions reduction, has a significant impact on the development of policy on this issue. However, the specific measures of international shipping emissions reduction are still outside the international legal framework of climate change, so the current international legal order is a “rough outline,” and specific shipping measures are mainly composed of global emissions reduction policies led by the IMO, and regional policies.

2.2 Evolution of IMO shipping emissions reduction policy

The IMO is a specialized agency of the UN responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution from ships. After the 1997 Kyoto Protocol established the IMO as the main body responsible for reducing emissions from shipping, the organization began to place a high priority on reducing GHG emissions from ships, and the Marine Environmental Protection Committee (MEPC) was specifically tasked with studying shipping emissions reduction matters. The MEPC is responsible for the study of shipping emissions reduction, and focuses on related technologies and methods. In the same year, the Conference of the Parties to the International Convention for the Prevention of Pollution from Ships (MARPOL), held by the IMO, adopted Resolution No. 8, which officially started the process of considering GHG emissions reduction from ships under the IMO framework (Zhang et al., 2020).

The Kyoto Protocol came into force in 2005, but developed countries criticized it for its strict distinction between the emissions reduction responsibilities of developed and developing countries, resulting in poor emissions reduction processes in shipping. In light of this, the IMO upgraded the study of international shipping emissions reduction from a technical and methodological approach to a political and legal level (Yao, 2012), to lead the low-carbon development of the international shipping industry through the changes to emission reduction policies. The EU and other developed countries used the IMO “simple majority” voting mechanism to adopt nine principles, including “equal emissions reduction,” which have had an important impact on the development of its subsequent policy formulation. Since then, the MEPC has developed operational and technical measures to promote the immediate decarbonization process in shipping. In 2009, in its 59th session (IMO, 2009), the MEPC presented some important technical and operational documents, including the Energy Efficiency Design Index (EEDI), Energy Efficiency perating Index (EEOI), Ship Energy Efficiency Management Plan (SEEMP). In 2011, the first mandatory energy efficiency regulation in shipping was adopted in the form of an amendment to MARPOL Annex VI, which applies to all maritime merchant ships of 400 tons or more (IMO, 2011). This is also the first legally binding regulation on GHG emissions adopted since the Kyoto Protocol. Thus, the IMO has established a specific technical and operational approach, such as

EEDI and SEEMP, to reducing emissions from shipping. The EEDI is the ratio of the energy consumed by a ship to CO₂ emissions and the effective energy of a ship to CO₂ emissions, and is only applicable to newly built ships. the higher the EEDI index, the lower the energy efficiency. The EEDI was established to establish a minimum energy efficiency standard for ships in the future. The SEEMP requires ship operators to establish an effective ship energy efficiency management mechanism to continuously improve the entire operating structure of the fleet and further reduce energy consumption through five steps: detailed planning, implementation, monitoring and self-assessment and improvement. It is applicable to all international vessels of 400 GT and above. In June 2021, the MEPC’s 76th session adopted amendments to MARPOL Annex VI on reducing the carbon intensity of international shipping, adding two new technologies as well as operational measures, energy efficiency existing ship index (EEXI) and annual CO₂ emission intensity indicator (CLL). EEXI is suitable for existing vessels and complements EEDI. The CLL is an operational energy efficiency rule, and the determination of its specific targets is a prerequisite for the development of baselines, discount rates and related calculation and verification guidelines. The CII value achieved by each ship will be compared to the CII specified by the GHG reduction target, and the ship will be given an A-E rating according to its achievement of the target. Ships rated D and E will be required to submit energy efficiency improvement measures.

The international legal framework on climate change provides the legal basis for IMO to develop a legally binding instrument, but Annex VI requires mandatory application by ships of all countries, which is contrary to the CBDR principle of the international legal framework on climate change. Thus, Annex VI was the fuse that ignited the dispute between the “principle of equal emissions reduction” and the CBDR principle. It also led to the eruption of the potential problem of Article 2.2 of the Kyoto Protocol mentioned above; this is because developed countries advocate the “principle of equal emissions reduction,” and developing countries prefer the CBDR principle. Both the “principle of equal emissions reduction” and the CBDR principle can find their own legal basis, while the adoption and implementation of Annex VI can be attributed to the climate game between countries with different positions. At the same time, according to the IMO mechanism’s design, in addition to developed countries’ strong promotion, the orientation of emissions reduction policy also reflects the IMO’s attempt to reverse the situation by means of mandatory obligations in response to the current failure to reduce emissions.

From a long-term perspective, Annex VI is indeed conducive to promoting ship innovation and thus shipping emissions reductions, but its technical aspects restrict the rights of developing countries in the global GHG emissions reduction space, constituting a breakthrough to the CBDR principle (Lee, 2012). The strong will of developing countries to oppose the CBDR principle and the practical barriers of their maritime capacity and decarbonization technologies prompted the IMO to adopt in 2013 a new agreement titled “Promotion of Technical Co-Operation and Transfer of Technology Relating to the Improvement of Energy: The Improvement of Energy Efficiency of Ships”. (IMO, 2013) To help developing countries improve their ability to comply with international rules and standards relating to maritime safety and the prevention and control of maritime pollution, the IMO has developed an (IMO,

2019), which is designed to assist governments that lack the technical knowledge and resources that are needed to operate in the shipping industry safely and efficiently. All of these are seen as the IMO's response to mitigate the impact of Annex VI on developing countries and to meet the demand for cooperation and the transfer of emissions reduction technologies from developed countries. Of course, it also effectively eases the sharp contradictions between developed and developing countries in shipping emissions reduction.

As the global management body of international shipping emissions reduction, the IMO's policy affects the development of the global shipping industry. Therefore, its policies are often located between the principle of equal emissions reduction and the CBDR principle; favoring either approach will trigger the dissatisfaction of its opponents, making it impossible to reach the unified pace of international shipping emissions reduction. The signing of the Paris Agreement provided an opportunity to break the "prisoner's dilemma" on this issue, and has greatly increased the IMO's confidence in leading international shipping emissions reduction. The "Initial IMO GHG Strategy" (IMO, 2018) (hereafter, Strategy) sets out the future vision, direction, and guiding principles for international shipping, expressing its ambition to achieve zero GHG emissions from shipping within this century, and setting specific targets for 2030 and 2050. The Strategy also sets out short-, medium-, and long-term measures based on mandatory ship efficiency, including an approved process for assessing the impact of candidate measures on countries, further improvements to the existing energy efficiency framework, and assistance to developing countries. Although the Strategy is not fully based on the CBDR principle and does not provide compensation mechanisms, it specifies mechanisms to build capacity for emissions reduction, technology transfer, research cooperation, and other safeguards to address the barriers encountered by developing countries in the implementation of future emissions reduction strategies. In the end, the IMO adopted the Strategy with support from 100 of 170 members; however, there are many developing countries among the supporters. Compared to the 2011 MARPOL Annex VI, developing country support for the Strategy reflects the willingness of more countries to move forward with emissions reductions. This is important not only because they do not want to continue to delay the overall process of reducing emissions in international shipping, but also because the Paris Agreement has had a significant impact on the new development of the CBDR principle. The Paris Agreement provides new ideas to reconcile the interests of different countries in the field of international shipping emissions reduction, to achieve the integration and coexistence of the CBDR principle and the "principle of equal emissions reduction," and to promote the implementation of a unified shipping emissions reduction system. Therefore, the adoption of the Strategy is not only a great contribution of the Paris Agreement, but also an important signal to the world that there is a compromise position that works for most developed and developing member countries, and that more countries can be persuaded to become involved in global emissions reduction (Doele and Chircop, 2019).

At present, the IMO is leading global shipping emissions reduction, and the Strategy expresses the IMO's ambition to continue to do so to achieve net zero emissions in the global shipping industry. In this sector, global and regional emissions

reduction policies are complementary and mutually influential. Only through the integration of regional policies and further alignment with the IMO's prescribed mitigation strategies can the sector achieve full decarbonization of international shipping and transportation (Aspasia et al., 2021).

2.3 The evolution of EU-ETS, the Main EU shipping emissions reduction policy

In the field of global climate change, the EU has been trying to act as a pioneer and advocate. In the shipping industry, currently about 40% of the global merchant fleet, in terms of gross tonnage, is controlled by EU shipping companies. The world's three largest shipping companies—Maersk, Mediterranean Shipping, and Duffy Shipping—all belong to EU member states, and 76% of the EU's foreign trade is transported by sea. The shipping industry is not only an important growth point for the EU's economic development, but is also regarded as a geostrategic asset by the EU (European Community Shipowners' Associations, 2022). Therefore, the EU attaches great importance to international shipping emissions reduction, and is committed to placing itself at the forefront of these efforts in an attempt to turn the challenges into a growth opportunity for Europe. On the one hand, the EU recognizes the IMO as the most powerful international organization to promote shipping emissions reduction, and they have called on the IMO to develop a binding international unified plan. On the other hand, the EU has tried to exert pressure on the IMO by taking certain unilateral shipping emission reduction measures to play a leading role in the formulation of international emission reduction rules and standards when the IMO pushed forward the maritime emission reduction process slowly with little effect. The MEPC's 63rd session has discussed whether to establish a shipping carbon emission market mechanism, and further evaluated the possible impact of the market mechanism on relevant countries. However, due to the complexity and uncertainty of the market mechanism, IMO has not yet established a market mechanism for international shipping emission reduction. Yet the EU has taken the lead in exploring the market mechanism of shipping carbon emissions. The EU-ETS is the EU's most important way to reduce emissions from shipping, and the evolution of its relevant policies will also have a very important impact on the future of international unified shipping emissions reduction policies.

In 2003, the European Parliament and Council adopted Directive 2003/87/EC (EU, 2003) establishing the EU-ETS. As climate stress intensifies, the EU domestic carbon trading mechanism is no longer able to cope with the impact of carbon emissions from international aviation and ship transportation. To achieve the GHG emissions reduction target by 2030, the EU has chosen to regulate external factors that affect the results, such as "carbon leakage" caused by the mobility of GHGs, through the extraterritorial application of the EU-ETS (Han and Li, 2021). Thus, in the absence of a specific obligation to reduce carbon emissions from international aviation and ships under international law, the European Parliament and Council included carbon emissions from aviation in the scope of trading in 2008, and have been eager to further expand the scope of their trading system to include carbon emissions from international ships. To provide supporting data for the inclusion of carbon emissions from

international ships in the adjustment of the EU-ETS, in 2015 the EU published “Regulation (EU) 2015/757—Thetis MRV” to monitor the carbon emissions data of international ships in 2018. Although the MEPC set up a market mechanism feasibility study and impact assessment expert group as early as 2010 to assess the feasibility and impact of the market mechanism from environmental, shipping, foreign trade, and legal and administrative aspects, up to now, the IMO has never established such a mechanism for international shipping; however, the EU has taken a big step forward in this regard. In the face of the EU’s aggressive pressure on the issue of shipping emissions reduction, the IMO began to establish a corresponding data collection system in 2016, which matched the EU’s scope of application, implementation, and timing. However, this move did not stop the EU from establishing a unilateral carbon emissions trading system for shipping, and in 2021 the EU announced its “European Green Deal” and “The European Climate Law” (EU, 2021b). In July 2021, the European Commission proposed the “Fit for 55” (EU, 2021a) package, which aims to ensure that the EU’s GHG emissions are reduced by at least 55% in 2030 compared to 1990 levels. The “Fit for 55” package gradually includes the shipping sector in the EU-ETS from 2023, with a three-year period to achieve full coverage of this industry. At the same time, the EU maritime fuel regulation set specific targets for emissions reductions, namely, 2% by 2025, 6% by 2030, 13% by 2035, 26% by 2040, 59% by 2045, and 75% by 2050. This legislation covers a broader scope and appears more aggressive than any previous legislative measures on emissions reduction.

The EU plays an important role in the global shipping industry, and EU-ETS covers 27 EU member states. It is undeniable that the EU, as the leader in the field of shipping emissions reduction, has made significant contributions to the cause, provided a series of wise solutions, and built a solid path for the promotion of the market mechanism. As the world’s first carbon emissions trading mechanism, the EU-ETS is regarded as a great practical experience for international shipping emissions reduction (Skjærseth and Wettestad, 2009). Therefore, this EU measure will exert more pressure on the IMO and the global shipping industry, and will also have an important impact on the formulation of future shipping policies. Here, we need to make it clear that the EU member states include many developed countries, and the EU’s shipping emissions reduction technology is at the forefront of the world. Therefore, the EU’s policy shows the will of developed countries and the will of shipping emissions reduction technology powerhouses. However, the participation of developing countries and their development interests are factors that should not be neglected when formulating future uniform international shipping policy.

2.4 China’s major shipping emissions reduction policies

China’s dual identity of a developing country and a shipping power led us to position the nation as a key country for observation. In 2021, China’s total maritime imports accounted for nearly one-fourth of total global maritime trade, and its share in the global fleet size reached 16% as of February 2022 (CNSS, 2021). Matching its status as a big shipping country is the fact that it is also a big shipping

carbon emitter. Specifically, Chinese shipping enterprises’ ships emit about 78 million tons of CO₂ per year, among which the international ships operated by Chinese shipping enterprises emit about 44 million tons of CO₂ per year (Peng, 2022). Objectively speaking, China, as a developing country, has a late start in research and practice in shipping emissions reduction compared to developed countries in the EU. As a result, China’s rapid development of international shipping has also led to a sharp increase in the total carbon emissions of the global shipping industry. However, as a responsible country, China actively participates in shipping emissions reduction and provides important practical experience and uniquely Chinese solutions for the development of international shipping emissions reduction policies.

In September 2020, Chinese President Xi Jinping pledged at the 75th session of the UN General Assembly that China will strive to reach peak CO₂ emissions by 2030 and work toward carbon neutrality by 2060. As a developing economy, China aims to put great efforts into achieving the dual-carbon goal, which has motivated studies on the decarbonization of transportation in the country. China’s ship decarbonization process still has a long way to go, and its economic development model and industrial structure must be shifted toward higher-quality green development (Li et al., 2022). Faced with the urgency of global shipping emissions reduction, China has chosen to face the challenge head-on and actively participate in finding a solution, which gives us hope that China can contribute to the formulation of a uniform policy on shipping emissions reduction and prompt the international community to make concerted efforts to achieve net zero emissions from global shipping.

Throughout China’s history of participation in international shipping emissions reduction, it has gone through three stages: following the implementation, high standard implementation, and leading innovation. First, in the implementation stage, China has followed closely the IMO’s pace of shipping emissions reduction and formulated relevant domestic policies linked to the IMO’s standards. In 2011, the IMO formally adopted EEDI, SEEMP, and other measures, and make them as the important element in MARPOL Annex VI. Since Annex VI is contrary to the CBDR principle, developing countries such as China, Brazil, India, Saudi Arabia, South Africa, and Venezuela have had reservations. China is opposed to making developing countries bear additional responsibilities and obligations, but perceives EEDI, SEEMP, and other measures to reduce emissions in shipping more positively. China actively assumes its responsibilities as an IMO member, using macro policies for guidance and promulgating the first national program to address climate change. The Ministry of Transport issued the first implementation plan for water transport emission reduction, which guides the promotion of shore power technology and ship drag reduction technology, and promotes the effect of carbon emission reduction. In 2012, the China Classification Society (CCS) released the world’s first “Green Ship Code,” which incorporates the requirements of EEDI and SEEMP into China’s domestic ship classification as an industry guideline for China’s shipping industry to achieve convergence with international policy. China also advocates that financial, technological, and shipbuilding capacity support from developed countries should be in place to enable developing countries to better implement EEDI and SEEMP measures (MEPC, 2012).

Second, in the high standard implementation stage, China pressed itself to make more stringent self-imposed requirements on the basis of IMO's policy. According to the IMO's "Ship Emission Control Area" (ECA) policy, China set up a ship emission control area in coastal waters in 2015, and issued the "Limits and Measurement Methods for Exhaust Pollutants from Marine Engines (CHINA I, II)" (Ministry of Ecology and Environment of the People's Republic of China, 2016) in 2016, with more stringent standards to control air pollutant emissions from ships. The nation will continue to increase the range of waters in which the sulfur content of fuel oil used by ships is limited. While the IMO is still discussing the market mechanism for emissions reductions, the Shanghai carbon emissions trading system is the first system in the world to include the shipping industry in the carbon trading market. In addition, China asserts that the IMO's future work should still adhere to the principle of CBDR, and submits its practical experience to the IMO's discussion in the form of government proposals, contributing to the improvement of relevant emissions reduction measures. For example, in the MEPC's 70th session, China put forward a set of principles to follow during the development of guidelines, and proposed modifications to several important items related to the draft amendments to the SEEMP Guidelines and draft guidelines for the administration data verification procedures. China also emphasized that guidelines are non-binding, therefore, language should be framed as guidelines (i.e., recommendatory) instead of as regulatory (i.e., mandatory) policies (MEPC, 2016).

Third, following the above two stages, China's shipping emissions reduction capacity continues to improve. Facing the double pressure of international and domestic emissions reduction, the Chinese government is paying more attention to this issue. At present, China is entering a new stage of innovation and leading the cause of international shipping emissions reduction, contributing Chinese wisdom to this policy area. In 2018, the Maritime Administration of the People's Republic of China released the "Regulation on Data Collection for Energy Consumption of Ships" (Maritime Safety Administration of the People's Republic of China, 2018). It addresses the construction of carbon emissions monitoring, reporting, and verification (MRV) systems for ships, and provides more accurate data for China to participate in international decision-making. What's more, China has provided a lot of useful suggestions for IMO's initial strategy. After more than ten years of shipping emissions reduction practices and data accumulation, China has enough experience to contribute unique wisdom and solutions for international shipping emissions reduction. At the same time, China's dual position as a shipping power and developing country will also play an important role in influencing the development of international shipping policy. In early 2020, the CCS released the "Rules for Green Eco-Ships" (CCS, 2020), which includes the latest guidelines for the green requirements of ships, fully reflecting the concept of ecological priority and green development, and more responsive to the market and the needs of the times. Based on the original requirements of energy efficiency, environmental protection, and the working environment, the green ecological ship index system is comprehensively constructed according to the development trend of green ecological technology. With environmental and ecological protection as the core elements, the technical and index requirements cover six aspects of GHG emissions control: prevention of alien biological transfer,

environmental benefits, water pollution emissions control, air pollution emissions control, and harmful material use control. These fully reflect the requirements of safety, environmental protection, and sustainable development. In November 2021, the CCS released the "Outlook for Low Carbon Development in Shipping 2021" (CCS, 2021). The report analyzed the evolution of GHG emissions reduction mechanisms in international shipping, the profound impact of relevant policies and measures of international bilateral/multilateral regional and industry organizations on the shipping industry, and the development of low-carbon shipping in three aspects: technical measures, management tools, and market mechanisms. It also explained the existing technologies of energy savings, energy efficiency, and low carbon; discussed the development path of the shipping industry to achieve annual emissions reduction targets; and proposed the technical development route of low-carbon and zero-carbon ships. China has always actively considered the IMO to be the most competent body to regulate the reduction of emissions in international shipping, and has actively supported the various emissions reduction rules (Table 1) that have been introduced by the organization to promote progress at the domestic and international levels. Because of similar economic and technological conditions, the positive response of the Chinese shipping industry has been supported and emulated by many developing countries (Zhang, 2014).

By observing the evolution of the shipping policies of three representatives with influence in the field of shipping emissions reduction—the IMO as the international shipping authority, the EU as the representative of developed countries, and China as the representative of developing countries—we find that the development of international shipping emissions reduction policies is not entirely untraceable, and the outline of future policies is beginning to become clear.

3 The future direction of international shipping emissions reduction policy

3.1 Key factors affecting international shipping emissions reduction policies

International shipping emissions reduction is a complex and important issue, and is regarded as the last bastion of the

TABLE 1 China's translational application of IMO measures.

IMO Measures	Management documents of China
EEDI	Fuel Consumption Limits for Operating Ships and Validation Methods CO ₂ Emission Limits for Operating Ships and Validation Methods Guidelines for Validation of Energy Efficiency Design Index (EEDI) for Ships
SEEMP	Guidelines for the Preparation of Ship Energy Efficiency Management Plans (SEEMP)
ECA	Limits and Measurement Methods for Exhaust Pollutants from Marine Engines (China I, II)
DCS	Ship Energy Consumption Data Collection Management Method
EEXI/CII	Guidelines for Calculating and Validating the Existing Energy Efficiency Index for Ships (EEXI)

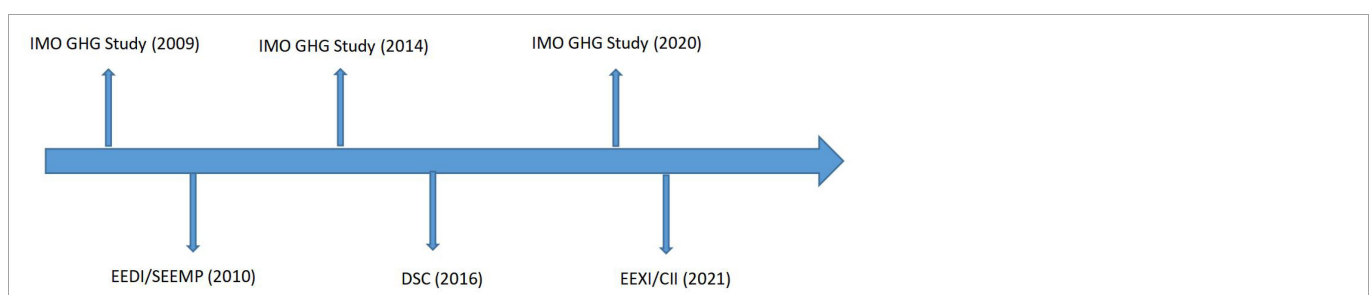
implementation of the Paris Agreement (Zhang, 2021). Throughout the evolution of these policies, the complexity and ambiguity of the policy direction can be identified. However, it is easy to see that the key factors influencing international shipping emissions reduction policy are the following: the urgency of shipping emissions reduction, the climate game between developed and developing countries, and the pushback pressure of the international community. Among them, the urgency of shipping emissions reduction is negatively related with the climate game, and positively related with the pushback pressure from the international community.

The urgency of shipping emissions reduction is the fundamental driver of the change in emissions reduction policy. The IMO GHG Study is an authoritative source for the international community to understand the state of emissions in the shipping industry. By combing through the timeline of major shipping emissions reduction policies, we find that most of the policies that promote important measures to reduce emissions from shipping were proposed in the context of the international community's recognition that the current situation of shipping emissions reduction is urgent and ineffective. The details are shown in Table 2. At the same time, the urgency will affect two other factors: the climate game between developed and developing countries and the pushback pressure from international players. First, the urgency of shipping emissions reduction is negatively related with the climate game. When the need to reduce shipping emissions is urgent, the climate game between developed and developing countries tends to slow, and it is easy to form a unified international shipping emissions reduction measure. From a game theory perspective, the climate game is a problem of rational choice faced by the participating subjects. Some researchers argue that with the advent of the climate crisis, the challenges of the prisoner's dilemma and the tragedy of the commons in the climate game will be overcome through collective rationality. The climate game is one among many rational subjects, but as the climate crisis is already here, the challenges of the prisoner's dilemma and the tragedy of the commons will give way to collective rationality (Yang, 2011). The global nature of the climate crisis and the implicitly positive nature of national decision-making behavior determine the endogenous nature of climate ethics. The climate crisis's effects go beyond national borders, so competing interests must recognize, clearly and soberly, that the only way out of climate negotiations is win-win cooperation (Qi, 2017). Therefore, addressing climate change is a matter of common concern for all people, and it is difficult for any country to do it alone; this is also the main goal pursued by people in the context of sustainable social development. The existence of a common crisis tends to make

humans more united, and opposing interests seem to be more willing to compromise temporarily to cooperate and deal with the crisis together. Second, the urgency of shipping emissions reduction is positively related with the pushback pressure from the international community. The formulation of international unified shipping policy often needs to consider many factors and to reconcile the different positions of developed and developing countries in order to promote the implementation of unified policy, so its formulation process is relatively long. However, given the urgency of this problem, some international players are very willing to reduce emissions and are already leading international emissions reduction; in doing so, they also are trying to push the development and updating of unified policy through unilateral measures and other means.

The climate game between developed and developing countries is an important factor influencing policy preferences. The UNFCCC and the Kyoto Protocol have established the strict CBDR principle, and Annex I of the Kyoto Protocol lists 37 developed countries that are required, individually or collectively, to ensure a 5% reduction in GHG emissions each year in the period 2008–2012 compared to 1990; meanwhile, other countries have no specific obligation to reduce emissions, but are only required to take relevant measures to address climate change. It is obvious that this arrangement is the result of the victory of developing countries in the climate game, which naturally triggered the strong dissatisfaction of developed countries. This was followed by the adoption of the Equitable Emissions Reduction Principles by the International Maritime Organization, which driven by developed countries and reflecting the rational choice of industry-leading shipping operators. Developed countries are in the leading position of shipping emission reduction technology and have a higher degree of economic development. Compared with the economy at the expense of environmental pollution, they pay more attention to green shipping and pursue environmental benefits, or a sustainable development benefit. In addition, developed countries have raised the threshold of the shipping industry by virtue of their own technological advantages, thus increasing the competitiveness of their own shipping industry and greatly reducing the development space of developing countries' shipping industry. As they said, they are trying to turn the challenges into a growth opportunity. Obviously, the strong shipping strength and advanced shipping emission reduction technology make some shipping powers like some EU countries become major participants in the process of making international shipping emission reduction policies, and they have a lot of discourse power and even become the makers of major policies. Compared with developed countries, the bargaining strength of developing countries in the formulation of shipping policies is

TABLE 2 Timeline for IMO GHG Study and shipping emission reduction measures.



weak. But countries like China, Brazil, India, Saudi Arabia, etc. have huge international shipping volume and shipping fleet. The shipping industry is an important hub for these countries to participate in world trade. If developing countries are required to apply the same standards as developed countries on an equal footing, obviously, their shipping industry will suffer a greater impact, and even the national economy will suffer huge losses. Developing countries are often at a disadvantage in the formulation of shipping emission reduction policies due to backward technology, and the existing and established CBDR principle is the most important “tool” to safeguard their own interests. Although developing countries have realized the importance of green shipping, they can’t afford to sacrifice huge shipping interests. They hope that CBDR principle will leave space and time for the development and green transformation of their shipping industry. As an important principle of shipping emission reduction, both the CBDR principle and the Equal Emission Reduction Principle cannot be easily overturned, and the Paris Agreement is an important turning point in the game of emissions reduction. The Paris Agreement continues CBDR as the guiding principle, but makes a historical breakthrough in its content. Thus, the “equal emissions reduction principle” in shipping and the original CBDR principle are integrated into the new CBDR principle, which can be understood as a win-win situation for the climate game between developed and developing countries. The shipping emissions reduction policy in the post-Paris Agreement era also reflects compromise in considering the interests of both sides.

Finally, the pushback pressure from the international community accelerates the international unified shipping emissions reduction policy and improves emissions reduction standards. The IMO is the competent body in this area, according to the mandate, and shipping emissions reduction policy may rise to the international unified policy only through the IMO. Other international subjects are only entitled to take unilateral measures within their jurisdiction, but in the absence of uniform measures, these unilateral steps may cause serious problems, such as legislative compatibility and multi-jurisdictional coverage (Psaraftis et al., 2021). On the other hand, in general, such unilateral measures are more aggressive than existing policies and have higher emissions reduction standards. Most of the countries that have adopted unilateral measures are with high technology of shipping emission reduction, and they have set up unilateral measures according to their own environmental protection needs with their own technology level rather than the overall technology development level of the global shipping industry as the standard. Such unilateral measures largely enhance the standard of green shipping, and thus are more conducive to shipping emissions reduction, which objectively encourages the IMO to deepen shipping emissions reduction.

3.2 Future development of international shipping emissions reduction policy

3.2.1 International shipping emissions reduction policy will be more stringent

First, with the continuous development of the world economy, the trend of increasing international shipping trade is unstoppable, and the number and tonnage of ships are increasing, which makes the

international shipping emission reduction face more severe challenges. In February 2022, the Intergovernmental Panel on Climate Change (IPCC) released [the Part II of Sixth Assessment Report \(IPCC, 2022a\)](#), which examines the vulnerabilities as well as the capacities and limitations of nature and human society to adapt to climate change, and highlights the urgency of rapid climate action to achieve social development goals. On April 4, 2022, the IPCC released [Part III of this report \(IPCC, 2022b\)](#), which provides an updated global assessment of progress and commitments to mitigate climate change, and examines the sources of global emissions. It also notes that, while the rate of growth in global CO₂ emissions has slowed over the last 20 years thanks to improved energy efficiency and low-carbon technologies, this slowdown has not been sufficient to offset the climate pressures that have continued to build up over time. Chapter 10 of the report specifically assesses the transport sector, noting that it will have to change to achieve the goals of climate action. The international shipping industry, as the “artery” of global trade, has attracted the attention of the international community for its emissions problems.

Second, the current shipping policy does not meet the green needs of shipping emission reduction as expected, so the international shipping policy should continuously improve the shortcomings of the current policy in the implementation process. [Xiao et al. \(2022\)](#) discussed the impact of international shipping policies on ship pollutant emissions. They evaluated the control effect of the ECA policies on pollutant emissions. Their results showed that ECA policies can effectively reduce the emissions of ship pollutants, especially for SO₂, but an effect on NO_x was not observed. EEDI, one of the important technical measures to reduce emissions in IMO shipping, has also not achieved the expected results. In theory, the use of derated engines with less power can yield significant EEDI reductions at the expense of speed without extra technology improvements. ([Psaraftis and Kontovas, 2013](#)). Obviously this simple speed reduction is not the best means to achieve the reduction of emissions in international shipping nor is it a long term solution. It can be seen that, although the current international shipping emissions reduction policy has achieved some effect, but some reduction measures’ level of implementation remains low and what can be called an “efficiency gap” exists between the actual level of implementation and the higher level which would be expected based on techno-economic analysis ([Rehmatulla and Smith, 2015](#)). Therefore, the situation of shipping emission reduction is still serious, and international shipping policies should be updated to bridge this “efficiency gap”, which may mean more detailed and strict requirements and a wider scope of ship regulations.

Third, growing social awareness of environmental protection will also drive the implementation of stricter standards in shipping policies. In 2021, at the second UN Global Conference on Sustainable Transport, UN Secretary-General Guterres called for “zero-emission ships to be the default choice, to be on the market by 2030 and to achieve zero emissions from shipping by 2050.” In the same year, the International Chamber of Shipping also submitted a plan to the IMO detailing the urgent measures that governments must take. The plan is significantly stricter than the IMO’s Strategy launched in 2018, and sets significantly higher standards of emissions reductions. In addition, the EU’s policy on shipping emissions reduction, especially the newly adopted EU-ETS for

shipping, is more radical than the IMO's guidance. The EU has set a faster timetable and stronger emissions reduction requirements, and major developed countries, including in Europe and the United States, nongovernmental organizations, and others have called for accelerating the pace of GHG emissions reduction in international shipping and exerting pressure on the IMO through various means. At the same time, more than 130 countries have put forward their carbon neutral targets, including many developing countries, which are trying to work together to maintain the sustainable development of human society (Energy and Climate Intelligence Unit, 2022). In addition, in the face of climate, technological development, and market competition, many shipping companies and research and development (R&D) institutions have added to the IMO's emissions reduction strategy in an attempt to seize the first opportunity in the wave of emissions reduction (ICS, 2021). Pressures to adopt "greener" behavior constantly come from various stakeholders, including institutions, customers, citizens, investors and others. In the shipping industry, customers' and investors' demands may be strong drivers for the adoption of more environmentally friendly practices as companies need their approval and legitimacy to stay in business (Linder, 2018). The study by Reference stresses that actors in a maritime supply chain should adhere to customers' expectations and identifies four main customer requirements, including competitive costs, pollution reduction, efficient use of fuel, and health and safety (Lam, 2015). An ever-increasing number of shipping companies and port operators are progressively investing in communication campaigns and initiatives aimed at promoting their green image to increase their environmental legitimacy.

In the face of the urgency of shipping emissions reduction, the climate game between developed and developing countries, and the international community's pushback, it is foreseeable that the international shipping emissions reduction policy will usher in major changes, the timetable will be advanced, and the intensity of emissions reduction will increase. IMO has proposed the Initial IMO GHG Strategy Strategy. To promote the realization of the objectives of the Strategy, IMO has formulated a series of relevant emission reduction measures, such as the newly proposed CLL requiring annual rating of ships. CLL determines the annual reduction factors needed to ensure that the carbon intensity of ship operations continues to improve within a given rating level. If the evaluation level is D/E, the ship will need to submit energy efficiency improvement measures. Implementation of these measures will give a strong impetus to the process of reducing emissions from international shipping, so the IMO may amend MARPOL again to give the relevant standards mandatory legal effect, so as to achieve the objectives of the strategy.

3.2.2 The timing and content of policy changes

The year 2030 is expected to be an important turning point for international shipping emissions reduction, including the market mechanism. The use of clean energy will become an important aspect of shipping emissions reduction policy, and the reward and punishment mechanism will be a significant auxiliary tool to promote shipping emissions reductions. There are several reasons for this. First, the IMO Strategy has a short-term goal of reducing the carbon intensity of international shipping to 40% of 2008 levels by 2030. Based on the average operating life of a ship (i.e., 20 years), 2030 will be an important turning point for the shipping industry. In addition,

research shows that clean-fuel ship technology will achieve full scale and engineering applications, electric low-carbon or zero-carbon fuel will achieve scale and sustainable supply, and zero-carbon clean fuel will be commercially applied in new ships all around 2030 (Li Q, 2021). Second, the IMO has put forward the technical candidate measures to achieve the CO₂ emissions reduction target in the Strategy, which is divided into short-, medium-, and long-term candidate measures. It has also continued to develop and revise energy efficiency measures, such as EEDI, SEEMP, EEXI, and CII, to continuously promote energy efficiency improvement; likewise, technologies and devices have been continuously developed and revised to encourage the application of energy efficiency on ships. However, relying only on the above-mentioned short-term technical measures can only achieve a part of decarbonization; moreover, energy efficiency measures always run through the emissions reduction process, and their role and effects are increasingly limited. For the current shipping industry, oil is an important raw material to provide energy and is also one of the main costs of international shipping. The current tension between Russia and Ukraine has led to high oil prices and great uncertainty in prices. Market factors for higher oil prices and the political instability of several regions holding important oil reserves raises important concerns about security and availability of fuel resources leading several countries to explore and invest in the development of alternative fuels. In the long run, the shipping industry needs to gradually use low/zero-carbon clean fuels and consider the complementary and facilitating role played by market mechanisms. The shipping industry has reached a consensus that green eco-technologies based on clean energy are one of the preferred options for shipping to achieve sustainable development goals (SDGs). The limited nature of the technical and operational measures implemented in recent years and the continued promotion of EU-ETS have drawn more attention to market mechanisms. The adoption of market mechanisms can balance the gap between the interests of developed and developing countries, is more suitable for developing countries, and is in line with the CBDR principle. Under the premise of adhering to the CBDR principle, developing countries can more easily reach consensus on the market path, thus maximizing the ability to mitigate the climate game between developed and developing countries. Third, the shipping industry is essential for maintaining the vitality of the world economy and trade, as well as for achieving the SDGs. Many countries, including China, have pointed out that any measure should not overly burden or even destroy international shipping and, consequently, world trade as a whole. To not overburden the shipping industry, the introduction of a reward mechanism would be necessary (IMO, 2022b). Moreover, Xu et al. (2021) concluded by establishing a tripartite evolutionary game that the existence of fines can effectively restrain the behavior of the three parties in the system. When the amount of fines is large enough, governments will be more proactive in choosing cooperative supervision, and shipping companies will be more willing to use clean energy. Jiang et al. (2020) used an evolutionary game model to analyze the dynamic changes in the decision-making of participants. The simulation analysis showed that, to encourage shipping companies to comply with ECA rules, the government should adopt a dynamic punishment strategy to encourage shipping companies to implement the rules faster. According to prospect

theory, the degree of marginal decline in the value function, namely, risk preference, reflects the decision-maker's psychological expectation for profits and losses. Therefore, the IMO should develop a reward and punishment mechanism. And according to the shipping industry's current state, IMO should adjust their strategies and countermeasures to promote more efficient action throughout the system to achieve the optimal evolutionary stable strategy (Xu et al., 2022).

3.2.3 The continuing controversy around the guiding principles of shipping emissions reduction

At present, there are two principles for shipping emissions reduction, namely, equal emissions reduction and the CBDR principle. The reason these two principles exist in the field of shipping emissions reduction is that shipping emissions reduction is not only an issue of marine environmental governance, but also one of the game between and distribution of world interests. The two positions reflect the interests of people in countries with different social backgrounds and economic conditions. Developed countries uphold the principle of equal emissions reduction, prioritizing the effectiveness of climate protection and the economic cost of emissions reduction. The principle does not require detailed examination of the levels of GHG emissions in each country, but applies equally to all countries. This not only effectively solves the carbon leakage caused by ships, but also avoids distorting the fair competition of international shipping. In contrast, developing countries advocate the CBDR principle, which places more emphasis on substantive equity (i.e., environmental justice). They argue that developed countries have an inescapable historical responsibility for climate change, while developing countries' top priorities are poverty eradication and economic development (Cao, 2016). Moreover, their financial and technological levels limit their ability to participate in shipping emissions reduction. Further, the battle between the two positions represents a game of climate discourse and national interests. Whoever has the right to speak will become the rule maker, and thus better protect their national interests. Thus, we cannot rule out the possibility that developed countries will try to set up shipping barriers through the principle of equal emissions reduction to restrict the growth of shipping in developing countries.

The CBDR principle is the fundamental principle for GHG issues negotiations in the UNFCCC, as well as in the IMO. It is recognized in the Strategy and shall be further enhanced in the Revised Strategy. The mid-term measures will have a higher potential negative impact on developing countries in comparison to developed countries. Therefore, this principle should be taken into full account when designing mid-term measures. The CBDR principle does not necessarily lead to differential treatment based on the country from which a ship operates (IMO, 2022a). At the same time, the importance of the principle of equal emissions reduction in promoting the work of international shipping emissions reduction should not be ignored. The effectiveness and cost economy of emissions reduction can only be achieved on the basis of fairness. With the efforts of China, small island states, and others, the IMO has made it clear that "how to ensure a just and equitable transition" will be an important issue in the future. MEPC 76 agreed to continue to review the impacts on states of the amendments to MARPOL Annex VI so that any necessary adjustments can be made, and to initiate a

lessons-learned exercise of the comprehensive impact assessment (IMO, 2022a). Therefore, we believe that the controversy over the guiding principles of international shipping emissions reduction will persist in the future, but the consensus of multiple parties is more likely to be based on the CBDR principle and appropriately integrated into the balance of the principle of equal emissions reduction. This can not only meet the legitimate requirements of developed countries to accelerate the reduction of emissions in international shipping, but also mobilize developing countries to participate in the reduction of emissions and prevent the growth of their shipping industries from being strongly impacted.

4 Position and path of China's participation in international shipping emissions reduction

The double identity of shipping power and developing country and the double pressure of international shipping emissions reduction and the domestic "double carbon" target make it necessary for China to participate in future international shipping emissions reduction; likewise, future emissions reductions are inseparable from China's participation. China will foster a dual-cycle development pattern (Government of the People's Republic of China, 2020); that is, its growth should rely on both domestic and international economic cycles. The shipping industry is important for building a dual-cycle development pattern. Therefore, China should follow the trend, participate deeply in the process of future policy formulation, and to promote the future unified international shipping emission reduction policy in a fair and operable way, and realize the net zero emission of global shipping as own goal.

4.1 Practicing and optimizing the CBDR principle

The current IMO has developed a global scope of emissions reduction targets and measures, but specific regional and national targets are not consistent. Separate actions will make the global regulation of carbon emissions of ships more complex, only the formation of an international unified shipping policy can truly achieve the goal of net zero emissions of international shipping; the key to this is to optimize the CBDR principle.

China's dual position as a major shipping country and a developing country dictates that it should be an important force in promoting international shipping emissions reduction and the best candidate for optimizing the CBDR principle. China insists on the reasonable distribution of shipping emissions reduction responsibilities under the international legal framework of climate change from the perspective of fairness and justice, and the international shipping policy should recognize the special characteristics of shipping and reflect the CBDR principle. China states (State Council Information Office of the People's Republic of China, 2021):

Developed and developing countries have different historical responsibilities in causing climate change, and there are differences in development needs and capacities, so it is inappropriate and unfair

to use a uniform scale to limit. It is necessary to fully consider the national conditions and capacity of each country, adhere to the institutional arrangement that each country can do its best and country can decide its own contribution, and not to make a one-size-fits-all.

However, based on its own position and the demands of international shipping emissions reduction, China has the will, obligation, and ability to promote the process of shipping emissions reduction. Therefore, according to the Kyoto Protocol Annex I/II, the CBDR principle, which strictly distinguishes national responsibility for emissions reduction should be reasonably optimized. At the same time, the Paris Agreement has laid a good foundation for optimizing the CBDR principle. As a political bargaining principle, the CBDR principle, with its inherent ambiguity and openness, leaves enough room for political maneuvering in international environmental dialogue and cooperation between developed and developing countries (Li, 2013). This provides room for further consultation on how the international community can contribute to the decarbonization goals of shipping.

China need to actively participate in IMO international affairs, enhance its influence and voice in the formulation of relevant policies in international maritime affairs, continuously strengthen exchanges with all parties. China should also actively advocate for the adoption of global coordinated measures under the leadership of the IMO and the premise of reaching consensus with many parties to solve the problem of international shipping emissions reduction, thereby avoiding scattered and overlapping unilateral measures. In the process of participating in international shipping emission reduction, China should aim at optimizing the CBDR principle. The core of optimizing the CBDR principle lies in its reasonable adaptation, not abandoning it. The purpose is to find the convergence of interests between developed and developing countries and reach a new consensus to jointly promote the shipping emissions reduction process. The new policy should be a fair, feasible, and unified measure that balances the interests of all parties. China could optimize the CBDR principle in two dimensions: its content and its implementation. First, the factors of the CBDR principle's division would be considered along multiple dimensions. The allocation of responsibility is the most important point related to fairness in international environmental protection actions. The original CBDR principle uses a country's development status as a single factor to divide the responsibility of emissions reduction; however, not all developed countries are big shipping countries, and some developing countries' carbon emissions from shipping are not necessarily lower than those of developed countries, which makes developed countries point to the contradiction of developing countries with big shipping emissions. Therefore, the CBDR principle should take into account the highly relevant economic, environmental, social, and technological indicators of a particular country, such as ship ownership, maritime capacity, decarbonization technology, shipping emissions per unit of GDP, and so on, to prevent overestimation or underestimation of a country's responsibility and capacity (Ari, I. and Sari, R., 2017). Second, future shipping policies would must take maximum account of the realities of the various stakeholders in different countries and regions. Further advancing shipping emissions reductions means implementing more stringent measures. However, developing countries are limited by their

economic development and technology level, which make them unable to meet the emissions reduction requirements, or require that they pay huge costs. Therefore, it is necessary to guarantee the development needs of developing countries through financial and technical support measures as well as buffer periods so that they are willing and able to participate in the international programs.

4.2 Promoting international cooperation and technology transfer for clean energy R&D

As the concept of green shipping becomes more popular, clean energy and technical measures for ships have also become a hot topic in the shipping industry, receiving growing attention (Xu, 2021). Researchers from the Danish Centre of Environment and Energy (Danish Centre of Environment and Energy, 2018) predicted the CO₂ emissions from shipping activities using different fuel types and found that using cleaner fuels could help reduce CO₂ emissions to a greater extent than conventional fuel types. The "Review of Maritime Transport 2021" (UNCTAD, 2021) released by the UN Conference on Trade and Development points out that the main challenge facing the shipping industry in the coming decades is the energy transition and the decarbonization targets associated with it. R&D of zero-carbon alternative fuels and low-carbon technology solutions is currently at a critical stage, which is key to achieving the emissions reduction targets for international shipping

Some countries already have the technology to manufacture clean alternative energy, but for the international community to further develop and implement relevant technologies and policies, we must accelerate the R&D and promotion of clean energy, effectively reduce the cost of clean energy, ensure the safety of its applications, and promote international cooperation and technology transfer.

The selection of the best low- or zero-carbon fuel for a ship should take into account numerous factors, including energy density, whether it is environmentally friendly, the need for new propulsion systems, and the global fuel replenishment infrastructure (Shen, 2021). Decarbonizing international shipping will require the uptake of low-carbon marine fuels, and it is paramount to ensure the availability, accessibility, and affordability of low-carbon fuels for the shipping industry in all parts of the world (IMO, 2022b). Different clean fuels have their own competitive advantages at different times and offer a variety of possible directions for the shipping industry to achieve its GHG reduction targets. It can be predicted that the shipping industry will not use a single type of zero-carbon fuel in the future, nor will there be a single type of propulsion system. Current research on clean energy for shipping mainly includes low- or zero-carbon fuels, such as liquid natural gas (LNG), methanol, ammonia, and hydrogen. Considering the comprehensive advantages of LNG in terms of energy availability, its contribution to emissions reduction, economy, technology maturity, and regulatory completeness, LNG has a good prospect of development until 2035, so it is the first approved alternative fuel. The advantages and disadvantages of LNG are such that it is currently defined by the shipping industry as the best transitional energy source. In the medium and long term, green methanol, hydrogen, and ammonia are the key development directions to achieve emissions reduction from ships in the future, but most of these clean energy sources have

characteristics such as being more flammable and explosive, biological toxicity, and special requirements for material compatibility (Li Y, 2021). Applications in shipping are still in the R&D stage, and the cost and availability of zero-carbon fuels are important factors in determining fuel deployment in shipping, while the diversification of zero-carbon fuels provides the shipping industry with a wide range of options while also providing more directions for technology development, which emphasizes the importance of international collaborative research.

Currently the CCS has issued guiding documents on clean energy for shipping, such as the “Natural Gas Fuel Power Ship Code,” “Guide to Application of Alternative Fuels for Ships,” and “Guide to Inspection of Pure Battery Power Ships.” Chinese shipping companies are also actively laying out carbon emissions reduction standards and vigorously promoting the R&D of green and clean energy. At the same time, China is actively participating in relevant international projects, such as “The Future Fuels and Technology for Low- and Zero-Carbon Shipping Project.” In view of the current demand and practical experience of clean energy R&D, we think that this will become a key effort direction for China to participate in international shipping emission reduction. We suggest that China would further promote international cooperative research on clean energy through the following steps.

First, China could promote international technical cooperation in clean energy to broaden the channels of scientific exchange and promote the update and reuse of information and data. The duplication of technology R&D should be reduced, R&D costs should be lower, and people with diverse talents should be brought together to jointly tackle technical challenges.

Second, international technology cooperation in clean energy should also aim to promote capacity building and technology transfer as an action objective, and encourage the coordination and supervision of the MEPC and Technical Cooperation Committee (TC). Developed countries have a variety of interests in promoting emissions reduction in shipping: for example, promoting green energy encourages other countries to introduce their advanced technologies and materials to foster new economic growth (Chen et al., 2016), and raising the threshold for emissions reduction in shipping can also form a green barrier (Xu, F., and Chen, G. 2021) to consolidate their dominant position in the shipping industry. Maritime capacity as well as technological gaps are a natural environment for breeding barriers, and such green shipping barriers will not only cause many shipping enterprises to increase their operating costs significantly, but also weaken the competitiveness of developing countries' shipping markets. The MEPC addresses environmental issues under the IMO's remit, and TC oversees the IMO's capacity-building program and the implementation of technical cooperation projects for which the organization acts as the executing or cooperating agency. Therefore, China should further seek a strong path of coordinated regulation between the MEPC and TC on clean energy issues, to promote capacity building and technology transfer of clean energy R&D, and break down barriers.

What's more, the intellectual property rights and technology standards involved in clean energy should be reasonably addressed, which is the expected goal that China should strive to achieve when participating in clean energy research and development. China states: “Addressing intellectual property issues was the focus of making the

innovative fuels/technologies accessible for developing countries and having them join the production of new fuels.” (IMO, 2022) For innovative fuels/technologies, such as low- and zero-carbon fuels, the development of technical standards is particularly important. Developed countries use “patent pools” and other means to write technology patents into standards in order to obtain competitive advantages. Since intellectual property rights are often territorial and exclusive, once the technology standard is popularized, a technical and market monopoly will be formed (Liu, 2009). The information asymmetry caused by the presence of monopoly privileges exacerbates the problem of information asymmetry. Therefore, China needs to promote the international community to jointly participate in the formulation of relevant technical standards, improve the non-tariff technical trade barriers of technical standards, and establish a technical knowledge-exchange mechanism to reasonably resolve the conflict of interest between the private attributes of intellectual property rights and the overall arrangement of international shipping emissions reduction; moreover, this may prevent developed countries from using intellectual property rights to form technical monopolies.

4.3 Promoting the construction of a reasonable international unified shipping carbon emissions trading market

The carbon emissions trading system pioneered by the EU provides a good path for current international shipping emissions reduction, but this unilateral trading system led by the EU weakens the authority of the IMO and may also produce a series of disadvantages. The high mobility of international shipping and the inherent uniqueness of transboundary operations determine that without globally accepted standards, unilateral measures based on countries alone cannot effectively achieve limits on GHG emissions from ships (Daria, 2017). Therefore, it is imperative to establish a global carbon emissions trading system. At present, there is a great call for the construction of a carbon trading market for the shipping industry internationally, but in reality, it will face a series of challenges. Studying and mastering the main problems of a carbon trading system and finding reasonable solutions may guarantee the effective operation of a carbon trading market in the shipping industry (Deng et al., 2022). And it is also an important advance to build an international unified shipping carbon emissions market mechanism.

Current stage, China should continue to use the domestic shipping carbon emissions trading market as an explorational tool to provide practical experience and data support for the establishment of an international unified shipping carbon emissions trading market. In October 2011, China clarified that seven provinces and cities—Shanghai, Beijing, Tianjin, Chongqing, Guangdong, Hubei, and Shenzhen—are carrying out regional carbon emissions trading pilot projects (National Development and Reform Commission, 2011). In 2013, Shanghai included the shipping industry in the pilot it launched and, since 2015, the Shanghai carbon emissions trading system has been the first to include the shipping industry in such a system. During the 2021 North Bund International Shipping Forum (Shanghai Municipal Government, 2021), Shanghai's municipal government and the IMO reached a consensus on cooperation.

This is the first time the IMO has accomplished this with a local government, and it is a milestone for Shanghai's international shipping center to integrate into the world and to serve the global shipping emissions reduction cause.

Furthermore, with the accumulation of experience, China could move to the forefront of carbon emissions trading market exploration and make participating in the establishment of international unified carbon emissions trading market as its own action goal. This includes further clarifying the implementation of shipping carbon trading, improving the supervision and management mechanism of carbon emissions of shipping enterprises, exploring the establishment of a fair and equitable total allocation system, and reasonably allocating the market shares of carbon emissions of different countries to achieve the CBDR principle in the shipping emissions reduction market mechanism. In addition, the establishment of EU-ETS has enabled the EU to gain the right to speak in the formulation of the rules of the carbon emissions market mechanism. According to the principle of profit-seeking, it is foreseeable that the rules of the EU in the carbon emissions market will be centered on its own interests. Once the EU and other developed countries dominate the development of these market rules, many developing countries, including China, will be at a disadvantage. Therefore, China would need to actively participate in the establishment of the carbon emissions trading market, accumulate practical experience, improve data collection capabilities and accuracy, effectively balance and contain developed countries such as those in the EU in the formulation of international rules, emphasize the development rights of emerging markets, increase the reservation of quotas for new entrants and newly established enterprises, and formulate a set of market mechanism rules that reflect the differentiated responsibilities of countries with different capabilities, without interfering with the level playing field of the international maritime industry and promoting zero-carbon emissions in international shipping.

5 Conclusion

Shipping emissions reduction is an inevitable trend in the development of international shipping, and the formulation of future policies will determine the timetable and roadmap of international shipping emissions reduction. In the face of the urgency of climate change and the pressure of unilateral measures of the EU and other countries, current shipping policy can hardly meet the needs of shipping emissions reduction. The international community calls on the IMO as the main regulator of international shipping to update the formulation of an international unified shipping emissions reduction policy that takes into account the synergy of operation, technology, and the market, and reasonably considers the interests of all countries.

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This paper analyzes and summarizes the key factors affecting international shipping policy, and reasonably speculates the future policy orientation in this field; that is, future shipping policy will be more stringent, a market mechanism and the application of clean energy will become important elements of shipping emissions reduction policy, and a reward and punishment mechanism may become an important auxiliary tool to promote emissions reduction. By reasonably speculating the policy orientation of international shipping, this paper provides a psychological expectation for the international shipping industry and its stakeholders to carry out the next phase of international shipping emissions reduction work. In addition, through the analysis of China's shipping emissions reduction trends, we argue that China has the will, obligation, and ability to lead global shipping emissions reduction efforts. We think that China, with its dual identity as a major shipping country and a developing country, should be considered a key player in influencing this policy. Therefore, this paper also points to a deepening direction for a series of actions that China is currently taking in favor of international shipping emissions reduction.

Author contributions

HL: Conceptualization, Writing – original draft, Funding acquisition. ZM: Conceptualization, Writing – original draft. XL: Study conception, manuscript revision, and submission. All authors contributed to the article and approved the submitted version.

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