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Unexpected side effects of the EU Ship Recycling Regulation call for global cooperation on greening the shipbreaking industry

Lin Lin[1,6], Kuishuang Feng[2,6,*], Zheng Wan[3,*], Peng Wang[4], Xianghui Kong[1], Ning Zhang[1], Klaus Hubacek[5] and Jiashuo Li[1,*]

[1] Institute of Blue and Green Development, Shandong University, Weihai 264209, People's Republic of China
[2] Department of Geographical Sciences, University of Maryland, College Park, MD, United States of America
[3] College of Transport and Communications, Shanghai Maritime University, Shanghai 201306, People's Republic of China
[4] KeyLaboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, People's Republic of China
[5] Integrated Research on Energy, Environment and Society (IREES), Energy and Sustainability Research Institute Groningen (ESRIG), University of Groningen, Groningen 9747 AG, The Netherlands
[6] K F and L L contributed equally to this work.
[*] Authors to whom any correspondence should be addressed.

E-mail: kfeng@umd.edu, zhengwan@shmtu.edu.cn and lijiashuo@sdu.edu.cn

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Abstract

The recent European Union Ship Recycling Regulation and other existing conventions aimed to reduce harmful environmental and health impacts of ship shipbreaking, may push the shipbreaking industry further to South Asian countries, where ecosystem and public health are threatened due to the lack of monitoring for dirty beaching methods for ship breaking. Such unsustainable patterns may continue to expand due to the mismatch of economic beneficiaries and environmental costs in the shipbreaking industry, the ineffectiveness of existing conventions and regulations, and the prospect of a large number of ships to be dismantled in the near future. Our study focuses on these emerging issues and raises the urgency of joint actions for the shipbreaking industry.

1. Introduction

Shipbreaking is the last stage of a ship's life cycle. More than 800 large ocean-going ships, such as container ships, oil tankers, bulk carriers, general cargo, and passenger ships, are sold for breaking and recycling (data from IHS Markit and Lloyd List Intelligence). A number of articles have looked at the movement down the value chain of shipbreaking, from developed to less developed countries, and how ship materials are reprocessed into other items (furniture, electronics and consumer durables, etc) (Gregson *et al* 2010, 2012). During the shipbreaking processes, many toxic substances, whose content ranges from 1% to 10% of a ship's weight, including asbestos, heavy metal, oils, and various other disposable materials, could be released into nature, which threatens the environment, ecology, and public health (Rahman and Kim 2020).

Most of the countries gain benefits from international trade via maritime transport, while only a few bear the environmental cost associated with shipbreaking. There are three main shipbreaking methods: At present, India, Bangladesh, and Pakistan dismantle 70%–80% of the world's end-of-life (EoL) ships by dirty beaching method that is characterized as the most dangerous and heavily polluting shipbreaking method with lower requirements for equipment and site infrastructure (Sarraf *et al* 2010). Sewage, oil, heavy metal, plastic, and other harmful substances are directly discharged into the sea, soil, and air (Reddy *et al* 2006, Nøst *et al* 2015, Rahman 2019). In contrast, China, the United States, the European Union (EU) mainly adopt the quay method and dry dock method and are equipped with professional anti-leakage facilities, which effectively avoid direct leakage of harmful substances (NGO Shipbreaking Platform 2020).

To mitigate the environmental and health impacts of shipbreaking, international organizations and local governments have issued a few conventions and regulations, such as Hong Kong International

Convention (International Maritime Organization (IMO) 2009) and EU Ship Recycling Regulation (EU SRR) (European Parliament 2013), as well as the Basel Convention (United Nations Environment Programme 1989) for transboundary movements of hazardous wastes in general. A study by Rahman *et al* found that shipbreaking yards in South Asia are slowly improving (Rahman *et al* 2018). However, The Non-Governmental Organizations (NGO) survey found no positive improvement in shipbreaking plants in South Asia (NGO Shipbreaking Platform 2020). As a large number of ships will be dismantled in the future, based on past and current ship stocks, an analysis of the effectiveness of existing conventions is needed to accelerate the reform of the shipbreaking industry in South Asian countries.

Our study shows that existing regulations and conventions have not effectively prevented the shipbreaking using beaching, and especially the EU SRR has significant loopholes. Furthermore, our projections show that the gross tonnage of EoL ships will increase by 3–5 times by 2050, which calls for urgent actions on stricter SRRs with much wider coverage and international cooperation to reduce the harm caused by shipbreaking.

2. Method and data

2.1. Method

2.1.1. Stock-driven dynamic material flow analysis

In this study, we estimated the future ship scrap by the following steps (see figure 1 for detailed analytical framework). First, figure Gross Domestic Product (GDP) is fitted with the amount of maritime trade, and the fitting results are as follows: $Y = 0.0661X + 2603.9$, $R^2 = 0.9948$. Second, the seaborne trade amount and ship stock are fitted, and the fitting results are as follows: $Y = 0.1474X - 440.09$, $R^2 = 0.9648$. We found a high correlation between GDP and ship stocks. Third, based on the shared socioeconomic pathways (SSPs)'s forecast of GDP data and the above two fitting results, the future ship stock is obtained. Finally, the stock-driven dynamic material flow analysis is used to estimate the gross tonnage of future ship scrap. The specific formula is as follows:

$$F_{\mathrm{OUTFLOW}}(t) = \sum F_{\mathrm{INFLOW}}(t_0) * f(t) \quad (1)$$

$$F_{\mathrm{INFLOW}}(t) = S_t - S_{t-1} + F_{\mathrm{OUTFLOW}}(t) \quad (2)$$

$$f(t) = \frac{1}{\sqrt{2\pi\delta}} \exp\left(-\frac{(t-\mu)^2}{2\delta^2}\right). \quad (3)$$

Here, $F_{\mathrm{OUTFLOW}}(t)$ represents the outflow in year t; $F_{\mathrm{INFLOW}}(t)$ represents the inflow in year *t; t* refers to the year; μ refers to the average and δ refers to the standard deviation of ships.

2.2. Data sources

Raw data for vessel recycling year, dismantling country, beneficiary country, flag state, vessel type, and gross tonnage of EoL ships were purchased from IHS Markit and Lloyd List Intelligence from Shanghai Maritime University. Usage is authorized by Shanghai Maritime University. This data is used to study the evasion path of EU regulations. Second, a large amount of data is collected to estimate the theoretical scrapping of ships over the next three decades. GDP data (supplementary table 1 available online at stacks.iop.org/ERL/17/044024/mmedia) was collected from World Bank and SSP projections (supplementary table 2) was obtained from the International Institute for Applied Systems Analysis. The data of seaborne trade from 1980 to 2018 was collected from the United Nations Conference on Trade and Development (supplementary table 1). In addition, this paper obtains the construction year and recycling year of EoL ships for the time period 2011–2019 from the NGO shipbreaking platform (a global coalition of organizations), and divides the ships into five categories (supplementary table 3), according to which the average age of various types of ships is calculated (supplementary table 4).

3. Result

3.1. Environmental and health crisis in the shipbreaking industry

Beginning in the 1990s, India, Bangladesh, and Pakistan replaced Taiwan, South Korea, Europe, and the United States as the most popular shipbreaking sites thanks to their unique geographical advantages. It is estimated that 100 000 tons of waste were generated from shipbreaking activities in 2016 in *South Asia*[7] (Rahman and Kim 2020). South Asia does not have sophisticated waste management systems due to lack of supervision and financial support, leading to a huge amount of waste accumulation (Rahman and Kim 2020). Many studies show that the sea, sediment, and air around the South Asian shipbreaking yards contain highly toxic substances such as copper, lead, and zinc being significantly higher than normal (Neşer *et al* 2012, Hasan *et al* 2013). Those heavy metals are not degradable. Once leaked into the sea, they will accumulate in organisms and eventually be transferred to humans through the food chain, affecting human health (Liu *et al* 2015). Moreover, several studies have shown that harmful substances discharged into the sea by shipbreaking activities can damage the diversity of fish and other marine life by changing the PH value, increasing the turbidity, and changing other physical and chemical properties in the seawater (Islam and Hossain 1986, Tewari *et al* 2001, Hossain and Islam 2006, Abdullah

[7] South Asia specifically refers to India, Bangladesh, and Pakistan in this paper.

and Mahboob 2010, Talukder *et al* 2015, Hossain *et al* 2020). In addition, the diffusion of toxic waste into the soil and sea will affect ecosystems (Talukder *et al* 2015) and eventually lead to the disappearance of mangroves and related vegetation (Rizvi *et al* 2020).

A more severe problem is the adverse impact of shipbreaking on workers' health. South Asian shipbreaking yards lack the infrastructure to prevent pollution and provide workers with inadequate respiratory protective gear. When dismantling the ships, the workers do not have sufficient protection measures. On the one hand, workers inhale lots of harmful substances (asbestos, fiberglass, Polycyclic aromatic hydrocarbons (PAHs)…), which increases people's health risks (Nøst *et al* 2015). It is estimated that nearly 15% of shipbreaking workers suffer from mesothelioma. Of the 31 000 workers, about 4513 workers died of mesothelioma (Singh *et al* 2020). Wu *et al* evaluated the cancer risk of shipbreaking in Taiwan, and their results showed that there were high cancer risk from shipbreaking, for instance, the carcinogenic rate of the high asbestos exposure group could be as high as 9.41% (Wu *et al* 2014), which is about 235 times of the world average of 0.04% for young people (Fidler *et al* 2017) (supplementary table 5). The working environment of workers in South Asian countries is not better than that of workers in Taiwan, or even worse. Singh *et al* estimated that the probability of contracting mesothelioma among Indian shipyard workers was 15% (Singh *et al* 2020). On the other hand, the accident rate is very high due to the poor shipbreakers and managers' safety awareness (Mitra *et al* 2020). For example, in Bangladesh, an average of one worker dies at the shipbreaking yards each week, and on average one worker is injured each day (Hossain and Islam 2006). Besides, the interests of workers at the South Asian shipbreaking yards are not guaranteed. The wages of shipbreakers are not enough to meet essential daily needs, and they often work for more than 8 h per day (Anonymous 2013).

3.1.1. Mismatch of economic beneficiaries and environmental costs

Dismantled ships mainly came from the European Union, followed by China, South Korea, India, the United States, and Japan from 2013 to 2019. Most of these countries are developed or emerging economies, and they benefit from shipping. However, ship dismantling activities are mainly concentrated in South Asian countries, which are less developed countries. The proportion of EoL ships transferred to South Asian shipbreaking yards reached 81% in 2019 (see supplementary figure 1). What's more, only 10% of the ships dismantled in the South Asia belong to South Asia (see supplementary figure 2). Shipowners view South Asia as a 'graveyard' for recycling EoL ships carrying large amounts of toxic substances, showing a serious mismatch between economic benefits and environmental costs. This situation has been described as a classic example of the 'pollution haven' hypothesis—waste from developed countries being dumped in a poor country.

3.1.2. Main drivers of moving shipbreaking yards to South Asia

First, dismantled ships generate high-quality recyclable resources (supplementary table 6), and downstream industrial supply chains rely heavily on the dismantling industry (Gregson *et al* 2010, Hsuan and Parisi 2020). In particular, EoL ships provide 60% and 25% of steel resources for Bangladesh and Pakistan respectively (Sarraf *et al* 2010). Second, shipbreaking activities in South Asia offer job opportunities, such as 30 000 (Garud 2012) and 50 000 (Rahman 2020) jobs for India and Bangladesh, respectively. Therefore, South Asian countries are more willing to import EoL ships in large quantities to earn revenues and create jobs. Thirdly, non-standard shipbreaking yards are more inclined to offer high prices to buy EoL ships. Bangladesh, India, and Pakistan pay 380–420 USD/light displacement Tonnage (LDT) for EoL ships, whereas the price is approximately 200 USD/LDT in Turkey and China and about 130 USD/LDT in Europe, respectively(Rahman and Kim 2020). In order to obtain high profits and avoid a series of compliance costs, shipowners tend to dismantle EoL ships in non-standard South Asia shipbreaking yards. Nevertheless, the pursuit of economic benefits at the cost of environmental quality and human health is not sustainable. If the shipbreaking industry in South Asia maintains the status quo, much more pollutants will be released into air, sea, and soil, thus leading to ecological destruction. Therefore, a coordinated policy to effectively control pollution from shipbreaking is urgently needed.

3.2. Effects of Convention and regulations

International organizations have issued a series of conventions and regulations to respond to the number of problems in the shipbreaking industry. A detailed list of adoption and start dates for the three conventions, their scope, and main content can be found in the supplementary table 7.

3.2.1. Effects of the EU SRR

To promote the EoL ship of the EU breaking in a safe and environmental-friendly environment, the EU passed Regulation (EU) No 1257/2013 (EU SRR) in 2013. The EU SRR is currently the strictest shipbreaking convention. First, the EU SRR lists three additional hazardous substances prohibited and restricted from use on ships than the Hong Kong Convention. Second, it stipulates that ships flying EU flags can only be recycled in listed shipbreaking yards.

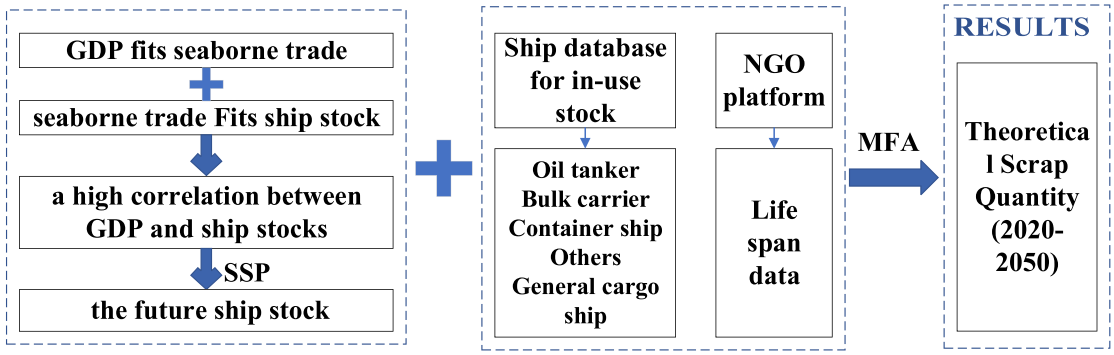

Figure 1. Frame diagram.

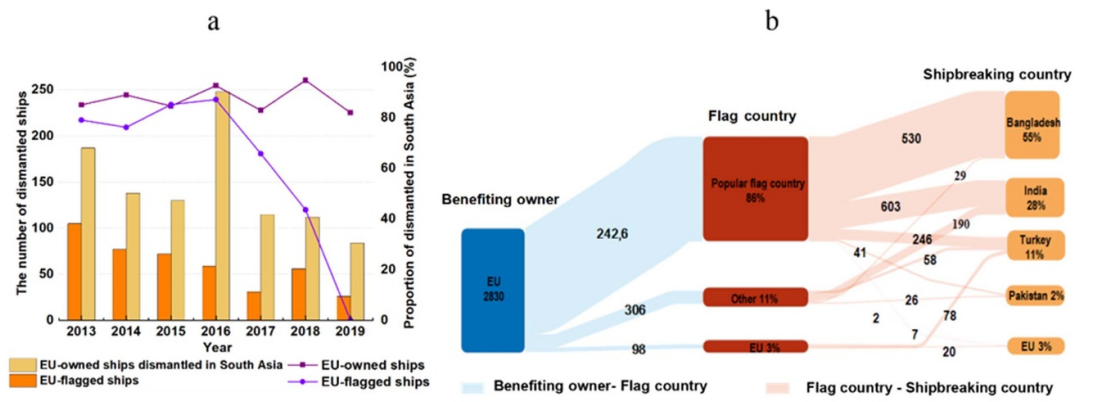

Figure 2. Analysis of EU-owned and EU-flagged ships for demolition from 2013 to 2019 (a) and flows of EU owned EoL ships in 2019 (b).
Note: Proportion calculated based on gross tonnage of ships; the blue box in the first column represents the benefiting owner of the dismantled ships in 2019, the red boxes in the second column represent the countries where these ships fly the flag, and the yellow boxes in the third column represent the countries where these ships were dismantled. Popular flag country (⩾5): Palau, Comoros, Panama, Liberia, Bahamas, Curacao, Togo. Other (<5): Tanzania, St Vincent & The Grenadines, St Kitts & Nevis, Kiribati.

Since the EU SRR was proposed in 2013, the gross ton proportion of ships flying the EU flag dismantled in South Asia has gradually decreased. After the regulations came into force in 2019, the percentage rapidly dropped to zero (see figure 1(a)). It seems that the regulation has been a resounding success and all ships flying the EU flag have been dismantled in green shipbreaking facilities. However, in our perspective, the EU SRR has not achieved its targets for the following reasons:

Firstly, the EU SRR only takes effect for flag states. After introducing the EU SRR in 2013, shipowners have been more active in changing flags to circumvent the regulations. In 2013, 105 ships flying the EU flag were dismantled, which dropped to 26 in 2019 (see figure 2(a)). Moreover, these ships are mainly small ships with an average gross tonnage of less than 4000. Only one-third of EU ships fly the EU flag in 2019, and the EU SRR was only valid for 26 ships in 2019. Secondly, the purpose of EU-owned ships changing the flags to Comoros, Gabon, Palau, Saint Kitts, and Nevis from 180 to 30 days (Alcaidea *et al* 2016) before scrapping is to reduce costs (see figure 2(b)). These flags are usually not used during operational life. Moreover, Palau, Saint Kitts and Nevis, Togo, and Comoros are black-listed shipping registries due to non-compliance with international maritime laws (Rahman and Kim 2020). Thirdly, the proportion of EU-owned dismantling in non-standard south Asian yards has always been above 85%. About 55% of EU ships were transferred to Bangladesh, 28% to India, and 2% to Pakistan in 2019. Only 3% were dismantled by the ship recycling facilities listed in the EU list (see figure 2(b)).

In short, the effectiveness of the EU SRR based on the flag state's jurisdiction is weakened by the owner's act of changing the flag. The enforcement of the EU SRR only prompted shipping companies to change their flags, but did not substantially improve the nature of the transfer of polluting EoL ships from EU countries to underdeveloped countries. The EU SRR has not achieved the goal of increasing the competitiveness of safe and environmentally sound shipbreaking methods. As a beneficiary of ships, the EU did not pay the final cost of pollution, but it made the most profit by selling scrap

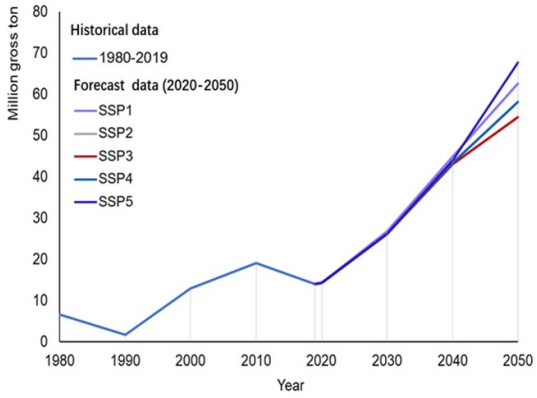

Figure 3. Amount of ship scrapped in 1980–2050 based on the five SSP scenarios.
Note: (1) The historical part is described by five data points in 1980, 1990, 2000, 2010, and 2019. (2) SSP1: Sustainability pathways; SSP2: Middle of the Road; SSP3: Regional Rivalry pathway; SSP4: Inequality pathway; SSP5: Fossil-fueled development pathway.

ships to South Asia with the highest bids and the worst pollution.

3.2.2. Other conventions

The purpose of the Basel Convention is to curb the transboundary movement of hazardous waste, especially the transfer of hazardous waste to developing countries. Also, the high pollution and high risk of EoL ships have become the focus of the Basel Convention. The guidelines only provide advice on green shipbreaking operations, but they are not mandatory and binding in practice. Therefore, the Convention has little effect in promoting and realizing green shipbreaking. In 1995, a group of representatives from developing countries disappointed by the Basel Convention's lack of effective implementation formulated the Basel Ban Amendment. However, the Amendment only came into effect on December 5, 2019. Its effect remains to be seen. To maximize safe and environmentally sound ship recycling, the International Maritime Organization adopted the International Safe and Environmentally Sound Ship Recycling Convention (The Hong Kong Convention) in May 2009. If the national convention comes into force, it will become the first international mandatory regulation on ship recycling that applies globally. However, so far, it has not come into effect.

3.3. A projected boom of EoL ships in the future

A large number of ships in use now pose challenges for future ship dismantling. Figure 3 shows that the amount of EoL ships in 2050 can reach 68 million gross tons under the development path of fossil fuels (SSP5). The gross tonnage of EoL ships in 2050 could potentially be 3–5 times of the current gross tonnage. The increase in ship scrapping in the future will further aggravate the pressure on the ecology, the environment, and workers' health.

4. Discussion

4.1. Socio-economic implications of the greening transition

In the short term, the green transition of shipbreaking industry may increase the cost, due to the initial investment of green facilities and providing protection gears to their employees. The most critical step in greening shipbreaking yards is to improve the facilities associated with shipbreaking yards. New docks, Antifouling equipment, and safety protection equipment for employees in shipbreaking yards requires billions of dollars investment, adding to the cost of dismantling. To achieve green recycling, the compliance cost of unqualified shipbreaking yards will also increase from 0% to about 50% (Choi *et al* 2016). As a result of increased dismantling costs, the number of orders for EoL ships received by South Asian ship recycling yards may decrease, affecting the local economy. Also, the shipbreaking industry provides a large amount of steel and non-ferrous metal resources to the local economy (Ko and Gantner 2016). Bangladesh, for example, has essentially no iron ore as a raw material for steel, and the shipbreaking industry alone provides more than 50% of the resources for local steel production (Rabbi and Rahman 2017). Therefore, the reduction of orders may lead to a short-term shortage in the supply of steel to the shipbreaking countries in South Asia.

The transition to green shipbreaking may have potentially positive implications for employment and employee safety. Many shipbreaking yards with environmental and safety problems will be down due to the green transition, resulting in reduced production capacity and unemployment of employees. However, it will also drive the rise of more green industries, such as the green technology research and development industry, pollution prevention facilities and safety protection equipment production, the waste reprocessing industry, and the recycling industry if those countries want to remain their shipbreaking scales. The rise of these industries is bound to create more green jobs, replacing the 'dirty' ones. In addition, the adverse impact of shipbreaking activities on workers can be greatly reduced if the shipbreaking industry undertakes sustainable reforms. The accident fatality rate can be decreased significantly from 0.113% to 0.013%. Meanwhile the accidental damage rate can also be reduced from 31.45 to 6% (European Commission DG Environment 2010, Wu *et al* 2014).

Greening transition is the future for the shipbreaking industry in the long term. On the EU list, there are 34 shipbreaking yards from 16 EU countries and Norway, 6 Turkish shipbreaking yards, and one US shipbreaking yard (European Commission 2021), but no shipbreaking yard from the world's top three shipbreaking countries (Bangladesh, India, and Pakistan). If the ship recycling industry does not carry out green reforms, it is highly possible that the

unqualified shipbreaking yards will face the situation of no ships being demolished after the regulations expanded with broader country coverage. Therefore, it is imperative that unqualified shipbreaking yards plan ahead to take place the transition to green shipbreaking.

4.2. Recommendations

The current high destructiveness of shipbreaking activities and the boom of EoL ships in the future, call for joint efforts. First, our analysis showed the limited benefits of the EU SRR. The current EU SRR only regulates the ships flying EU flags and the owners of the ships likely to change their ships' flags a few years before scrapping. We propose the use of financial instruments to address the EU SRR loopholes. The European Commission proposed the Ship Resource Recovery Regulation (Directorate-General for Environment 2016), which is equivalent to a deposit system charging a fee for ships visiting EU countries. The deposit will be refunded if these ships are demolished in an EU-listed shipbreaking yard. Implementation of such regulations may incentivize ship owners to dismantle their ships at green shipbreaking sites (Devaux and Nicolaï 2020) and incentivize South Asian shipbreaking plants to improve the shipbreaking environment and green shipbreaking activities if they want to be on the EU qualified shipbreaking yard list. For this financial instrument, more adjustments are required. First, the existing EU-compliant ship recycling facilities are not sufficient to meet the needs of the ship recycling industry. It is recommended that the EU reach an agreement with the South Asian unqualified ship recycling yards to use the money collected to improve the ship recycling facilities of the unqualified ship recycling yards. Continue to strengthen the dialogue between the two sides, establish a coordination mechanism, promote the green reform of the South Asian ship recycling facility, and finally include it in the EU recycling facility list to solve the problem of insufficient green recycling capacity. Second, this financial instrument needs to interact with other regulatory tools, which can be facilitated by introducing a range of exemptions and fiscal deductions (Devaux and Nicolaï 2020). Finally, periodic reviews are required. The first is to review the amount and use of funds collected from shipowners to prevent the funds from being used improperly. The second is to regularly review whether the ship recycling yards that have joined the EU dismantling list meet the standards, and whether the ship recycling yards that are not included in the list have improved and met the standards. Therefore, we believe that if the above problems are solved, the implementation of such financial instruments is economically feasible and improves economic efficiency. Because the social cost of shipbreaking will no longer be borne by onsite workers or local residents living nearby, but by shipowners.

Secondly, the current unqualified ship recycling facilities dismantle more than 70% of the world's ships. In order to meet the global ship recycling industry's demand for green ship recycling capacity, the transition to the sustainability of substandard ship recycling yards needs to be accelerated. First of all, it is necessary to standardize the management of unqualified ship recycling yards. In Bangladesh, where the ship recycling industry is booming, although there are many departments and government agencies involved in ship recycling activities, there is no unified agency to coordinate the jurisdiction of different departments, and there is no effective regulation to directly manage the environmental pollution of the ship recycling industry (Hossain *et al* 2016). Second, improving the facilities of unqualified shipbreaking yards requires financial support. On the one hand, government investment could solve the dilemma of funding shortages. On the other hand, the polluter pays principle and 'the burden of the beneficiaries' may provide financial support for greening ship recycling activities. We offer a solution for reference: a third party can charge a certain amount of tax to the ship beneficiary country and use the fund to improve the unqualified shipbreaking yard facilities. Finally, to promote a sustainable path for the shipbreaking industry, safety issues must be considered. We recommend shipbreakers or shipowners are required to provide shipbreaking workers with personal protective equipment, and to set up fire stations or hospitals near the shipbreaking yard to ensure that workers can receive timely treatment in the event of an accident and avoid serious losses caused by any accident (Hossain *et al* 2016). In short, the approach of reaching a point close to the sustainable solution in this field is not that straightforward. A regular and continuous dialogue involving all parties (owner, policymakers, and breaker) needs to be ensured.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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Authorship contribution statement

L L and K F contributed equally to this work. L L, K F, Z W and J L designed the study; Z W provided data; X K, P W, L L and K F provide methodology; L L and

K F, J L conducted the analysis; All authors contributed to the writing of the paper.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

ORCID iD

Klaus Hubacek https://orcid.org/0000-0003-2561-6090

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