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SHIP RECYCLING

AN OVERVIEW

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Table of contents

Executive Summary	6
1. Introduction	8
2. Market for ship recycling	11
2.1. Descriptive statistics of vessel demolitions	11
2.2. Determinants of ship demolition.....	14
2.3. Ship recycling methods.....	18
2.4. Main market players	19
2.5. Economics of ship recycling	19
2.6. Ship recycling and subsequent steel use	21
3. Outlook for ship demolitions	23
3.1. Baseline scenario	23
3.2. Effect of Ballast Water Management Convention	25
4. International and regional policies	28
4.1. Basel Convention (1989)	28
4.2. IMO Hong Kong Convention (2009).....	28
4.3. EU Ship recycling regulation (2013)	29
5. Recycling policies in comparable industries	32
5.1. Aircraft industry.....	33
5.2. Vehicle industry.....	34
6. Conclusion and further remarks.....	37
References	39
Annex A. Value estimates	43
Annex B. Estimation results	45
Annex C. Scrap value estimates	46
Annex D. Demand for vessel retrofit	47
Endnotes.....	48

Tables

Table 1. Number of vessels demolished by year	12
Table 2. Current recycling methods	18
Table 3. Economics of ship recycling	20

Figures

Figure 1. Adjusted eco-efficiency (inverse) for the three ship life cycles	9
Figure 2. Annual demolition volumes as % of global gross tons by ship recycling country	11

Figure 3. Annual demolition volume and demolitions as share of fleet, 2000 - 2017 (Sept.).....	12
Figure 4. Median and mean size of demolished vessels.....	13
Figure 5. Demolitions in % of total GT and # of vessels by ship type.....	14
Figure 6. Size of major ship types demolished.....	14
Figure 7. Scrapping decision process	14
Figure 8. Median demolition age (lhs) and histogram of demolition age (rhs).....	15
Figure 9. Density of fleet age	15
Figure 10. ClarkSea Index.....	16
Figure 11. Median demolition price in USD/LDT by demolition country (lhs) and World steel price index (rhs).....	18
Figure 12. Main participants in the scrap process	19
Figure 13. Estimates of marginal costs of sound ship recycling	21
Figure 14. Example of decision-making process by ship owner.....	23
Figure 15. Value estimates by ship group across age.....	24
Figure 16. Effect of BWMS installation costs on ship value function.....	26
Figure 17. Estimates of demolition volumes by cost scenario	27
Figure 18. Major ship breaking locations by flag state	30
Figure 19. Percentages of vessels sent for demolition to South Asia.....	30

SHIP RECYCLING – AN OVERVIEW

Karin Gourdon

This report includes an overview of the ship recycling market by providing descriptive statistics, describing the determinants for the decision of ship-owners to demolish vessels, and elaborating on the main market players and the economics of ship recycling. It furthermore provides an outlook of demolition volumes based on ship value estimates, and assesses the impact of the latest implemented international regulation – the Ballast Water Management Convention – on the industry. Since this market faces challenges to recycle vessels in an environmentally sustainable and health-protecting way, the report offers ideas to help solving these difficulties by looking at policies implemented in other industries. Special focus is given to the aircraft and vehicle industries as their characteristics in terms of recycling approach and earnings model are relevant to ship recycling. Most of the presented policies and initiatives have at least one aspect in common, namely the shared responsibility throughout the supply chain.

The paper was authored by Karin Gourdon from the Structural Policy Division (SPD) at the OECD Directorate for Science, Technology and Innovation (STI) with essential inputs from Christian Steidl (OECD). Laurent Daniel (OECD/STI) and Nick Johnstone (OECD/STI) contributed with insights and suggestions, and supervised the project.

Keywords: Ship recycling, Recycling policies

Executive Summary

The ship breaking and recycling industry disassembles steel and other recyclable items of end-of-life vessels. Many parts of a ship – from the hull structure to the machinery – can be recycled and reused as scrap metal. However, if this task is not carried out in a proper and safe way, ship recycling poses high risks to human beings and the environment, and can lead to high levels of fatalities, injuries and work-related illnesses. Ships contain many hazards, such as carcinogens and toxic substances, which can intoxicate workers and can easily be dumped into the soil and coastal waters, resulting in significant negative impacts on the environment.

While there are certainly efforts to find solutions to improve health and environmental standards in this industry as presented in this report, for the time being regulations have been discussed but have not yet entered into force. This report gives an overview of the market for ship recycling (i) by providing some descriptive statistics of vessel demolitions, (ii) by describing the determinants for the decision of ship owners to demolish vessels, as well as (iii) by elaborating on the main market players and the economics of ship recycling. It furthermore provides an outlook of demolition volumes based on ship value estimates, and assesses the impact of the latest implemented international regulation – the Ballast Water Management Convention (BWMC) – on the recycling market.

Since this market faces challenges to recycle vessels in an environmentally sustainable and health-protecting way, the report provides some ideas to help solving these difficulties by looking at policies implemented in other industries. Special focus is thereby given to the aircraft and vehicle-recycling industries as their characteristics in terms of recycling approach and earnings model are relevant to the ship recycling industry. Most of the presented policies and initiatives have at least one aspect in common, namely the shared responsibility of recycling solutions throughout the supply chain from producer to user.

Market for ship recycling

Due to low labour costs and other factors, the ship recycling industry is nowadays mainly concentrated in Asia, notably in Bangladesh, Pakistan, India, and China. These four countries together account for around 91% of global demolition volumes in 2017. As of September 2017, the industries of those four countries demolished around 9 million compensated gross tons (CGT) or 16 million gross tons (GT) which represents around 628 vessels and around 1.1% of fleet size in CGT. These vessels are mostly large ocean-going vessels whose size ranges between 20 000 to 45 000 GT and can even reach close to 175 000 GT for oil tankers or ore carriers. The development of steadily increasing vessel size creates new operational challenges to the ship recycling industry. The recycling methods vary among these major ship demolition countries. While India (305 vessels demolished in 2016), Bangladesh (222) and Pakistan (141) apply the beaching method, Chinese recycling facilities (74) demolish the vessels off the beach.

Outlook of ship demolitions

The results of the forecast of ship demolitions show that by September 2018 around 1.4% of the fleet (as of September 2017) in terms of GT (2.8% of the fleet in CGT) will be scrapped, which corresponds to around 18 million GT (23 million CGT).¹ The three main ship types bulkers, tankers and containers account for approximately one third of these demolitions. The implementation of the BWMC will probably result in additional

retrofitting activities for at least two-thirds of vessels that fall under the regulation (under the high costs scenario). The ship recycling business may expect additional demolition volumes during the next seven years of 13 million GT to 51 million GT compared to the baseline scenario that does not take into account the BWMC installation costs. The Convention might lead to an increase in demolition volume by an additional 0.5% to 3.4% (measured as share of the fleet in GT in 2017). In other words, the policy might trigger additional demolitions over (at most) the next seven years of one-third to two times of the size of usual annual demolition volumes that are related to the renewal of the fleet.

International and regional regulations on ship recycling

At the international and national levels, there have been many attempts to regulate the ship recycling industry, with the first attempt to apply the Basel Convention (1989) on transboundary movements of hazardous wastes and their disposals to the ship recycling industry. However, its application was hampered due to difficulties in determining the precise moment a ship becomes waste. The Hong Kong Convention (HKC) from 2009 negotiated at the International Maritime Organization (IMO) followed the Basel Convention. As of March 2017, only five countries representing 20% of the necessary fleet volume for ratification have acceded to the Convention. Finally, the regulation on ship recycling (2013) of the European Union (EU) completes the overview of relevant regulations. The EU regulation is based on the HKC. It extends the Inventory of Hazardous Materials by two substances. It also includes additional requirements on Health, Safety and the Environment (HSE) for ship recycling facilities and on downstream waste management. Furthermore, it provides the European List of ship recycling facilities – a list open to facilities located both in and outside the EU that meet the requirements of the Regulation. In the light of this trend in regulations for the ship recycling industry, it is becoming important for substandard ship breaking facilities to adopt stricter safety and environmental standards in order to be able to stay in business.

Recycling policies in comparable industries

Several examples in comparable industries in terms of recycling approach and earnings profile, i.e. the aircraft and vehicle recycling industries, illustrate the efforts made to address challenges of recycling activity throughout the supply chain. In those industries, both producers and consumers share responsibility to find appropriate solutions to reduce the burden on the nature and human health. Despite the distinct features of the ship recycling industry compared to these industries, the examples might be useful for a better understanding of ways to improve the current standards and processes of ship recycling. Furthermore, the case studies collected could provide information on how to better integrate all actors throughout the ship life cycle. It could help in the elaboration of means to internalize the negative externalities generated by ship recycling and finding appropriate solutions for the difficulties faced by recycling end-of-life vessels. Despite singular initiatives, efforts from the shipping or shipbuilding industry to improve recycling activity of vessels remain limited. Yet, as the report's estimates show, international regulations can have a significant effect on demolition volumes. Against the background of the analysed BWMC, the results suggest a significant increase in demolition requirements in the future. This increase highlights furthermore the need to discuss adequate solutions with supply chain participants and the international community in order to reduce the negative impact of today's ship recycling activity on human health and the environment.

1. Introduction

The ship recycling (also: ship breaking and ship demolition) industry converts end-of-life ships into steel bars, billets, and rods for the construction industry, as well as electronic equipment and tools for homes and small businesses (Gregson, 2011_[1]). On the one hand, such transformation of ships into new products positively affects the environment in the sense that it avoids extracting iron ore – which is often associated with energy-intensive processes (Weisz, Suh and Graedel, 2015_[2]; Yellishetty et al., 2011_[2]). In addition, the usage of ferrous scrap extracted from vessels contributes to the greater use of Electric Arc Furnaces that usually emit less CO₂ per ton of steel produced than Blast Furnaces/Basic Oxygen Furnaces. On the other hand, ship recycling poses high risks to human health and the environment if it is not carried out in a proper and safe way, thereby leading to high levels of fatalities, injuries and work-related diseases. Ships contain many toxic substances, such as PCBs, PVCs, PAHs, TBT, mercury, lead, and asbestos, which can intoxicate workers and can have significant negative effects on the environment when dumped into the soil and coastal waters (World Bank, 2010_[2]).

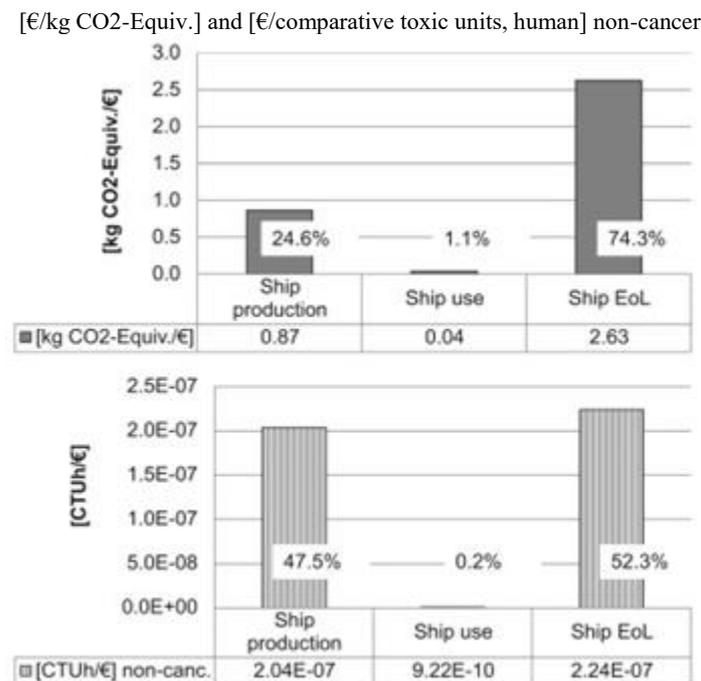
The International Labour Organization (ILO) describes ship breaking to be "[...] amongst the most dangerous of occupations, with unacceptably high levels of fatalities, injuries and work-related diseases." (ILO, 2019_[3]). Statistics on fatalities are scarce and – if existent – are often under-reported either because fatalities are not properly registered or because in some cases they are a result of long-term illnesses caused by the workers' permanent exposure to hazardous materials. Such illnesses are often difficult to attribute to the occupation directly. A report about the working and living conditions at an Indian shipbreaking yard shows records of fatal accidents and cites official figures from the Final Report of the Supreme Court-appointed Technical Experts Committee which found an average annual number of fatal accidents equal to 2.0 per 1 000 workers. This number is six times higher than in the Indian mining industry which is considered to be the most accident-prone industry (Sahu, 2014_[4]).

The controversy over shipbreaking with respect to environmental effects concerns mainly the disposal of hazardous waste in the environment instead of the usage of proper waste management facilities.² Several studies describe the negative impact of unsound ship breaking activity on the region's ecosystem, in particular with respect to the high levels of polluting substances released into the environment, which lead to a decline in biomass and species diversity in ship recycling areas (Demaria, 2010_[5]; Bhatt, 2004_[6]; Reddy et al., 2004_[7]; EC, 2016_[8]).

A study by Ko and Gantner (2016_[5]) illustrates the impact on the environment and on human health over the ship life cycle by putting value added into relation to the costs for humans and the environment. The authors use kg CO₂-equivalents to estimate potential environmental impacts on global warming per value added by ship life cycle phase, encompassing the ship production, ship use and ship end-of-life stages (Ship EoL/ship recycling). For the impact on human health they use the toxicity indicator "comparative toxic units, human" (CTUh) which describes the "increase in morbidity in the total human population per unit mass of a chemical emitted" (Rosenbaum et al., 2008_[6]). Figure 1 shows the share of environmental impact and impact on human health per local value added in euro for each ship life cycle phase.

In these two graphs, the end-of-life phase dominates the other life cycle phases with a share of over 50% for the impact on human health and with approximately 75% for the impact on the environment. The use phase shows very little environmental impact per euro although the transport sector is a large contributor in terms of CO₂ emissions across industries. CO₂ emissions from transport make up around 20% of total fuel combustion according to IEA Statistics (2014^[7]). The primary reason for its low share in this calculation lies in the fact that the shipping industry generates high value added in relation to its emissions. This illustrates the significant negative impact of ship recycling on the environment and human health given the low value added generated by this sector.

Figure 1. Adjusted eco-efficiency (inverse) for the three ship life cycles



Note: The toxicity indicator "comparative toxic units, human" (CTUh) assesses only potential non-cancerous effects on human health. It is important to note that this indicator does not include the local impact on human health due to the manual labour from ship breaking. The results therefore underestimate the true impact of the ship recycling on human health. Estimates are based on a ship with 4 108.4 ldt over the lifetime of 25 years.
Source: Ko and Gantner (2016^[5]).

This report presents two selected regulations at the international and regional levels, which aim to mitigate the environmental impact and impact on human health in the ship recycling industry by establishing standards on health, safety and environment (HSE).

- **The Hong Kong Convention (HKC)** of 2009. The International Maritime Organization has been making efforts to implement the HKC, which however has not entered into force due to the insufficient number of ratifying countries.
- **The Ship Recycling Regulation** of 2013. This regulation decided by the European Union (EU) builds upon the HKC and has entered into force in December 2013. However, only some of its requirements apply, such as the need for EU ships going for recycling to carry an Inventory of Hazardous Materials on-board. The

obligation for EU flagged ships to be recycled in facilities on the EU list (the most important requirement) will apply from December 31, 2018.

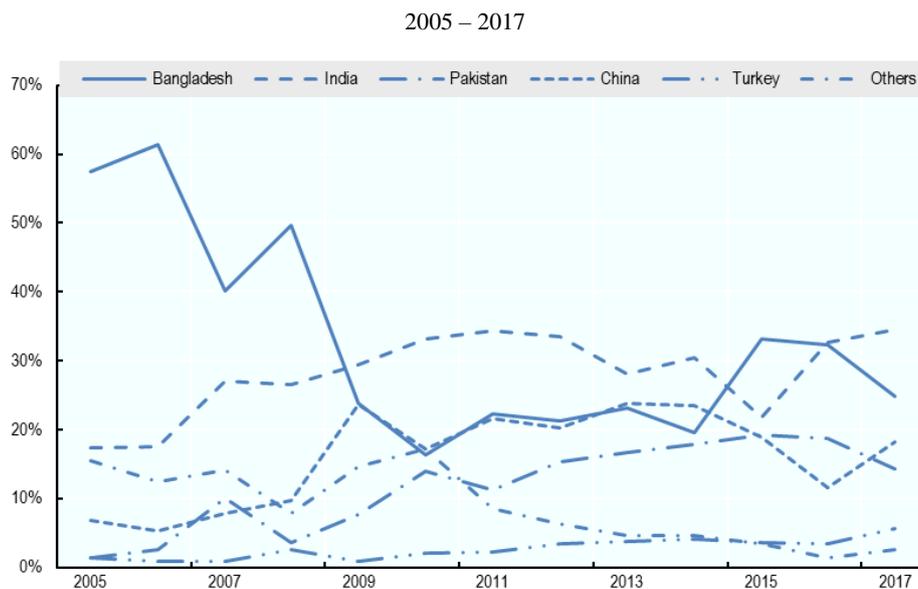
The first part of this report gives an overview over the functioning of the ship recycling market and a forecast of ship demolition volumes, as well as an assessment of the impact of the Ballast Water Management Convention (BWMC) of the International Maritime Organization (IMO) on scrapping activity. The second part of this work describes the aforementioned two policies in more detail and presents phase-out policies in two industries which are comparable in terms of recycling approach (i.e. sales of large parts and blocks) and earnings model (i.e. importance of component based earnings), notably the aircraft and vehicle industries. The goal of this overview is to learn from other industries to decrease the environmental and health impact and internalize the negative externalities caused by the ship recycling industry.

2. Market for ship recycling

2.1. Descriptive statistics of vessel demolitions

Ship recycling centres operated in the United States (hereafter “USA”) and Europe from around 1945 until 1980, but have subsequently shifted to Asia. Nowadays, ship-recycling business takes place mostly in Bangladesh, the Peoples’ Republic of China (hereafter “China”), India and Pakistan, which together account for 91% of recycling volume in gross tons (GT), as of September 2017. Turkey, as the fifth largest breaking destination, accounts for around 6% of world total (Figure 2).³ Major reasons for the relocation of ship breaking business to these countries were the presence of lower labour costs, lower safety and environmental standards and associated compliance costs along with high local demand for recycled goods (Choi et al., 2016^[8]; Cavalieri et al., 2011^[9]). The use of the beaching method in South Asia usually results in lower operational costs, as it does not require the same level of investment in infrastructure as other types of recycling methods.

Figure 2. Annual demolition volumes as % of global gross tons by ship recycling country



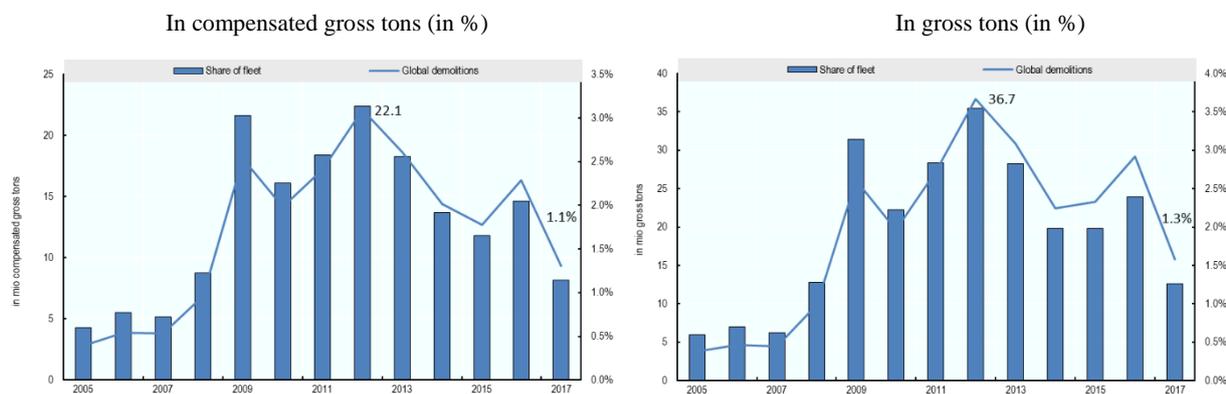
Source: based on Clarkson World Fleet Register.

Demolition volumes are counter-cyclical; as Figure 3 shows demolitions have increased in 2009 with the slowdown of the economy resulting from the economic crisis of 2008, which led to a decrease in the utilisation rates of the global merchant fleet. In contrast, volumes were lower between 2004 and 2008 when economic activity was stronger, allowing ship owners to exploit the vessels' capacity following increased demand. In general, demolition volume increases during economic downturns when demand for cargo-carrying ships decreases (Stopford, 2003^[8]). Higher demolition activity is usually driven by increased demand for and prices of ferrous scrap.

Over the last 11 years, annual demolitions made up between 0.5% and 3% of fleet size in compensated gross tons (CGT) per year with its peak in 2012 at around 22 million CGT

(36 million GT) and about 1 674 vessels after the economic crisis. As of September 2017, total demolition volume amounted to around 9 million CGT (16 million GT) and represented around 628 vessels and a historically low rate of approximately 1.1% of fleet size in CGT (Figure 3 and Table 1).

Figure 3. Annual demolition volume and demolitions as share of fleet, 2000 - 2017 (Sept.)



Source: based on Clarkson World Fleet Register, 2017.

Table 1. Number of vessels demolished by year

2005 - September 2017

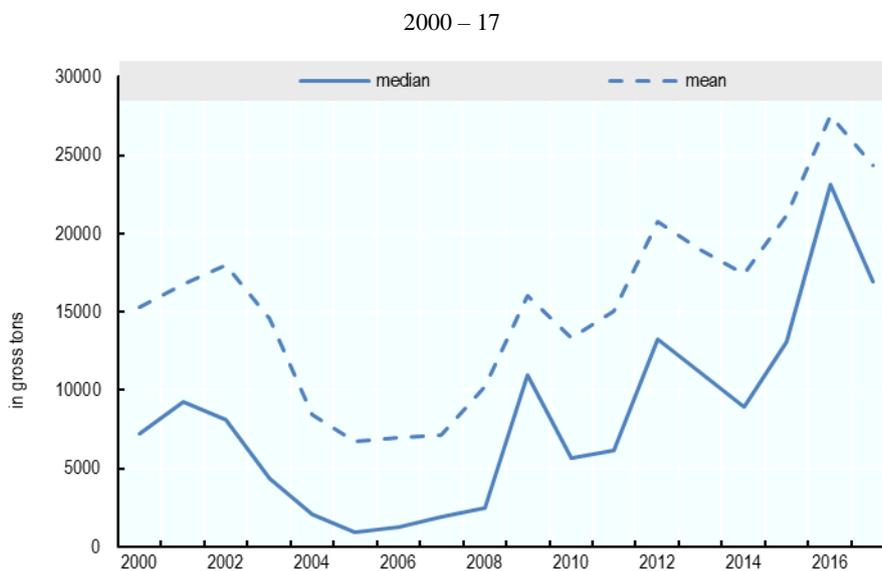
Year	Number of ship demolitions
2005	326
2006	424
2007	421
2008	563
2009	1 372
2010	1 236
2011	1 499
2012	1 674
2013	1 388
2014	1 154
2015	884
2016	992
Sept. 2017	628

Source: based on Clarkson World Fleet Register, 2017.

Main drivers for the increase in demolition volumes since 2009 were the growth in fleet size (i.e. the stock of vessels) and the increase of the median size per vessel scrapped, as Figure 4 depicts. Between 2009 and 2016, the median vessel size scrapped has almost doubled from around 10 000 GT to about 22 000 GT. Furthermore, during the boom years of 2004 to 2008 there were mainly small vessels demolished.

Vessel size has increased over the last years, and the pattern of demolition of relatively small vessels during an economic upturn can be explained by economies of scale in the shipping industry (ITF, 2015^[9]). If ship owners expect increased freight for the future, the purchase of a larger (and more efficient) vessel for replacement goes along with lower unit costs. In comparison, the use of a fleet of several small vessels that are more flexible to operate during volatile demand bear higher unit costs. More specifically, unit costs to transport one ton of cargo depend on the discounted capital costs of the ship (CC), the cost of operating the ship over its life (OPEX) and the cost of handling the cargo (HC) divided by the tonnage of cargo it can carry (T), see [$Unit\ cost = \frac{CC+OPEX+HC}{T}$]. As the size of ships increases, unit costs fall because capital, operating and cargo handling costs do not increase in proportion to the cargo capacity (Stopford, 2003^[8]).

Figure 4. Median and mean size of demolished vessels



Source: based on IHS Seaweb (2017).

The fact that the mean in Figure 4 is larger than the median ship size suggests that there is only a small number of ultra-large vessels demolished. A closer look at the types of vessels scrapped in 2015 and 2016 reveals that mainly ocean-going vessels were demolished (e.g. bulkers, containers) with a size range of between 20 000 to 45 000 GT (Figure 5 and Figure 6). However, there is also a small number of ultra-large vessels reaching a size of around 175 000 to 250 000 GT, such as oil tankers and ore carriers (Figure 6).

Figure 5. Demolitions in % of total GT and # of vessels by ship type

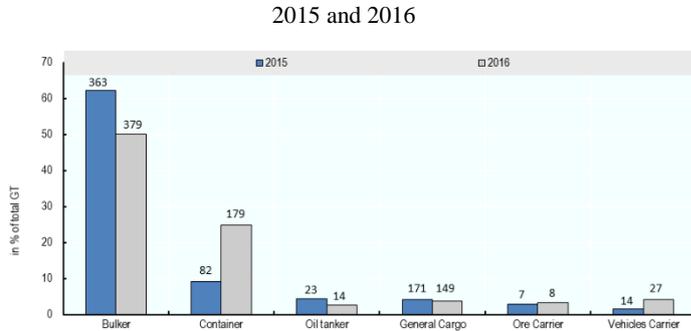
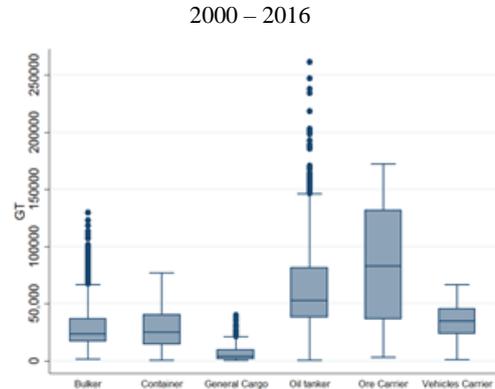


Figure 6. Size of major ship types demolished

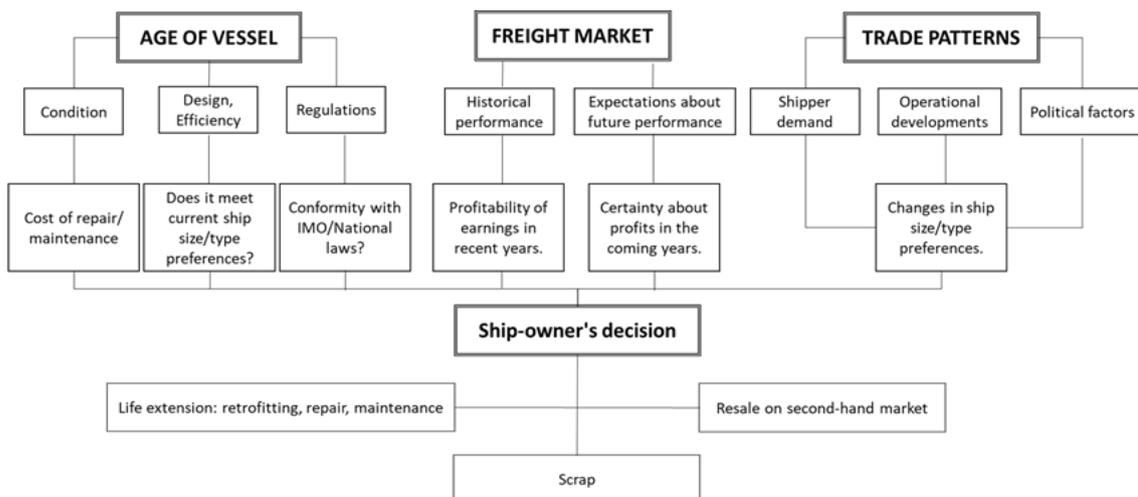


Source: based on IHS Seaweb (2017).

2.2. Determinants of ship demolition

Ship owners usually decide on three actions based on calculating the net present value of the vessel, which are i) continuing to operate the vessel; ii) selling it for further trading to the second-hand market (i.e. to another shipping company); or iii) selling it for scrap (i.e. where scrap dealers bid at a scrap price). The value function of a ship is thereby determined by several factors, notably its age and other ship characteristics, the freight market conditions (e.g. the stage of the shipping market cycle) which determine the freight rates and market sentiments, as well as trade patterns, such as charterer's preferences, operational developments or new regulations which mandate certain ship features. Figure 7 summarizes the main factors on which ship owners usually base their decisions.

Figure 7. Scrapping decision process

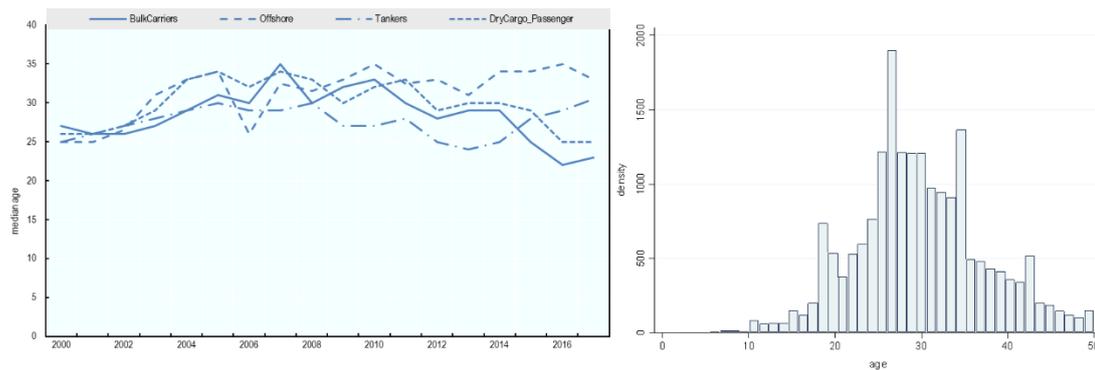


Source: based on Drewry Shipping Consultants Ltd. (1996_[10]); Legaspi (2000_[11]).

2.2.1. Age of Vessel

Knapp, Kumar and Remjin (2008_[12]) found a negative relationship between age and demolition probability, as older vessels are more likely to be scrapped *ceteris paribus*. Between 2000 and 2017, the median scrappage ranged between 25 and 35 years and (except for offshore service vessels) has been decreasing since 2008/2009. In general, tankers seem to be demolished at a younger age and offshore service vessels at an older age than the median scrappage across all ship types (Figure 8, lhs). Between 2000 and 2017, statistics show only a small number of vessels demolished under age of 20 years (Figure 8, rhs).

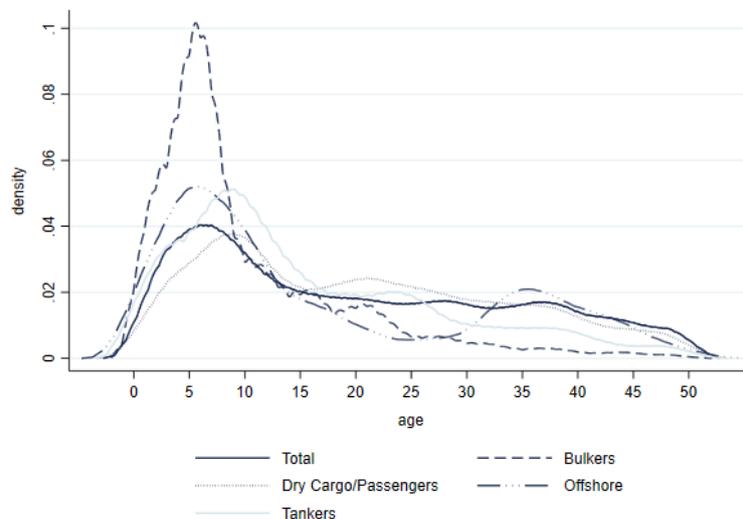
Figure 8. Median demolition age (lhs) and histogram of demolition age (rhs)



Source: based on IHS Seaweb, 2017.

The age distribution of vessels in the fleet of September 2017 shows that most of the vessels are around 7 years old, while the average age amounts to 20 years (due to the long tail of the distribution up to 50 years) as illustrated in Figure 9. By looking only at ship age as a driving factor for demolitions, ships on the long tail of the right hand-side (i.e. above age 25) will likely exit the fleet in the coming years. Section 4 illustrates the negative impact of age on ship value that in turn increases the probability of demolition.

Figure 9. Density of fleet age

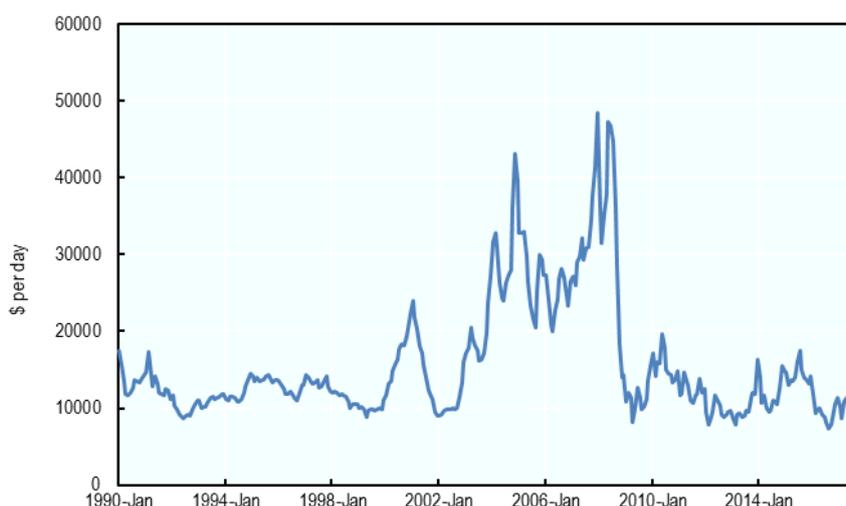


Source: based on IHS Seaweb, 2017.

2.2.2. Freight market

Results by Knapp, Kumar and Remjin (2008_[12]) provide evidence for the negative relationship between forecast earnings and demolition probability. An increase in earnings decreases the likelihood of demolition because owners would rather use the vessel as a source of future revenue if the market conditions allow. The ClarkSea Index from Clarkson shows the development of freight rates over the last 27 years (Figure 10). During the boom years between 2004 and 2008, shipping revenues were higher than average earnings. After the economic crisis, revenues plunged and remained subsequently at those low levels. Revenues play a major role in determining the value of a ship, as ship owners derive net present ship values by incorporating their expected future revenues and current expectations about future freight.

Figure 10. ClarkSea Index



Note: ClarkSea Index is a weighted average index of earnings for the main vessel types where the weighting is based on the number of vessels in each fleet sector.

Source: based on Clarkson Shipping Intelligence Network, 2017.

Trade patterns - changes in vessel features

Changes in trade patterns in terms of operational developments or new regulations may have an impact on demolition volumes. For instance, the Energy Efficiency Design Index (EEDI) is a mandatory regulation based on an index specifying a minimum energy efficiency level per tonne mile for different ship types and size categories.⁴ OECD (2017_[13]) provides an assessment of the effectiveness of the EEDI regulation.

Furthermore, on September 8, 2017 IMO's Ballast Water Management Convention (BWMC) entered into force after it was ratified in 2016 by 55 states representing a total of 53% of the global fleet measured in GT. This Convention aims to prevent the spread of harmful and invasive species with the usage of ballast water management systems (BWMSs) installed on ships.

At its 71st meeting, the Marine Environment Protection Committee (MEPC) agreed upon an amendment on compliance dates for ballast water discharge. Under the approved amendments, new ships (i.e. ships constructed on or after 8 September 2017) shall conduct

ballast water management that meets at least the standard from the start date of vessel operation. For existing ships (i.e. ships constructed before 8 September 2017), the date for compliance is linked to the renewal survey of the ship associated with the International Oil Pollution Prevention (IOPP) Certificate under MARPOL Annex I. For existing ships this would be the first or second five-year renewal survey after 8 September 2017 (IMO, 2017^[14]):

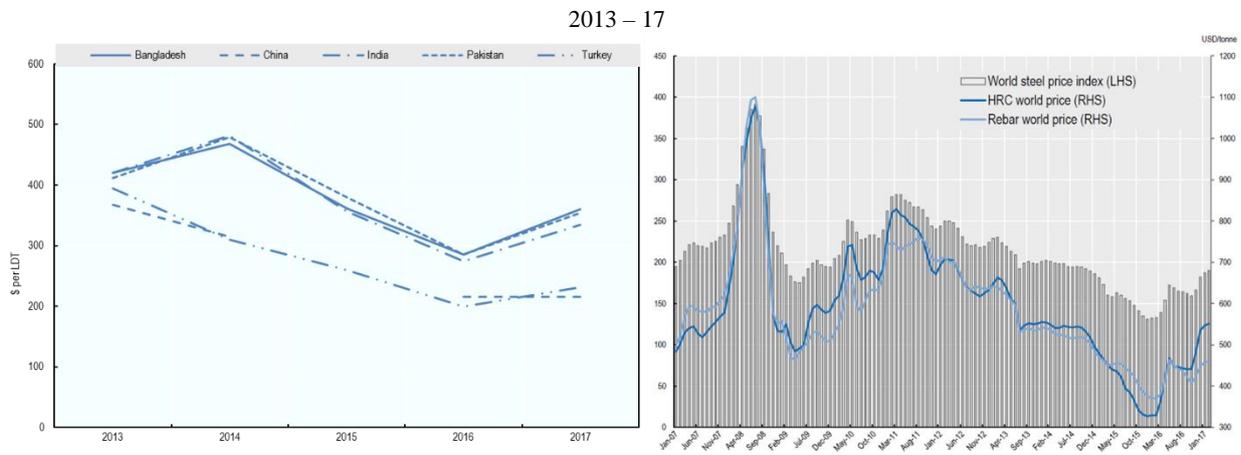
- By the first renewal survey: this applies when the first renewal survey of the ship takes place on or after 8 September 2019 or a renewal survey has been completed on or after 8 September 2014 but prior to 8 September 2017.
- By the second renewal survey: this applies if the first renewal survey after 8 September 2017 takes place before 8 September 2019. In this case, vessels must comply by the second renewal survey (unless the previous renewal survey was completed in the period between 8 September 2014 and 8 September 2017).

Although there are no concrete estimates of the technological and installation costs, Clarkson's provided a cost range of between USD 0.5 million to USD 3 million per ship. These additional retrofitting costs decrease the ship value and should therefore lead to increased demolition volumes in the coming years. Section 4 provides an estimate of additional demolitions as a consequence of implementing the BWMC. As data on the ship specific IOPPC renewal date are rather scarce, the results in the report's section on outlook on demolitions refer to demolition volumes in the next seven years based on the information available for vessels in the fleet as of 2017.

Scrap prices

In addition to the determinants described above, scrap prices have a positive impact on the likelihood of ship demolition.⁵ Scrap prices are usually expressed in USD per light displacement tonnage (LDT). Since 2014, demolition prices declined for each demolition country, as depicted in Figure 11 (lhs). Turkey and China show the lowest scrap prices across all available years while prices are similar for Bangladesh, India and Pakistan. As the lion's share of revenues from ships comes from the steel content, scrap prices strongly correlate with steel prices. Figure 11 (rhs) illustrates the decline of steel prices since 2013 which is in line with the development of scrap prices for the same years.

Figure 11. Median demolition price in USD/LDT by demolition country (lhs) and World steel price index (rhs)



Note: The box in the graph on the right hand side indicates the same time-period from 2013 to 2017 like in the graph on the left hand side.

Source: based on IHS Seaweb (2017) (lhs); OECD (2017_[15]) (rhs).

2.3. Ship recycling methods

There are currently four recycling methods used across the world, which encompass dry-docking, pier breaking, landing and beaching (Table 2).

Table 2. Current recycling methods

Recycling method	Countries applied
Dry Docking	In some places in Europe
Pier breaking/alongside	China, Europe and the US
Landing/slipway	Turkey
Beaching	Bangladesh, India and Pakistan

Source: based on Litehauz (2013_[16]).

2.3.1. Dry Docking

The ship is sailed into a dock and the water is pumped out. Subsequently workers dismantle the vessel and upon termination, the dock is cleaned and flooded again. The important advantage of this method lies in the fact that the risk of environmental pollution remains low because the work is conducted in an enclosed area (Litehauz, 2013_[16]). As building and maintaining a dock is relatively costly, this method is hardly used for ship recycling purposes only.

2.3.2. Pier breaking/alongside

In this method the ship is secured along a wharf or quay in calm waters (i.e. mainly in rivers or harbours) where a crane removes the pieces of the ship until the vessel is lifted or sent to a dry dock for final cutting. This method is mainly used in China, certain facilities in Turkey and the US (Litehauz, 2013_[16]).

2.3.3. Landing/slipway

For this method, the vessel is sailed against the shore or a concrete slipway which extends into the sea at sites with little or no tides. The ship is subsequently dismantled with the use of a mobile crane located onshore or on barges. Additionally, temporary quays or jetty are used on-site to use heavy lifting or cutting equipment. Turkey is using this method (Litehauz, 2013_[16]).

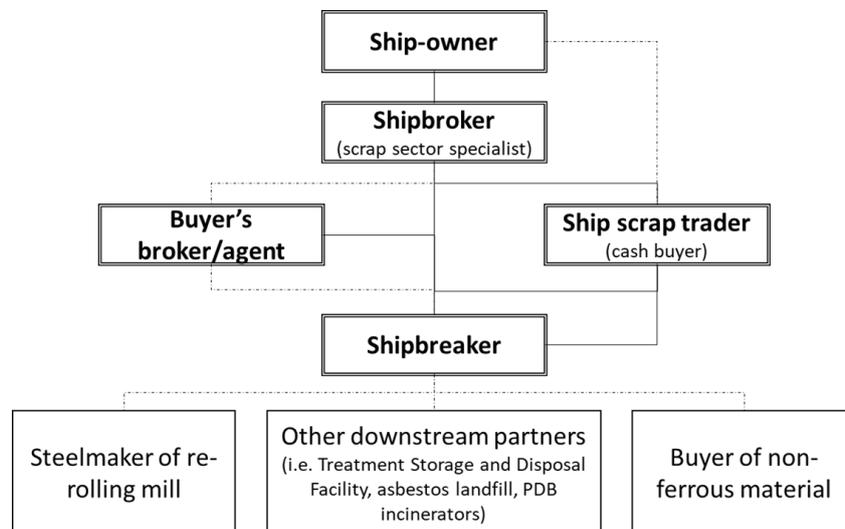
2.3.4. Beaching

The beaching method is currently the most used method and applied in Bangladesh, India and Pakistan. This method involves sailing a lightened vessel full steam onto a tidal beach so that workers have access to the ship in order to cut off the ship's pieces (Litehauz (2013_[16]); Choi et al. (2016_[17]); Demaria (2010_[18]); Ahammad and Sujauddin (2017_[19])).

2.4. Main market players

In order to sell their ships, ship owners are often working with ship brokers or cash buyers as intermediaries who offer a price per LDT given the present market conditions, such as steel prices, demand for demolition etc. (Figure 12). These intermediaries are in contact with the ship recycling facilities and prepare the ship for demolition.⁶ Finally, the ship recycling facilities sell the recyclable items after demolition to (local) steelmakers or buyers of interior equipment.

Figure 12. Main participants in the scrap process



Source: based on Drewry Shipping Consultants Ltd. (1996_[10]) and Legaspi (2000_[11])

2.5. Economics of ship recycling

Ship recycling is a commercial business with scrap facilities paying owners significant amounts of money to salvage raw materials from the ship. These raw materials include steel scrap, electric cables, pipes, engines, fuel, interior equipment, and so on. Table 3 illustrates reported revenues and costs of ship recycling for a sample ship⁷ (World Bank, 2010_[2]).

The example shows that the steel revenues are similar in Bangladesh and Pakistan with around USD 322 per LDT and USD 337 per LDT, respectively.⁸ Bangladesh has lower labour costs and taxes as well as financing compared to Pakistan. While workers in Pakistan are on average longer employed than in Bangladesh, the wage differential outweighs this factor. Interest rates in Pakistan range between 17% and 18% per year, making financial costs considerably higher than in Bangladesh. These differences result in profits per LDT being almost five times higher in Bangladesh than in Pakistan, making the former country more attractive to ship recycling facilities (World Bank, 2010_[2]). These figures should be viewed with caution, since this cost and profit information refers to 2010 and may likely have changed in 2017. However, the general message about the cost differences in these two countries should still be valid.

Table 3. Economics of ship recycling

In USD

Category	Element	Bangladesh	Pakistan
Revenue	Steel	4 771 500	4 992 800
	Other recyclable items	842 000	512 700
	Total revenue	5 613 600	5 505 500
Costs	Purchase of ship	3 848 000	3 848 000
	Investment costs	21 900	18 300
	Financial costs	147 900	265 700
	Labour costs	92 700	233 400
	Consumables	302 200	230 000
	Taxes, tariffs and duties	263 000	693 600
	Rents, levy and permits	2 700	500
	Other costs	13 800	51 300
		Total costs	4 692 200
Profit	Profit	921 400	164 600
	%	15%	3%
	USD/LDT*	62	11

Note: Due to lack of data, consumable costs in Pakistan are estimated based on data from India, 2 Light Displacement Tonnage; all amounts are rounded to full hundreds.

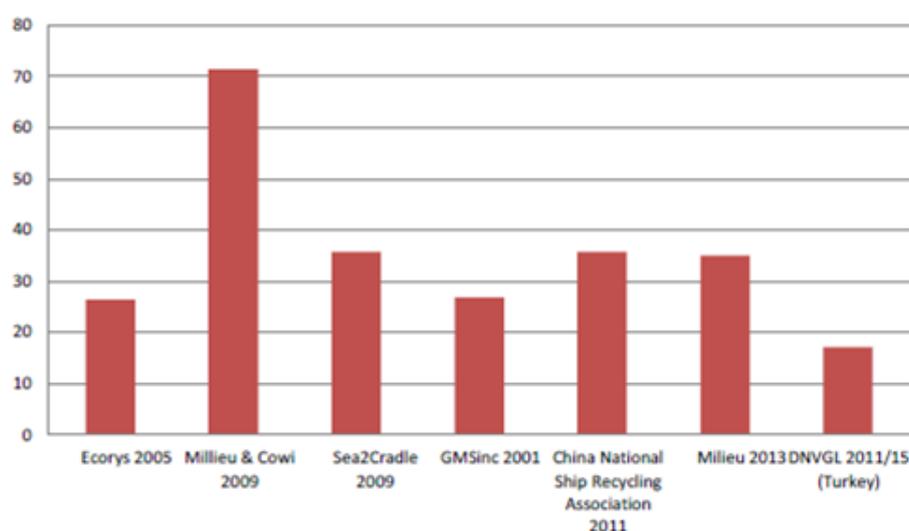
Source: World Bank (2010_[2]).

A recent study conducted by Ecorys et al. (2016_[20]) provides a comparison of different estimates of the marginal costs of ship recycling that is safe for human health and the environment. The results indicate that except for the estimate by Millieu Ltd. and COWI (2009_[21]), these “sound” recycling costs range between additional 15 EUR/LDT and 35 EUR/LDT (Figure 13). It is important to note that these cost estimates assume an already largely compliant downstream waste management infrastructure. Therefore, major capital investments are necessary in yards without such an infrastructure. In case the downstream waste handling facility invests in a proper waste management system, the marginal costs for the ship recycling facility will increase, as it would need to pay the disposal cost for each demolished ship (Ecorys et al., 2016_[20]). In particular, the following cost components are necessary for safe and environmentally friendly ship recycling: hazardous material replacement on-board, preparing an inventory of hazardous materials, consulting and monitoring for soil, air and water protection, waste storage, waste transport, training,

personal protective equipment, build structure for cutting zones and waste disposal. These detailed cost estimates provide a basis for measures internalizing the costs of negative externalities on human health and the environment through ship recycling.

If we assume that the example of the Panamax oil tanker in Table 3 does not include the costs for sound ship recycling and we consider costs of around 35 USD/LDT, it will be possible to implement sound recycling measures in Bangladesh where profit amounts to around 62 USD/LDT, but it will hardly be possible to do so in Pakistan where the profit level is around 11 USD/LDT. In relative terms, 18-40 USD/LDT (i.e. 15-35 EUR/LDT) make up around 5% to 12% of additional costs. It is important to note that this estimate is based on the available example above.

Figure 13. Estimates of marginal costs of sound ship recycling



Note: USD data converted using 2011 exchange rates.

Source: Ecorys et al. (2016_[20]), see in graph.

2.6. Ship recycling and subsequent steel use

Globally, about 650 million tonnes of steel are recycled annually, making up an important share of inputs for new steel and thus providing a major contribution to a circular economy. The advantage of steel is that it can be completely recycled without loss of quality (World Steel Association, 2015_[22]). Furthermore, the operation of Electric Arc Furnaces (EAF) that mainly use steel scrap as inputs is more environmentally friendly than Basic Oxygen Furnaces (BOF) which use iron ore and coal, and the use of steel scrap partly replaces the energy intensive mining of iron ore needed for 'new' steel (Weisz et al. (2015_[23]); Yellishetty et al. (2011_[24]). Thanks to its high recovery rate of scrap steel, ship recycling as such contributes significantly to a circular economy of steel.

The importance of steel sourced from ship recycling can be demonstrated on the example of Bangladesh. The World Steel Association estimates the steel consumption in Bangladesh to around 4 million metric tons (finished steel products) in 2015 (World Steel Association, 2017_[25]). However, as Sujauddin et al. (2017_[26]) argue, this does not take into account the significant contribution ship recycling provides to steel consumption, as a high percentage of steel recuperated from ship scrapping circumvents the normal production process and is thus not counted into World Steel Association Statistics. In fact, approximately two-thirds

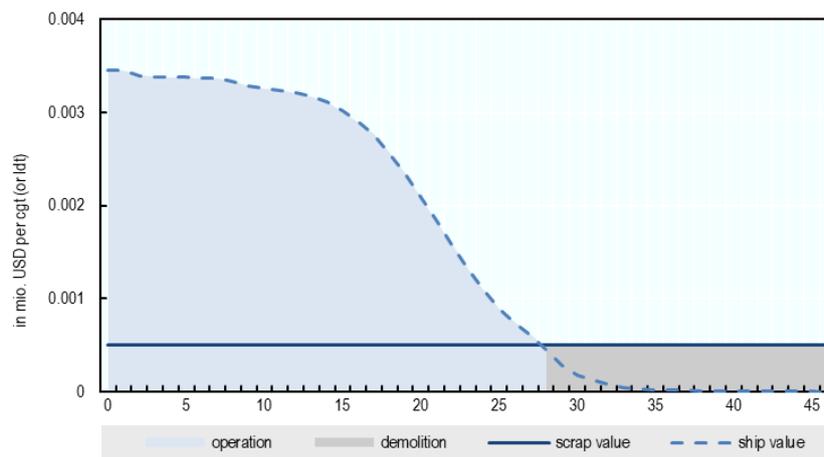
of the steel recovered from ship recycling is either directly reused or re-rolled (Sujauddin et al. (2017_[26])).⁹ Taking this steel use from ship breaking into account, Bangladesh steel consumption increases significantly. Sujauddin et al. (2017_[26]) find that in 2008, Bangladesh had a higher steel consumption per capita than other countries of a similar GDP/capita ratio, reflecting largely the importance of the ship recycling industry. Further estimates indicate that scrap metal feedstock sourced from recycled ships in relation to total steel production amounts to approximately 50% (Sujauddin et al. (2017_[26]); World Bank (2010_[2])). Although these estimates are outdated, they shed some light on the high dependence of Bangladesh on ship recycling as a source for its steel demand, which is mainly used for the construction industry.

3. Outlook for ship demolitions

3.1. Baseline scenario

To derive an estimate of demolition volumes for 2017-18, we derive ship values from historical second-hand market prices and compare those values to the vessels' scrap value in USD per LDT. As already elaborated above, a vessel's value function depends on the ship's age, the expected demand for freight transport, upcoming regulations but also on the backlog of a yard as longer time to build makes the existing vessel more valuable to be used for immediate transport services. Ship owners compare the vessel's net present value (reflecting future earnings from transport services, current backlog and the vessel's age and other characteristics) with the current scrap value and decide on that basis between the two options, notably continuing operating the ship or sending it for demolition (see Figure 14 as an example). This analysis is entirely static in the sense that we use the fleet as of 2017 and the scrap values of 2017.

Figure 14. Example of decision-making process by ship owner

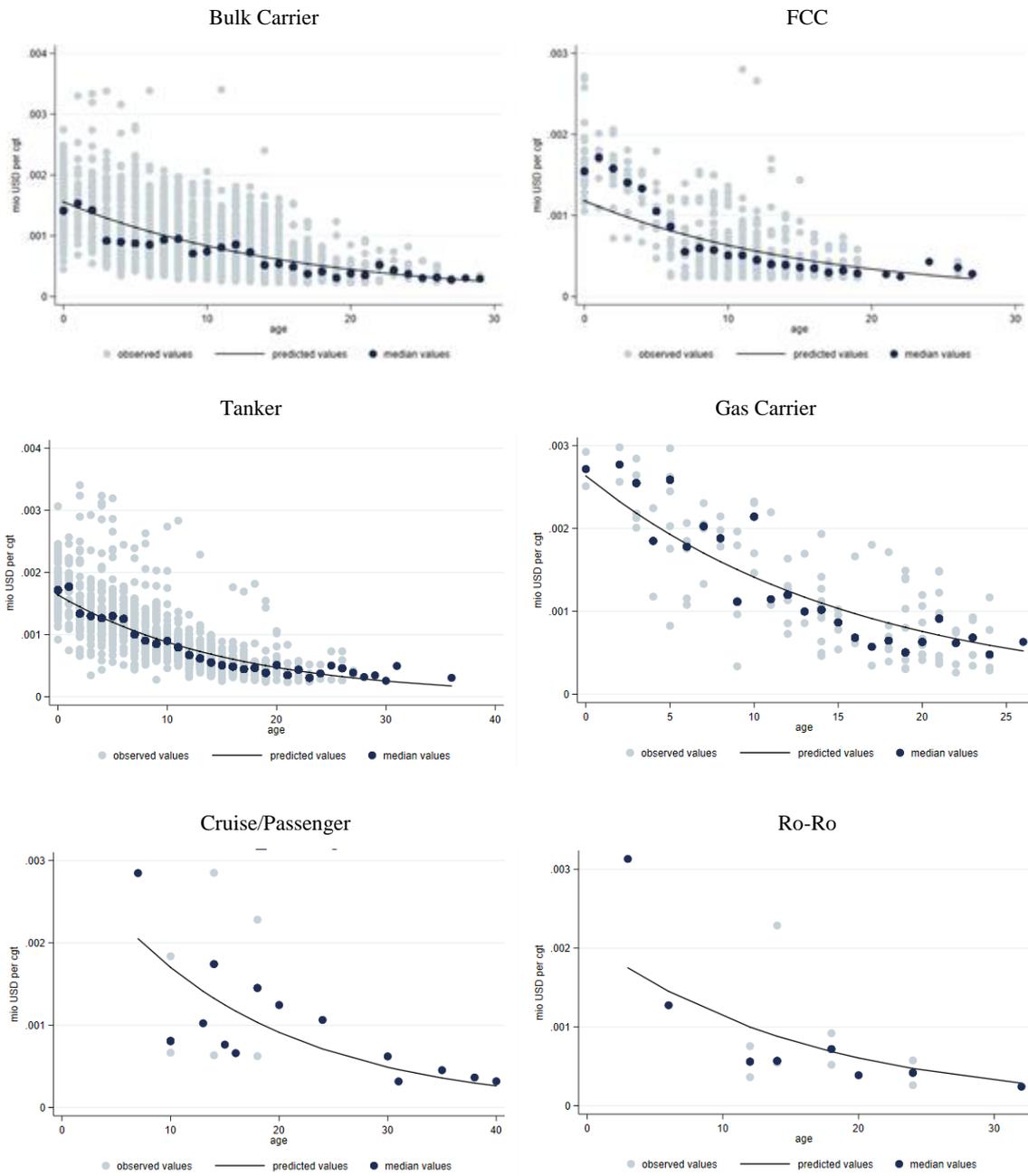


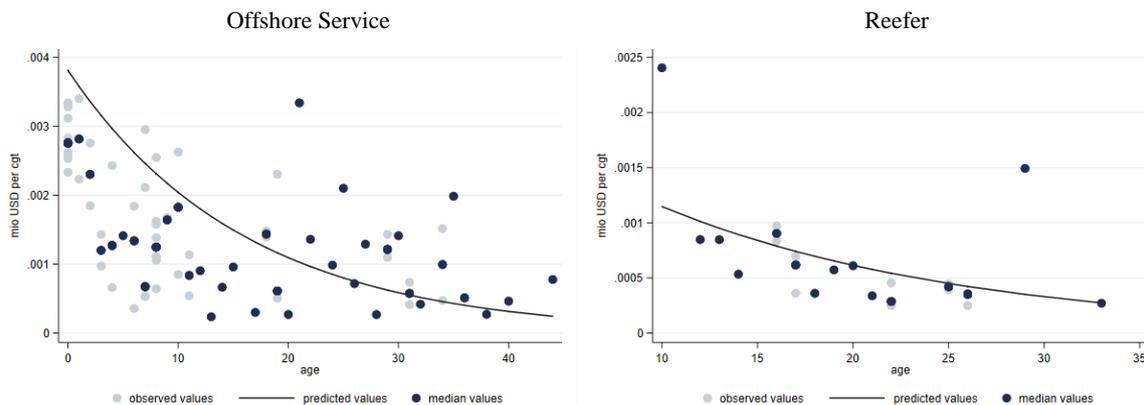
Source: Author's own representation.

We derive a ship value in million USD per CGT by ship age and by ship type since we assume that all other factors, such as expectations about regulations, expected time to delivery, freight demand, are already reflected in the second-hand market price. Figure 15 shows statistically derived second-hand market prices in million USD per CGT across age and ship group.¹⁰ The charts clearly show a decrease in ship value per CGT by age.¹¹ Our estimated depreciation rate of 6% is in line with the assumption of shipbrokers that vessels lose 5% to 6% of their value annually (Stopford, 2003_[8]).

Figure 15. Value estimates by ship group across age

In million USD per CGT





Source: based on Clarkson's World Fleet Register (2017).

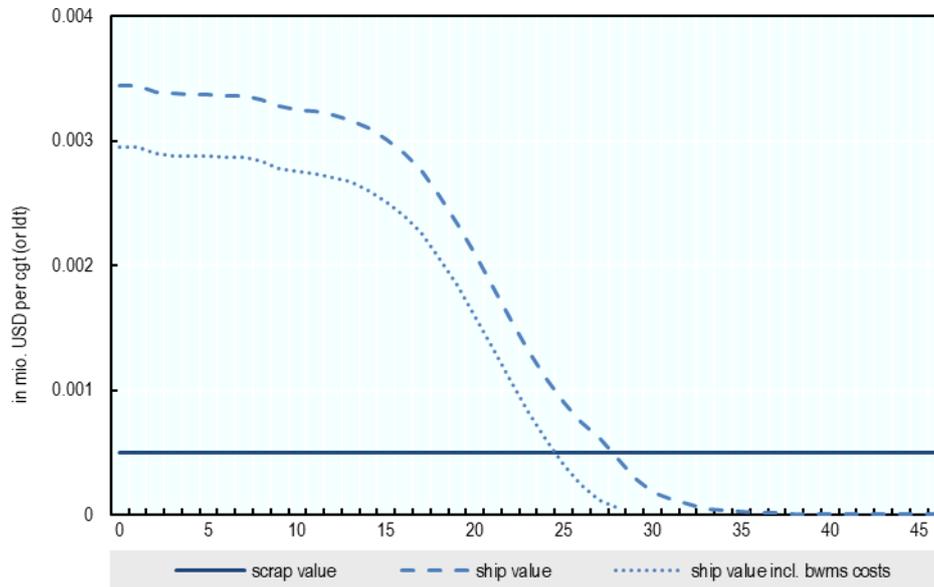
In a second step, we derive the scrap value per CGT by using observed demolition prices in USD per LDT over the last five years. As ferrous scrap prices play the major role¹² in determining a vessel's demolition price and these are very volatile over time, we use weighted average scrap values in USD per LDT of 2017 by ship type (Figure A C.1 in Annex C). For missing observations of LDT we use CGT to derive scrap values. To do so, we convert LDT into CGT to obtain USD per CGT for a vessel's scrap value on the basis of the ship group specific median.

The results suggest a demolition volume of around 18 million GT or 1.4% of the global merchant fleet as of September 2017 (around 23 million CGT or about 2.8% of the fleet as of September 2017).¹³ Back casting of demolition rates with the same approach shows results very similar to actual values based on GT for the same period covered by the analysis, September 2017 to August 2018 (12 months), with an estimated scrap ratio of 1.4% compared to an actual ratio of 1.6% (Clarkson World Fleet Register, 2019). These results lend some support to the validity of our estimation method. The three main ship types account for approximately one third of these demolitions with 11% for bulkers, 5% for containers and 17% for tankers, while both dry cargo vessels and other smaller vessels in the category miscellaneous make up each around one third.

3.2. Effect of Ballast Water Management Convention

As noted above, new policies and regulations can have an impact on the level of scrapping rates. The decision to phase out single hulled tankers, for instance, likely led to increased scrapping rates of vessels not complying with the new regulation. The BWMC is such a current policy that will likely affect the decision of ship owners to demolish or continue operating a vessel. This policy is expected to significantly impact the market as it applies to a wide range of ship types. To estimate the effect of the BWMC on scrapping activity we use the cost estimates provided by Clarkson as an indication of installation costs. For the simulation, we thus use three scenarios with assumed installation costs of USD 3 million per ship, USD 1.5 million per ship and USD 0.5 million per ship. These installation costs shift the ship's value function downwards, as depicted in Figure 16.

Figure 16. Effect of BWMS installation costs on ship value function

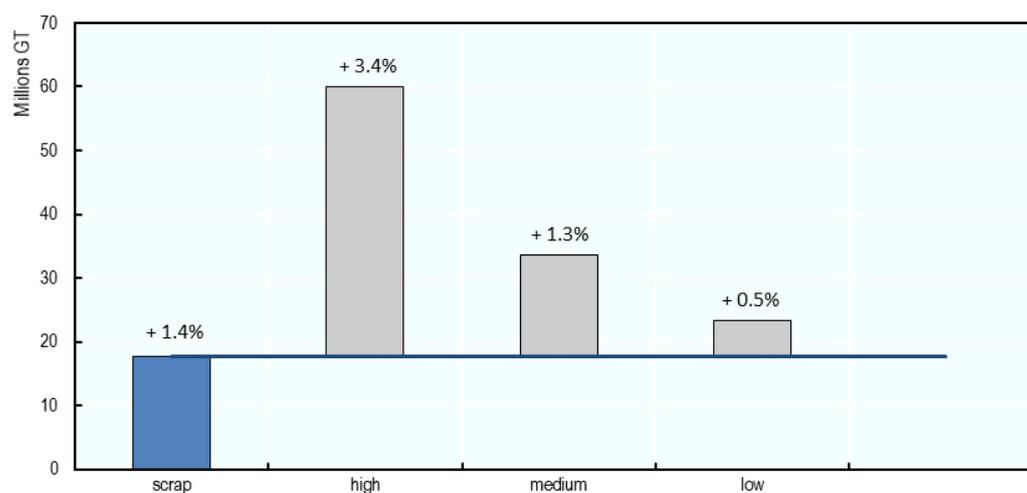


Source: Author's elaboration.

We exclude all vessels which already have a BWMS installed (around 4 600) as well as ships which are domestically trading (around 34 000) because they are operating in the same waters¹⁴ and therefore do not require a BWMS.¹⁵ The remaining 43 500 vessels fall under the regulation and for those we follow the same approach as above by comparing the vessels' net present value to the scrap value.

The results suggest that more than two-thirds of vessels, which fall under the regulation (about 95% of vessels in total GT),¹⁶ will be retrofitted. However, the additional demolition volume for the next seven years as a consequence of the BWMC is estimated to range between 6.5 million to 44 million GT (11 million to 54 million CGT) compared to the baseline scenario which does not take into account the BWMS installation costs (Figure 17). In other words, the Convention might lead to an increase in demolition volume by an additional 0.5 to 3.4% when measured in GT (or 1.3% to 6.5% measured in CGT as share of the fleet in 2017) in the next seven years maximum (depending on the ship specific IOPPC renewal date which makes compliance obligatory). In other words, the policy might trigger additional demolitions over the next years of one-third to two times of the size of usual annual demolitions related to the renewal of the fleet. The difference between the results in GT and CGT reveals that mainly vessels high in CGT size may be demolished, which are not necessarily large in GT. It is important to keep in mind that these results do not take into account sufficient docking and yard capacity for retrofitting, and bottlenecks for installation demand remain a reasonable concern.

Approximately 6% of all vessels in the baseline scenario have an EU flag, while in the case of vessel retrofits this applies to 7% to 10% (high to low cost scenario).

Figure 17. Estimates of demolition volumes by cost scenario

Note: The high cost scenario assumes installation costs of USD 3 million the medium scenario of USD 1.5 million and the low scenario of USD 0.5 million. In the high cost scenario around 95% of total GT of vessels obliged to install a BWMC will be retrofitted, in the medium scenario around 97% and in the low case scenario about 99%. This corresponds for the high scenario: to ~64% of the number of vessels obliged to install a BWMC will be retrofitted; for the medium scenario: 74% and for the low scenario 84% to be retrofitted (see Appendix). *Source:* based on Clarkson's World Fleet Register (2017).

4. International and regional policies

4.1. Basel Convention (1989)

At the international and national levels, there were many attempts to regulate the ship recycling industry. As a first attempt, parties considered ship dismantling to be covered by the Basel Convention (1989). The Convention controls transboundary movements of hazardous wastes and their disposals. Because end-of-life ships comprise an array of hazardous materials, such as asbestos, PCB and waste oils, this activity can represent a cross-border movement of hazardous waste. Difficulties arise, however, as prior notifications for demolition are not always sent or do not necessarily reflect the hazardous contents on board of the ships. This lack of clarity hindered the application of the Convention to shipbreaking.

4.2. IMO Hong Kong Convention (2009)

At the 7th meeting of the Conference of the Parties to the Basel Convention in 2004 the International Maritime Organization (IMO) agreed to continue its work aimed at the establishment of mandatory requirements to ensure the environmentally sound management of ship dismantling (VII/26 UNEP/Basel decision).¹⁷ After several discussions and drafting sessions, the IMO adopted the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (the HKC) in May 2009 at a diplomatic conference in Hong Kong, China.

The HKC is a control system with obligations for flag states, ship owners, recycling states and recycling facilities. The Parties to the Convention have an obligation to prohibit and/or restrict the installation/use of hazardous materials. The banning of hazardous materials, however, has already been regulated by other conventions, such as SOLAS. All ships are required to have a ship specific Inventory of Hazardous Materials on board (updated throughout the ship's life).

Authorized ship-recycling facilities under the Convention are able to undertake all the recycling activities, prepare a recycling plan, outline plans that detail how to prevent hazardous conditions, such as explosions, fire, accidents, spills, emissions, waste management on-site, emergency preparedness and response, worker safety and training, reporting on incidents/accidents/occupational diseases and so forth. In contrast to the EU regulation (outlined below) the IMO HKC does not cover downstream waste management.

Article 17 of the Hong Kong Convention for the Safe and Environmentally Sound Recycling of Ships (2009) stipulates that the Convention will enter into force 24 months after the date on which:

- i. **at least 15 States** have either signed the Convention without reservation as to ratification, acceptance or approval, or have deposited the requisite instrument of ratification, acceptance, approval or accession in accordance to article 16,
- ii. the combined merchant fleets of the States under i. amount to at least **40% of the gross tonnage of the world's merchant fleet**, and

- iii. the combined maximum **annual ship recycling volume** of the States under i. during the preceding 10 years constitutes **not less than 3% of the gross tonnage** of the combined merchant shipping of the same States.

As of September 2017, six states have ratified or acceded to the Convention, namely Belgium, Denmark, France, Norway, Panama and the Republic of the Congo, whose combined merchant fleets account for 21.23% of the world's merchant fleet. The combined annual ship recycling volume of the Contracting States during the preceding 10 years is 112 161 GT, i.e. only 0.042320%.

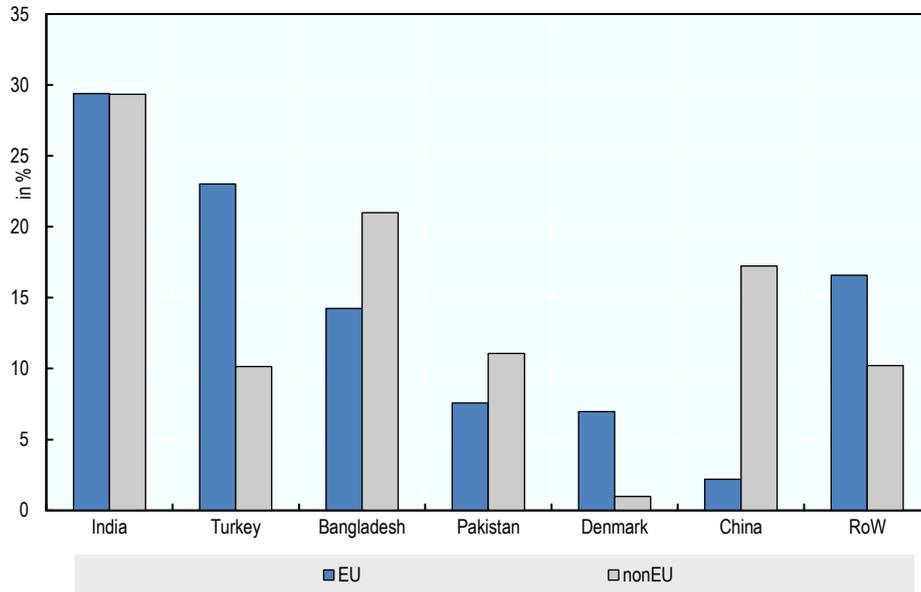
4.3. EU Ship recycling regulation (2013)

The EU regulation on ship recycling (2013) is based on the HKC, with additional stipulations related to (i) Health, Safety and Environmental (HSE) requirements, notably referring to guidance by ILO on ship recycling, (ii) downstream waste management, (iii) control mechanisms and (iv) the HKC Inventory of Hazardous Material where it adds two substances to the inventory. It is thus considered to be more stringent than the Hong Kong Convention. The regulation sets standards for the recycling of EU-flagged ships, including the prohibition or restriction of the installation/use of certain hazardous materials in vessels and a legal obligation for ships to carry an IHM on-board. The European Maritime Safety Agency elaborated best practice guidance on the compilation of IHM in November 2016, to assist ship owners and public authorities in the development and monitoring of this tool and ensure that it provides complete information on the presence of hazardous materials on board of ships before the dismantling operations.

As of September 2017, around 13% of vessels fly an EU flag, which makes up around 16% of total GT. Around 8% of annual demolitions (in number and GT) are vessels under EU flag (OECD based on Clarkson, 2017). Over the last four years, respectively 30% of EU and non-EU flagged vessels were sent for demolition to India, making it a primary destination for scrapping (Figure 18). While EU flagged vessels were sent to Turkey (22%), Bangladesh (15%), Pakistan (7%) and Denmark (6%), non-EU flagged vessels were mainly scrapped in Bangladesh (20%), China (17%) and Pakistan (12%).

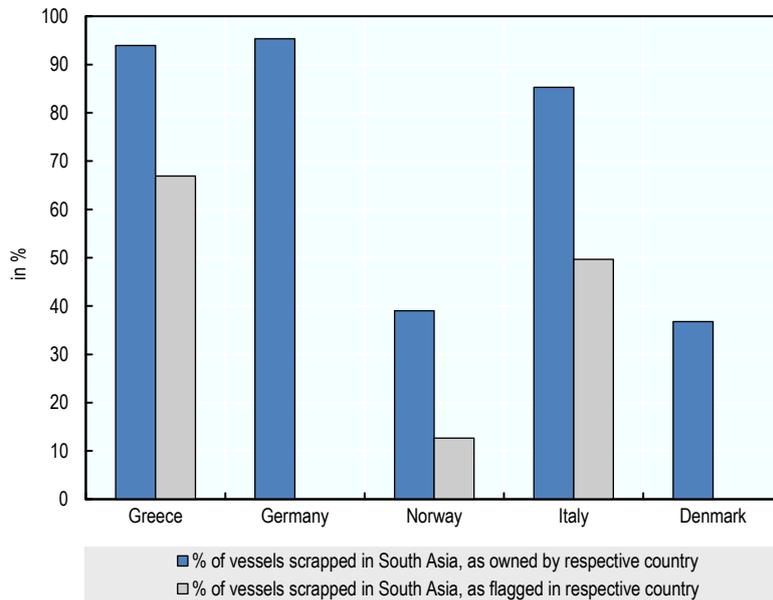
In this respect, it is important to note that there is anecdotal evidence that vessels that are EU-flagged during operation and sent for demolition to South Asian yards are often re-flagged from EU states to non-EU states for this purpose. Figure 19 shows the percentage of vessels that are sent for scrapping to South Asia (for 2014, in relation to all vessels sent for scrapping from the respective country, measured in GT) owned by or flagged in the respective owner country (of the top 5 EU owner countries). For example, in the case of Germany and Denmark in the year 2014, approximately 95% and 37% of the vessels owned by these countries, respectively, were sent for demolition to South Asia. At the same time, none of these end-of-life vessels has been flagged in these countries. The fact that during operation, Germany and Denmark each represent the flag state with 1% of the operational fleet, illustrates that owners can circumvent recycling standards that are based on the flag state of the end-of-life vessel by simply choosing a flag of convenience for demolition of the vessel. This can be furthermore confirmed by the finding that black or grey listed flag states register a disproportionately high number of end-of-life vessels (NGO Shipbreaking Platform, 2015^[27]). This illustrates the limitations of regulations on ship recycling based on the responsibilities of flag states.

Figure 18. Major ship breaking locations by flag state



Source: based on Clarkson World Fleet Register (2017).

Figure 19. Percentages of vessels sent for demolition to South Asia



Source: based on NGO Shipbreaking Platform (2015_[27]).¹⁸

In order to improve ship-recycling standards, the EU is establishing a list of EU facilities complying with the regulation’s requirements (articles 13, 15 and 16, title III of the Regulation). As of October 2018, this list contains 20 EU facilities and it is expected that it will contain 26 facilities by the end of 2018 (including two facilities from Turkey and

one from the USA). In total, 27 yards located outside the EU have applied for inclusion in the EU list.

As the regulation requires EU-flagged ships to be scrapped at recycling facilities on the European List, studies suggest that many ship owners could easily circumvent the regulation by changing the flag as already indicated above. Therefore, a study by Ecorys et al. (2016_[20]) was contracted by the Commission as part of its reporting obligation under Article 29 (and recital 19) of the Regulation and analysed the concept of a Ship Recycling Licence. Under this proposal, ship owners would have to buy such a licence per month, per three months or per year (depending on the frequency their ships call at EU ports) in order to enter the port. The licence fees would be paid into a fund managed by a European agency and would be paid out at the ship's end of life in case it is demolished at an EU listed facility. This financial incentive would apply to all ships irrespective of the flag and would aim at preventing market players to circumvent the regulation by changing the vessel's flag. This instrument has not been implemented yet as the EU might further discuss this option in the future (EC, 2017_[28]).

5. Recycling policies in comparable industries

Some evidence of the shipping industry's efforts to improve recycling activity came from the company “Maersk-Line” which aimed at developing a "Cradle to Cradle Passport" (Maersk, 2016_[29]). This passport would resemble the Inventory of Hazardous Materials (IHM), comprising an online database with all vessel's information with the aim to sort and process hazardous materials more effectively. However, this initiative has not been implemented based on the information available as of January 2018.

In the ship finance sector, some banks developed the “Responsible Ship Recycling Standards” (RSRS), in which they acknowledge that ship recycling is part of the shipping industry's value chain. The standards, announced in May 2017, set out guidelines of lending practices aimed at minimizing the negative environmental and social consequences from ship recycling and recall the importance of the Basel Convention, the Hong Kong Convention as well as the EU Ship Recycling Regulation. The banks should not be financially involved in facilities with unsustainable ship recycling practices and should try to promote the RSRS among clients as well as the ship finance sector (ABN AMRO, 2017_[30]). These efforts could increase pressure on the shipping industry to comply with the standards, especially those outlined in the EU Ship Recycling Regulation. Members to the RSRS further pledge to use their best effort to finance only new ships that carry an Inventory of Hazardous Materials (IHM) and only refinance existing ships that establish such an Inventory during or before the next dry-docking. The effect of this requirement remains, however, limited given the fact that in due time the IHMs will be a legal obligation for all ships. In this regard, all newbuilt ships will carry by default such an inventory on-board. However, as described above the quality of these Inventories may vary and a caveat of this obligation could be an Inventory without any added value for ship recycling facilities. In order to improve the quality of these inventories an idea would be to combine the commitment of financing only ships with an IHM compiled in accordance with the best practice guidance of October 2016 developed by the European Maritime Safety Agency (EMSA, 2018_[31]).

Further examples in this industry remain limited. Therefore, this section describes attempts to improve recycling practices in comparable industries, notably the aircraft and automotive industry. Aircraft recycling involves disassembly of reusable components and subsequently shredding the remaining hull in order to obtain ferrous and non-ferrous scrap (van Heerden and Curran, 2010_[32]). Similarly, the ship recycling industry is mostly based on recovering as many components as possible that have a value in the resale market, and cutting the ship's hull (i.e. ferrous metal) into plates and blocks (Andersen et al., 2001_[33]). On the contrary, the vehicle recycling industry mainly relies on shredding the vehicle hull to obtain ferrous and non-ferrous scrap for recycling because there is no market for reusable components (Sakai et al., 2014_[34]). To put it into a nutshell, the high demand for end-of-life ships' machinery, equipment and other reusable items is similar to aircraft recycling. The high demand for high value non-ferrous scrap, such as special bronze and ferrous scrap in the form of plates and blocks is similar to that of the vehicle recycling industry. Still, the ship recycling industry remains a specific case as it involves vessels of greater size, of various types and specificities as well as of large age ranges. Furthermore, end-of-life vessels are infrequently supplied and changes in regulations over time lead to a dynamic composition of ships that require changes in demolition approaches (Jain, Pruyn and Hopman, 2016_[35]).

This section describes an overview of recycling schemes in the aircraft and vehicle industry to offer ideas for the ship recycling industry. The shipbreaking industry is and remains essential for recycling all possible parts of end-of-life vessels. However, it faces difficulties to do so in an environmentally sustainable and health protecting way. The goal of this section is therefore to deliver an understanding of policies implemented in other industries, which could ideally lead to ideas to be implemented in the ship recycling industry in order to help solving the problems it is currently facing. Most of the policies and initiatives presented in the following have at least one aspect in common, namely the shared responsibility of recycling solutions throughout the supply chain from producer to user.

5.1. Aircraft industry

Similar to ships, aircrafts have a working life of around 20 to 30 years. Once they reach their end-of-life, passenger aircrafts are generally either converted for the use in freight transport or demolished where part of the components are reused or recycled. However, aircraft recycling can result in a poorly controlled process where dangers arise due to inappropriate handling of potentially hazardous wastes or secondhand components re-entering the supply chain without proper monitoring.

In 2006, Boeing launched the AFRA initiative with ten other founding members. The aim of the membership-based cooperation was to be proactive on recycling of aircrafts and develop industrial standards. In doing so, it involves members from throughout the supply chain (AFRA, 2017^[36]). AFRA has published an Aircraft Disassembly Best Management Practice in 2009 and an Aircraft Recycling Best Management Practice in 2012, which together form the basis of the initiative's accreditation programme for facilities (Dickstein, 2017^[37]). The AFRA initiative not only defines minimum standards, but also suggests control technologies that a facility should adopt in order to meet the standards. Such standards and control technologies include, among others, fully protected ground surface, storm-water runoff pathways physically protected with spill barrier equipment, oil/water separator, wastewater treatment with airplane fluid capabilities. Apart from promoting sustainable recycling practices, the initiative's aim is also to reuse scrap parts in operational airplanes (Boeing, 2008^[38]).

The other main aircraft manufacturer, Airbus, launched the project “Process for Advanced Management of End-of-Life of Aircraft” (PAMELA) in 2005. The project was implemented by Airbus, EADS, the French recycling company Suez-Sita, and was co-financed by the EU's working group LIFE-Environment programme, France (*l'Instrument Financier pour l'Environnement*). The project demonstrated that an aircraft's components can be safely dismantled and recycled for reuse in the aviation or other sectors.

Prior to PAMELA the industry had no standardized procedures for aircraft dismantling. The project ensured compliance with relevant waste regulations, and encouraged recycling firms to work towards achieving a recycling rate of 85%, which is comparable to the rate of the EU End-of-Life Vehicles Directive 2000/53/EC (which does not apply to aircraft). Furthermore, the success of this project resulted in the establishment of TARMAC Aerosave, the first company dedicated to dismantling end-of-life aircraft in an environmentally friendly way. Airbus and waste specialist SITA France created the company as a joint venture which started operations in 2009.

Airbus established a fully integrated lifecycle approach by sharing the experience and information from the recycling process with its design teams and suppliers, for instance on aircraft ageing and changes in dismantling techniques. The company provides this data to

engineers who work at the beginning of the aircraft lifecycle by helping them to improve the design of existing and future aircrafts. The project started with the establishment of a process for properly dismantling end-of-life aircrafts and became a network of producers and demolition companies which together apply lessons learned from PAMELA (Ribeiro and de Oliveira Gomes (2015_[39]); EC (2011_[40])).

5.2. Vehicle industry

5.2.1. European Union End-of-Life Vehicles Directive

The ELV Directive [2000/53/EC and Amendments M1-M13] comprises provisions for the collection of end-of-life vehicles (ELVs) and states deadlines for material recovery rates, such as a minimum reuse and recovery rates of 85% from January 1, 2006. Producers must thereby carry a proportion of costs for collection and recovery measures. The Directive also requires EU Member States to establish collection systems for ELVs and ensure that all vehicles are transferred to authorised treatment facilities (i.e. vehicle dismantlers must obtain a permit for ELV dismantling). This transfer requires a vehicle deregistration based on a certificate of destruction. Furthermore, the last holder of an ELV may deliver it free of charge to an authorised treatment facility ("free take-back possibility"). Annex I of the Directive defines detailed procedures for storage and treatment of ELVs, such as depollution procedures and designated parts removal requirements. The Directive furthermore obliges vehicle manufacturers to compile specific data and report regularly to designated authorities, and requires Member States to report every three years to the European Commission on the status of their ELV Directive implementation (EC, 2000_[41]).

A study by the European Commission assessed the effectiveness of the ELV Directive and concluded that good progress has been made towards achieving the objectives of the Directive. Those include preventing waste from vehicles (including the reduction of hazardous substances), increasing re-use, recycling and recovery rates, and ensuring that end-of-life vehicles are treated under environmentally sound conditions (EC, 2014_[42]).

5.2.2. Sweden

Sweden implemented its first car scrappage law (a deposit-refund program) in 1975 that has been replaced in 1997 with the Ordinance on Producer Responsibility. The law required manufacturers to accept ELVs free of charge and established a system for their management. The Extended Producer Responsibility (EPR) requirements also apply to a number of other consumer products. Between 1999 and 2002, the Swedish automobile industry and its partners formed the Environmental Car Recycling in Scandinavia (ECRIS) project to develop advanced recycling methods for dismantling and sorting vehicle components (European Parliament, (2006_[43]); US EPA (2016_[44])).¹⁹

5.2.3. Netherlands

The Dutch automobile industry established the organisation "Auto Recycling Netherland (ARN)" which collects all scrap cars and oversees their dismantling and recycling without costs to the last vehicle owner ("free take-back"). ARN furthermore cooperates with certified car scrapping and recycling facilities and compensates them for the unprofitable parts of their operations. The system is fully self-financed through a waste disposal fee payable as part of the vehicle registration. Due to this fee, the car manufacturers and importers as well as the car purchasers pay the full cost of the ELV management. The ARN manages vehicle collection and recycling activities by entering into contracts with car

dismantling companies and was responsible for recycling 91% of all end-of-life vehicles in the Netherlands in 2006 (European Parliament, (2006_[43]); US EPA (2016_[44]))

5.2.4. *United Kingdom*

The government passed regulations in 2003 and 2005, which implement the EU ELV Directive. The 2003 UK regulation includes the use of improved standards for vehicle treatment facilities and the establishment of a system to handle certificates of destruction. The 2005 regulations require vehicle producers to establish networks of demolition facilities where last owners of their brands of vehicles may dispose their ELVs free of charge. Furthermore, a collaborative project (CARE, 2019_[45]) enables UK motor vehicle manufacturers/importers and vehicle demolition facilities to research and test material reuse and recycling processes in order to reduce demolition waste (European Parliament, (2006_[43]); US EPA (2016_[44])).

5.2.5. *Japan*

The ELV Recycling Law is based on a "shared responsibility" principle and entered into force in 2005. The law requires consumers in Japan to pay a recycling fee upon purchasing new cars (and at the first periodic inspection for cars purchased before the law entered into force). The fee is determined by individual car manufactures/importers and depends on the car's features (e.g. simplicity to take of airbags, quantity of shredder dust) (METI, 2016_[46]). The Japan Automobile Recycling Promotion Center (JARC, 2018_[47]) manages the recycling fee and monitors the flow of ELVs in the recycling system to ensure its proper functioning. The Law instructs also the final disposition of CFCs/HFCs, shredder residue, and airbags (METI (2016_[46]); US EPA (2016_[44])). From the industry side, the Japan Automobile Manufacturers Association (JAMA) has established voluntary recycling targets and some car manufacturers published yearly vehicle recycling and/or sustainability reports referencing JAMA's set targets.²⁰

5.2.6. *United States*

In the United States there does not exist any federal law governing EPR. However, practices related to EPR is "product stewardship" which requires all parties involved in a product's life cycle (i.e. producers, manufacturers, retailers, users, and disposers) to share responsibility with the aim to reduce a product's negative environmental impact. Most of these stewardship programs related to vehicles at the national level consist of voluntary measures which address contaminants of concern of state specific recycling goals, including the following aspects:

- i. mercury switches: In 2006 a coalition of federal, State, industry, and environmental non-profit partners established the National Vehicle Mercury Switch Recovery Program (NVMSRP) with the aim to promote the safe removal of mercury switches from ELVs before they are shredded for recycling. Furthermore, steel and auto manufacturers established voluntarily a USD 4 million fund in order to provide incentives for switches to be returned through the NVMSRP. The national non-profit corporation "End of Life Vehicle Solutions (ELVS)" which was established by automobile manufacturers provides educational materials, and collects and recycles automotive switches free of charge (US EPA (2016_[44])).
- ii. vehicle tires: At a national level, US programs dedicated to tire recycling and reuse include procurement guidelines for recycled content products (e.g. retread) and environmentally-preferable purchasing practices (US EPA (2016_[44])).

From the industry side, Chrysler and General Motors formed the automobile industry's Vehicle Recycling Partnership in 1992, which undertakes collaborative research and pilot programs to promote integrated and sustainable vehicle recycling practices in North America and globally. Later on, US manufacturers placed increasingly more importance on life cycle analysis to understand and develop sustainable vehicle design and production while the government rather promotes recycling approaches. In General Motors' corporate responsibility report, the company illustrates how life cycle analysis can support sustainability and ELV goals in vehicle design and manufacturing. Automobile companies also work together and share information on materials in vehicles in order to facilitate reuse and recycling, such as it is the case for the "International Materials Data System" (2017^[48]) established by automobile manufacturers in Europe and Japan (US EPA (2016^[44])).

6. Conclusion and further remarks

This report provides an initial overview of the ship recycling industry and a forecast of ship demolitions as well as an assessment of the impact of the Ballast Water Management Convention (BWMC) on demolition volumes and retrofitting activities. The report also presents phase-out policies in two industries which are comparable in terms of recycling approach (i.e. sales of large parts and blocks) and earnings model (i.e. importance of component based earnings), notably the aircraft and vehicle industries.

The results of our predictions show a demolition volume of around 18 million GT or 1.4% of the fleet in GT (as of September 2017) between September 2017 and August 2018 (12 months). Back casting of demolition rates with the same approach shows similar results for the estimated and actual scrap ratios, lending some support to the validity of the applied estimation method. In addition, our results suggest that the BWMC will have a significant effect on future demolition volume although more than two thirds of vessels that fall under the BWMC are likely to be retrofitted. The additional demolition volume due to BWMC is significant and is expected to range between 13 million GT and 51 million GT (11 million and 54 million CGT). These results correspond to additional demolition volumes as share of the world fleet in 2017 of 0.5 to 3.4%. In other words, the policy might trigger additional demolitions over the next seven years of one-third to two times the size of usual annual demolitions related to the renewal of the fleet. The three main ship types bulkers, tankers and containers account for one third of these demolitions.

The results do not take into account whether there is likely to be sufficient docking and yard capacity for retrofitting, and bottlenecks for installation demand remain a reasonable concern. Going a step forward, a more integrated supply chain from construction and retrofitting/repair to recycling could counterbalance capacity differences of the respective facilities used for different purposes (i.e. ship production, repair/retrofit and recycling). Indeed, there may be different requirements in terms of equipment and machinery for newbuild, retrofit/repair and recycling work. However, there exist also many synergies across the different activities, which may encourage more environmentally sound ship recycling, namely yard's infrastructure such as dry docks and heavy lifting cranes used for the dismantling of vessels in a clean and safe way.

There are already efforts in the industry that show a move into this direction, such as at Zhoushan Changhong International Industrial Park. This multifunctional industrial park combines shipbuilding and repairing, ship recycling and steel structure fabrication with metal resource recycling. As a bottom line, a closer collaboration across the supply chain would benefit all participants from production, retrofit/repair, shipping and recycling. For instance, the Turkish maritime industry is strong in shipbuilding and recycling, and as mentioned in the OECD report on Turkey's shipbuilding industry (2011_[49]), recycling facilities could become more competitive by collaborating with local shipyards which produce more environmentally friendly ships (i.e. avoiding hazardous materials in ships), follow a designed entire-life cycle approach and use materials facilitating dismantling. A more integrated supply chain could reduce the overall impact on the environment and on natural resources (OECD, 2011_[49]).

Several examples from the aircraft and vehicle recycling industries show the efforts made throughout the value chain where both producers and consumers share responsibility in order to find appropriate recycling solutions, which reduce the burden on the environment

and on human health. Despite the distinct features of the ship recycling industry compared to the aircraft and vehicle industries, these examples could provide useful ideas for improving the standards and processes in ship recycling activities and ensure a better integration throughout the value chain. Furthermore, it could help identify how to internalize the negative externalities generated by ship recycling to achieve appropriate solutions for end-of-life vessels. As the estimation results show, international regulations can have a significant effect on demolition volumes. Based on the analysed Ballast Water Management Convention, the results suggest a significant increase in demolition requirements in the future and highlight the need to discuss adequate solutions with supply chain participants as well as the international community in order to reduce the negative impact of today's ship recycling activity on human health and the environment.

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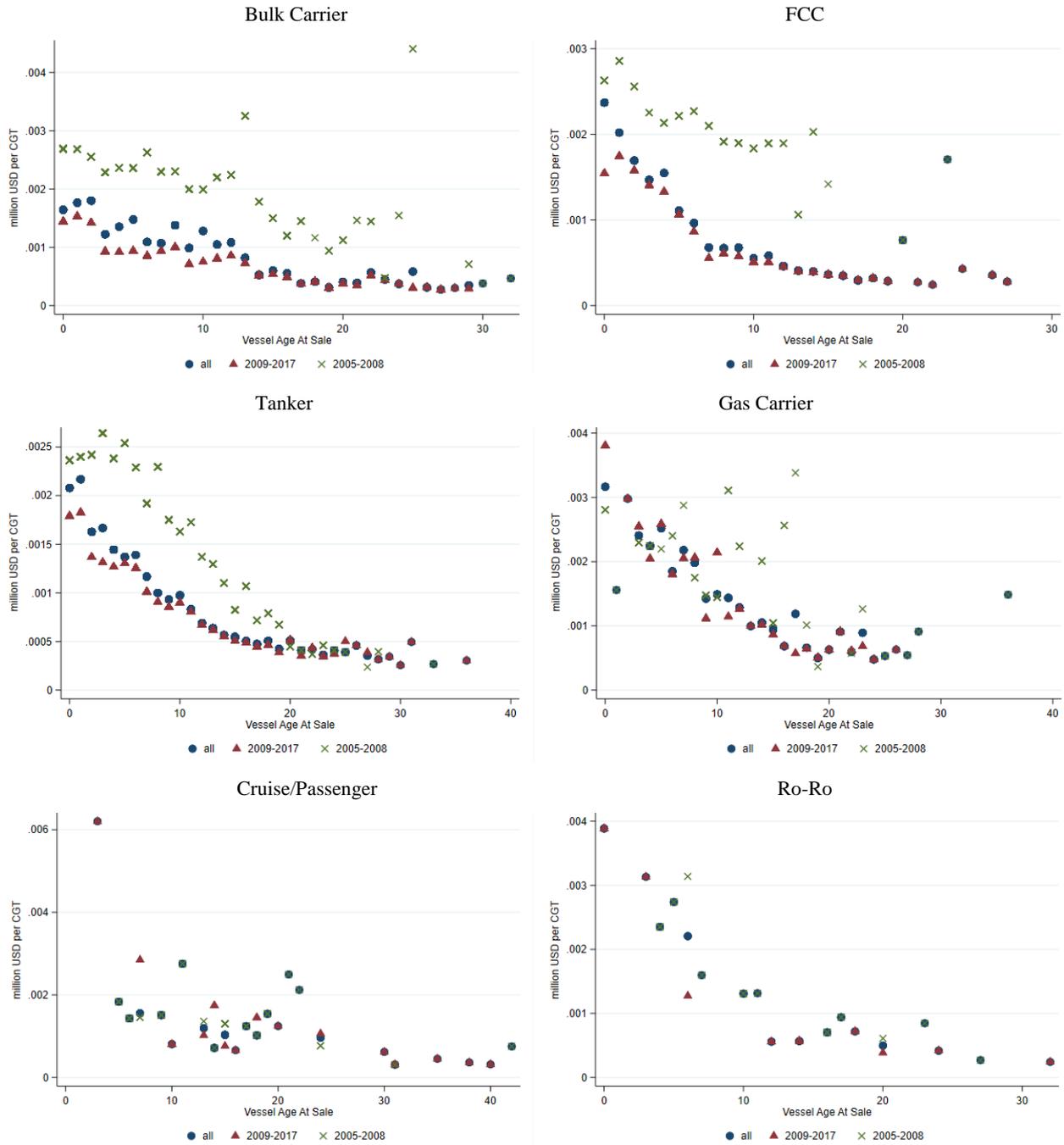
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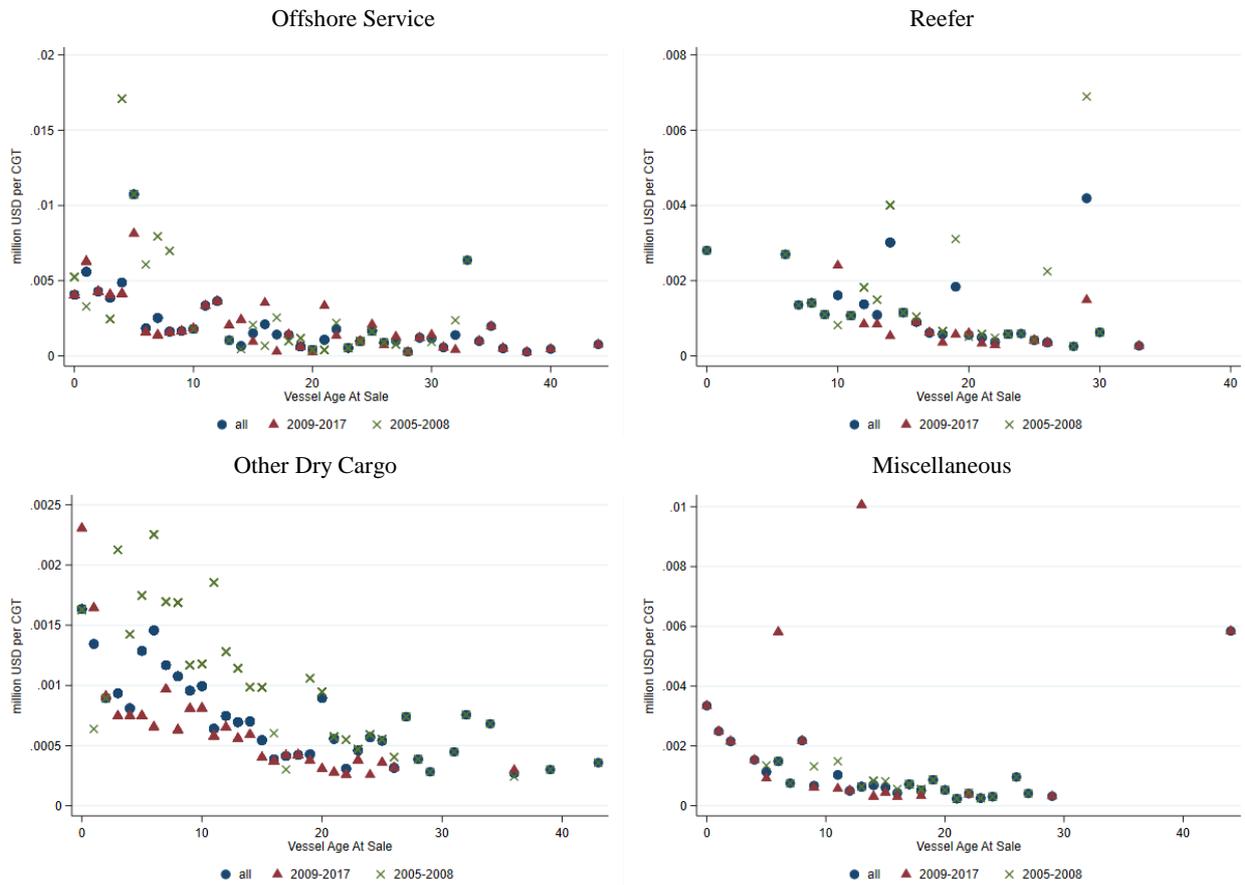
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Annex A. Value estimates

Figure A A.1. Value estimates by ship group and age

Median of million USD per CGT





Source: based on Clarkson's World Fleet Register (2017).

Annex B. Estimation results

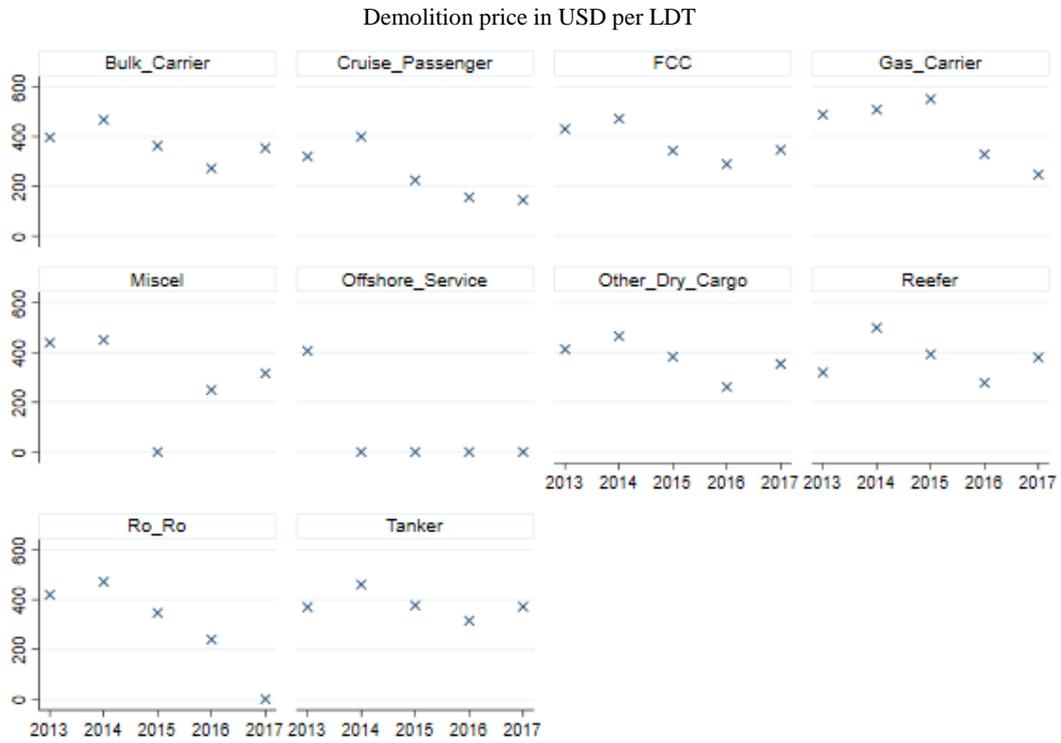
Table A B.1. Regression output of generalized linear method (GLM)

Variables	USD million per CGT
Cruise_Passenger	0.713*** [0.0477]
FCC	-0.276*** [0.00354]
Gas_Carrier	0.526*** [0.0169]
Miscel	0.00337* [0.00189]
Offshore_Service	0.895*** [0.0426]
Other_Dry_Cargo	-0.153*** [0.0134]
Reefer	0.318*** [0.0461]
Ro_Ro	0.305*** [0.0227]
Tanker	0.0516*** [0.000604]
age	-0.0623*** [0.00395]
Constant	-6.465*** [0.0375]
Observations	4287

Note: Robust standard errors in brackets *** p<0.01, ** p<0.05, * p<0.10 Reference category: bulk carriers. In order to derive predictions of ship values, we run a GLM log-linear regression of second hand market prices for ships expressed in (log of) million USD per CGT on the ship age and include a ship type dummy to account for idiosyncrasies in value functions between ship types. This results in the formula: $\ln(2HMP)=\alpha+\beta[\text{age}]+\gamma[\text{ship type}]+\varepsilon$, with 2HMP as 2nd hand market ship price in USD per CGT and ε as clustered error term. As specification of the GLM we use a log-link and a gamma distribution to account for the geometric decrease of ship values and their skewed distribution. Finally, as errors might be correlated within ship types, we cluster the error term on the level of ship groups. Using the coefficients resulting from this estimation with second hand market prices we then predict the ship values of the entire fleet dataset. *Source:* based on Clarkson's World Fleet Register (2017).

Annex C. Scrap value estimates

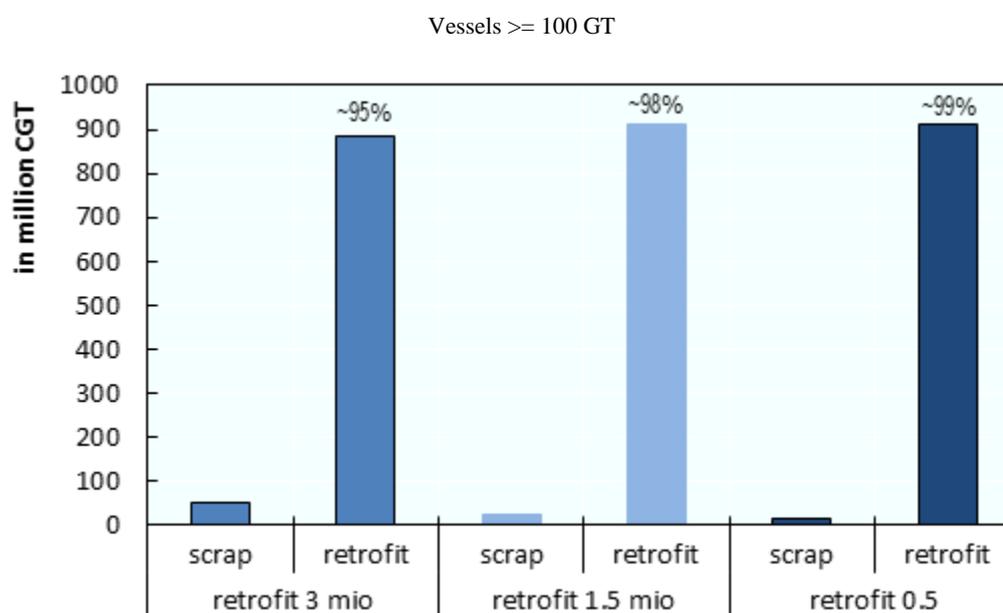
Figure A C.1. Weighted average scrap values by ship group and demolition year



Source: based on Clarkson's World Fleet Register (2017).

Annex D. Demand for vessel retrofit

Figure A D.1. Retrofitting demand: no of vessels and in million GT



Note: The shares hardly change when considering vessels equal or above 500 GT only.

Source: based on Clarkson's World Fleet Register (2017).

Endnotes

¹ A back-casting exercise to validate the results shows that the estimate of 1.4% (measured in GT) is in line with observed scrap rates. Between September 2017 and August 2018 (12 months), demolitions as share of the fleet (as of September 2017) make up around 1.6% (measured in GT) but they are lower when measured in CGT (estimate of 2.8% versus actual share of 1.3%), according to Clarkson World Fleet Statistics.

² Demaria (2010_[18]) discusses three methods of disposal: *Decontamination prior to export* that must be done by ship owners but is very costly and requires expertise, *Environmental sound management on-site* with proper waste management which is the method recommended by the IMO Hong Kong Convention and *Dumping* where the materials are freely released into the environment.

³ Turkey's ship recycling industry demolishes primarily vessels from European Union members, and especially smaller vessels that may not be economic to sail to recycling yards in South Asia (OECD, 2011_[49]).

⁴ The formula for the EEDI is the ratio of estimated CO₂ emissions divided by the product of the ship's deadweight and speed that is measured under trial conditions with 75% of installed power.

⁵ For more information see the study by Knapp, Kumar and Remjin (2008_[12]) on the results by demolition location, indicating that Bangladesh is more sensitive to changes in earnings and more likely to demolish larger and older vessels compared to other locations.

⁶ Some of these intermediaries are vertically integrated by combining cash buying and ship recycling activities, such as Priya Blue Industries owning cash buyer "Best Oasis" and ship recycling facility "Priya Holding" in India (Priya Blue, 2017_[50]).

⁷ A Panamax oil tanker of 14 800 LDT (80 000 DWT).

⁸ With regard to this example, it is important to note that it dates back to 2010 and numbers might have changed in the meantime.

⁹ This might also explain the huge gap between the tonnage of scrap ships imported and the actual crude steel production in Bangladesh according to World Steel Statistical Yearbook (World Steel Association, 2017_[25]) and UN Comtrade Data.

¹⁰ See Annex B for more information on the regression and estimation results.

¹¹ Due to the low number of observations of second-hand market prices per year, we pooled the data during the post-crisis years, i.e. 2009 to 2017. Graphs in the appendix show for certain ship groups that the resale prices in USD per CGT differed significantly between pre- and post-crisis levels.

¹² The major portion (60% to 80%) of the weight of a ship is steel (Schneekluth and Bertram, 1998_[53]). Please note that vessel's age seems to play a small role to determine the scrap value of a vessel since a buyer of a scrap vessel aims to maximize its revenues and refers therefore to current scrap steel prices (and equipment prices).

¹³ According to Clarkson World Fleet Register, the merchant fleet in 2017 amounts to around 94 500 vessels with a total of around 1 300 million GT (about 831 million CGT). However, we use only those vessels of the merchant fleet which are in service (- 5 000 vessels), and as not all of those vessels have GT (CGT) reported, we also exclude those vessels (- around 1 500 vessels). Furthermore, a closer analysis reveals that around 4 600 vessels are older than 50 years (up to 140 years) and are not in continuous service. In addition, we exclude around 1 000 observations for which we could not derive any ship value. We therefore exclude those vessels from the data. We

end up with a fleet of approximately 82 000 vessels which represents a clean sample of the merchant fleet. For the analysis on larger vessels we restrict the fleet to vessel size to minimum 500 GT.

¹⁴ The MEPC defines several exceptions for certain ships, among others, as follows: "[...] exception to the ballast water management requirements in the case of the discharge of ballast water and sediments from a ship at the same location where the whole of the ballast and those sediments originated and provided that no mixing with unmanaged ballast water and sediments from other areas has occurred (regulation A-3.5),[...]" As we cannot select from the level of data aggregation in the World Fleet Register whether or not domestically trading ships mix up several locations with differences in water content, sediments etc. we generalize domestically trading ships as being excepted from the Convention, in line with Clarkson (2017).

¹⁵ Note: around 230 vessels are domestically trading but have a BWMS installed.

¹⁶ See Annex D.

¹⁷ The Basel community let the IMO design their own rules.

¹⁸ The NGO Shipbreaking Platform is a non-governmental organisation which is financed to 58% by European Commission's LIFE Programme (Annual Report 2016 of NGO Shipbreaking Platform).

¹⁹ In this ECRIS project, non-recyclable items will be used as an energy source, e.g. in Gotenburg they are used in a heating plant (EC, 2002_[51]).

²⁰ See for instance Toyota's yearly reports (Toyota, 2017_[52]).