The Ship Recycling Conundrum:

An Econometric Analysis of Market Dynamics and Industry Trends

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Abstract

Ship recycling has received considerable attention during the last two decades for a variety of reasons and the industry is currently under a thorough scrutiny with the likelihood of the adoption of a new multilateral convention under the auspices of the International Maritime Organization (IMO). This study applies econometric modeling to a unique dataset to provide a holistic insight into the dynamics of the ship recycling market. The dataset contains information on 51,112 ships over 100 gt and includes 748,621 events over a period of 29 years. The binary logistic regression models confirm a negative relationship of earnings and a positive relationship of scrap prices for all locations while Bangladesh seems to be more prone to changes in the shipping market than the other locations. Flag and ownership patterns vary across scrapping locations with Malta an Cyprus indicating potential importance from a registry perspective versus other major flags which do not reveal any significant importance. The overall safety profile of a vessel seems to be less important towards the probability of a ship being scrapped. Possible implementation of the convention under EU jurisdiction is mostly likely affect Turkey while non ratification of one of the major flags not under EU jurisdiction will most likely affect China.

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The following disclaimer is added to this paper: "The report and related findings discussed in this paper do not reflect the view of the United States Maritime Administration and the European Maritime Safety Agency".

1. INTRODUCTION

The recycling of ships has received considerable attention during the last two decades for a variety of reasons. For one, it is an eminent application of Akamatsu's *flying geese* paradigm (1962), a Japanese economic model that is built around the symbolism of geese flying in unison. The metaphor is often used to explain the industrial growth of East Asian countries with Japan being in the lead, and could very well be applied in the case of ship scrapping by observing how the foci has shifted in the post-WWII era from Japan to South Korea to China to primarily South Asian countries today based on shifting comparative advantages. More importantly, in recent years, it has gained the attention of environmental advocates and human rights activists as well as a host of regulators and policy makers, engrossed in "greening" maritime operations and ending unsafe labor practices. In addition to the unilateral and regional (i.e. EU) initiatives of various nations geared toward responsible ship recycling, there are ongoing multilateral discussions at the International Maritime Organization that focus on a cradle to grave regulatory approach in the life-cycle of a ship.

The Marine Environment Protection Committee (MEPC) of IMO was requested by the General Assembly to develop a new legally-binding instrument on ship recycling (Assemby Resolution A.981(24), providing regulations for:

- The design, construction, operation and preparation of ships so as to facilitate safe and environmentally sound recycling, without compromising the safety and operational efficiency of ships;
- The operation of ship recycling facilities in a safe and environmentally sound manner; and
- The establishment of an appropriate enforcement mechanism for ship recycling, incorporating certification and reporting requirements.

The key objective of the Convention is to effectively address the environmental, occupational health and safety risks related to ship recycling, taking into account the particular characteristics of world maritime transport an the need to secure the smooth withdrawal of ships that have reached the end of their operating lives.

The proposed International Convention on the safe and environmentally sound recycling of ships ("the Convention") is planned for adoption by the year 2009. This will slightly predate the anticipated peak in ship scrapping expected to happen in 2010 because of the mandated accelerated phase-out of single hull tankers. However, the convention is not expected to come into force before 2012 at the earliest, and therefore interim measures may have to be considered by parties involved to address the expected peak in ship recycling.

At the regional level, the European Commission has recently launched a Green Paper on ship dismantling (COM(2007) 269 final, 22 May 2007) in order to prepare the ground for future action in the context of EU policies and to address the interim period, i.e. until the future Convention will come into force. The aim of the Green Paper is the protection of the environment and human health rather than proposing the reinforcement of ship recycling volumes in the EU, which would carry the risk of depriving countries in South Asia of a major source of revenue.

The above scenario raises a number of questions that merit serious economic analyses. It is expected that some major ship recycling nations and flag states will not immediately sign and ratify the convention, which may lead to the development of two different ship recycling markets operating in parallel. Whereas one market will cover the convention ships that are recycled in facilities that comply with the convention's standards of safe and environmentally sound recycling, a separate market for recycling non-Party ships in facilities operating in States which are not a Party to the convention. Prevailing market dynamics and corporate social responsibility trends will determine how these two markets will develop and co-exist. It is worth to mention in this context that the US has submitted a proposal to MEPC to introduce a provision in the convention allowing compliant recycling facilities located in non Party States to have access to the Convention market, i.e. to recycle vessels flying the flags of Parties to the convention. This proposal is still being negotiated at IMO.

Veldeler (2006) touches upon the topic of value chain responsibility of shipping companies in the context of industry conditions and the necessary changes needed to transform ship recycling into a vital service participant rather than maintenance of the proverbial *bottom of the heap* status quo. A report by ECORYS Transport (2005) raises the possibility of establishing a ship recycling fund. Mikelis (2007) presents a timely and highly informative statistical overview of ship recycling and emphasizes some of the key economic relationships in the ship recycling market such as a possible correlation between freight rates and ship recycling prices and the impact of other aspects such as local labour costs and the demand for scrap steel. The European Commission (DG ENV) study on ship dismantling and pre-cleaning of ships (COWI / DHI, June 2007) addressed the status and projections for European end of life ships until 2020. In general, other than the above contribution, there is a dearth of empirical studies in this field.

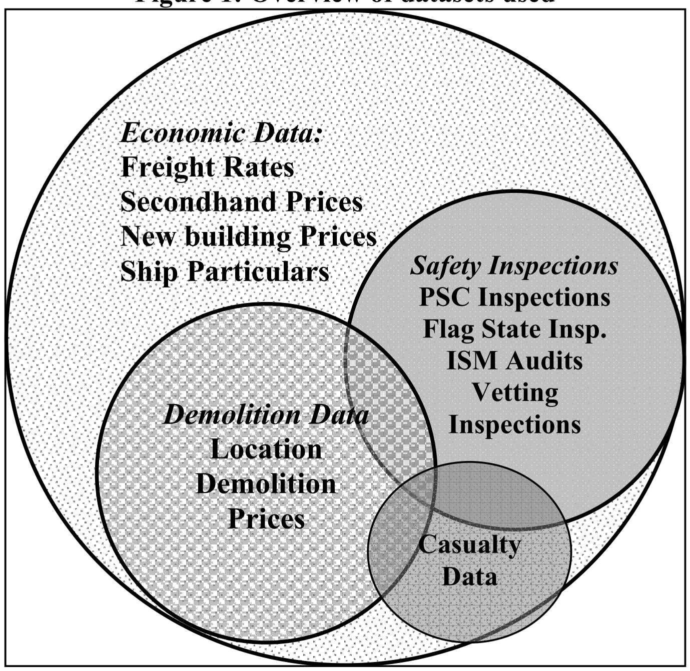
The objective of this study is to apply econometric modeling to test some of the relationships hypothesized by Mikelis (2007) and elevate scholarly treatment of ship recycling to the next level. It uses the probability of a ship being scrapped to provide better insight into the dynamics of the ship scrapping market. The study is based on a unique dataset that combines information from multiple data sources. The data gathered compiles information about changes in ship particulars such as ownership, registry, and classification society, and integrates them with the results of safety inspections, changes in shipping market conditions and also information on ship scrapping. It is believed that the uniqueness of this data will allow a more accurate measurement of the dynamics of ship recycling.

The outcome of this study may benefit the ongoing multilateral discussions at IMO. It will help clarify the proposed convention's impact on the ship recycling market and its effectiveness in improving standards for ship recycling worldwide. Section 2 describes the construction of the dataset used in this article and Section 3, an analysis of the current trends in shipping markets including a discussion of ship demolition markets in the overall context. The section discusses some descriptive statistics helpful in understanding the study and also defines the variables used in the econometric analysis. Section 4 provides mechanics of the econometric analysis and interpretation of results. The concluding section, Section 5, summarizes main findings of the study and its potential contributions to any dialog on ship recycling in future years.

2. EXPLANATION OF DATASET AND VARIABLES USED

It is ideal if an empirical study on recycling of ships has a holistic perspective and considers variables that may sometimes be overlooked in an analysis of this nature. Accordingly, variables typically used in analyzing the ship scrapping market are combined with data from safety inspections and also data from casualty statistics. This provides a robust and thoroughly comprehensive picture of ships and their relevance for the recycling market. The combination of the used datasets is presented in Figure 1 and is based on an extension of a dataset by Knapp (2006).

Figure 1: Overview of datasets used



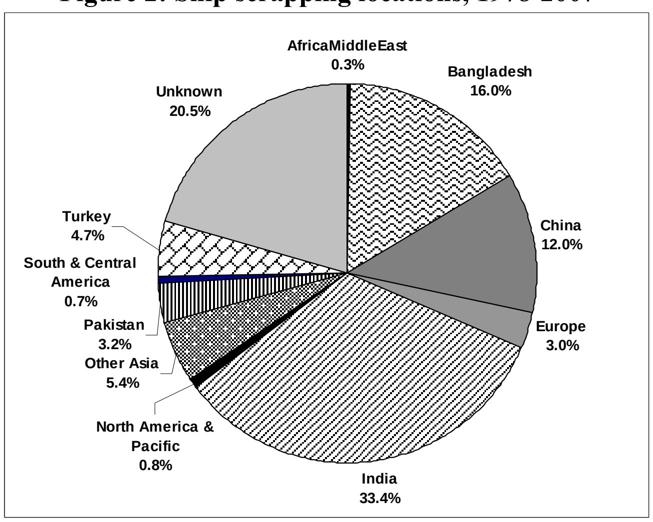
The dataset contains information on 51,112 ships over 100 gt and includes 748,621 events over a 29 year period (1978-2007). It was determined that 4,090 of the ships in the database have been scrapped. The data sources that provide information on changes in ship particulars such as ownership and flag came from Lloyd's Register Fairplay and Rightship. These were then matched with data from Lloyd's Maritime Intelligence Unit and Clarkson's Shipping Intelligence Network. Six port state control regimes (Paris Memorandum of Understanding (MoU), Caribbean MoU, Indian Ocean MoU, Viña del Mar Agreement on Port State Control, United States Coast Guard and the Australian Maritime Safety Authority (AMSA)) provided data on ship safety inspections. CDI, SIRE, Rigthship, and Greenaward Foundation provided data on ship inspections.

The observations describe events of interest that intuitively affect the dynamics of the scrapping market such as general changes in ship particulars (ownership and flag) along with information on class withdrawals and overdue surveys. According to a submission made by the United Kingdom to MEPC 56 in May 2007 (MEPC 56/3/22, Annex 1) which gives a timeline for the process of recycling a ship, the decision to recycle is made by the owner who then involves a broker or cash buyer who assists in the process of selecting the recycling location. Annex 2 of the same document further indicates that 90% of the contracts foresee *"delivery at the recycling yard"*, whereas 10% is delivered *"as is/where* *is"*. Once the decision is made, the flag state administration will get involved in the process. Given this scenario, we believe that for the development of the convention, ownership and flag are important variables to consider.

These general variables are combined with inspection-related variables such as port state control inspections, flag state inspections, detentions, total number of deficiencies found during an inspection, ISM audits and vetting inspections. In addition, casualty data classified *very serious, serious and less serious* (as per the MSC Circular 953 of 14th December 2000) were also added to the database along with economic variables in the in the shipping market such as freight rates, new building prices, secondhand prices, and scrap prices. Such combination of multiple data elements helps build a general risk profile which when combined with economic variables that may influence the decision to scrap results in a superior model.

It is difficult to obtain accurate data on the scrapping location of ships. In order to create the best possible combination of data for this analysis, information from Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit, and Clarkson's were combined. Despite this, the demolition location is unknown for one out of every five ships scrapped (see Figure 2). India dominated the market during the period, scrapping one out of every three ships followed by Bangladesh with 16% and China, 12%.

Figure 2: Ship scrapping locations, 1978-2007



The next section provides an overview of the shipping markets that have an indelible impact on ship recycling. This is followed by a more substantive discussion on ship scrapping market that will help interpret the econometric models explained in Section 4.

3. OVERVIEW OF THE SHIPPING MARKETS

In general, the shipping markets have been particularly robust during the past few years compared to the lackluster 1980s and 1990s. They reached a crescendo in 2004 with high returns of investment in every related sector. All three major shipping freight markets, viz., liners, tankers, and dry bulk hitting the market highs concurrently, guided by the invisible hand, is an extra-ordinary phenomenon. The conditions were so favorable in

2004-05 that R.S. Platou, the Scandinavian shipbroker, referred to them as *not since the days of the Vikings* (The Platou Report 2005). It even seemed that anyone who had a ship could do no wrong in such lucrative market conditions. The impetus for this drastic change in shipping fortunes can be traced to the 1990's liberalization of global trade and China's entry into the World Trade Organization both of which led to a flurry of trade activities. One could easily argue that innovations in the shipping industry have greatly lowered the landed cost of goods in target markets thereby directly facilitating increased globalization. The interdependency between global commerce and the merchant marine sector (Kumar and Hoffman, 2002) has never been so transparent as today.

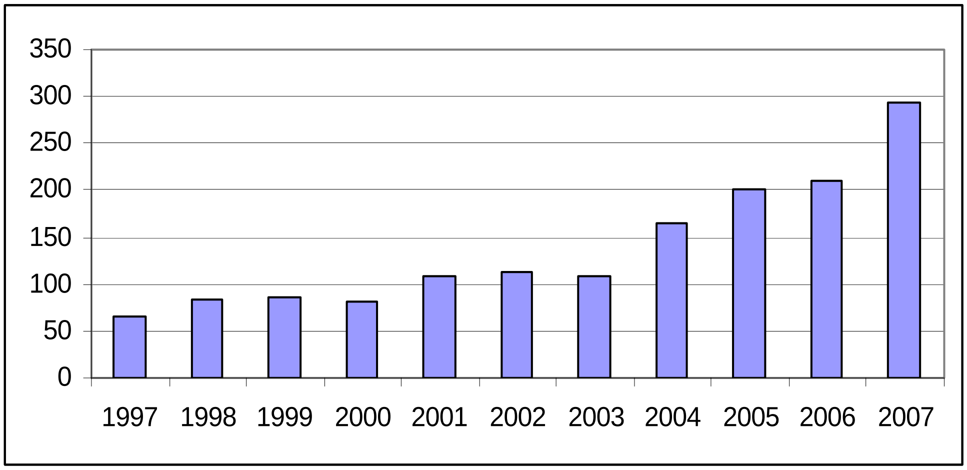
Another major aspect of the current shipping boom is the emergence of Asian countries as key drivers of modern shipping. The balance of power in the maritime sector has swung undeniably toward the fast growing Asian economies. The continent is now home to the bulk of human resources involved in port and shipping activities besides being home to a majority of the busiest ports and some of the largest shipping companies. The continued Chinese economic growth and their huge trade surplus with the United States in particular have contributed to the ongoing boom and optimism in shipping. This is a completely new experience for ship owners and maritime observers of the current genre most of who had grown accustomed to the industry's relatively mediocre levels of profitability prior to the turn of the century.

Many observers and analysts predicted that the buoyant market conditions would not last for long and that cyclical conditions would return (Kumar 2006). While the cyclical nature of shipping markets was never in question, what was uncertain was how precipitous the market decline would be after the recent historic highs. Although the market conditions have now receded, in particular in the tanker market and the liner market, the dry bulk market continues to be extra-ordinarily robust, crossing the charter-hire milestone of $200,000 per day in October 2007. With ship utilization rates reaching unprecedented levels, shipowners were left searching for new tonnage to accommodate the rising demand for bulk carriers, tankers and large container ships. Thus the prolonged overall boom in shipping has had a profound impact on the shipbuilding sector as well as the market for second had ships and are discussed next.

Figure 3 shows the orderbook in million dwt during the past decade. A noticeable increase in the order book is visible from 2003 onwards. In 2006 alone, the total demand for newbuildings exceeded available capacity by 20%. All major shipyards have been fully booked for the next three years from 2004 onwards. Accordingly, they responded to market conditions by reactivating idle capacity and building new yards as well as through outsourcing part of the construction to lower cost building locations. Non-traditional new shipbuilding nations have emerged on the scene such as China, ascending directly to the upper echelon and India, Vietnam and others making a relatively modest but noticeable market presence.

Despite these strategic initiatives, the new-building costs have escalated, going up by 17% in 2006 alone (The Platou Report 2007, 8). The increase in steel price and the decline of the U.S. dollar have also contributed toward the escalation in shipbuilding prices. These developments have directly impacted shipowners' vessel acquisition plans and accordingly the resale price of good quality used ships, the next logical option.

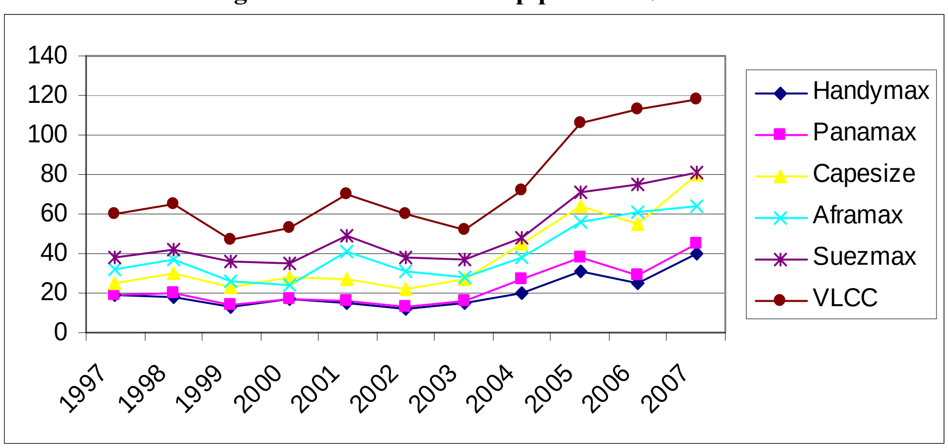
Figure 3: Newbuilding orders, 1997-2007 (in million dwt)



Source: The Platou Report 2007

During the past decade, the cost of acquiring good second ships has multiplied by a factor of 2 to 3 as shown in Figure 4. Understandably, shipowners have cut back their ship scrapping plans drastically and opted to prolong the commercial use of older tonnage. Tanker tonnage sold for scrap in 2006 was only 18% of the tonnage scrapped in 2002 and dry bulk tonnage, 38% (R.S. Platou 2007). A discussion of the market for scrapping ships follows next.

Figure 4: Second hand ship prices in $million

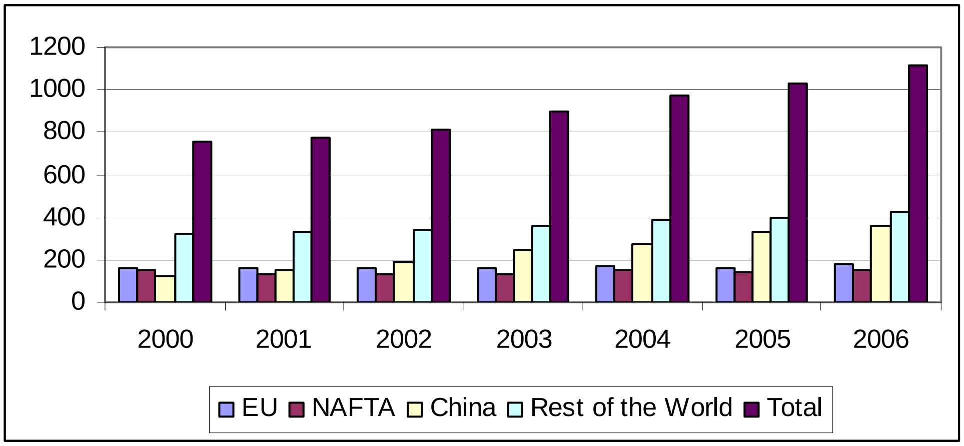


Source: The Platou Report 2007

3.1 The Ship Scrapping Market

Many factors drive the market for scrapping ships, also referred to as ship demolition market. The supply of ships for demolition is mostly a function of the freight market conditions, the type and age of the ship, and current and anticipated regulations. The market demand is a direct function of the price of steel and the costs associated with the scrapping activity itself. Figure 5 shows the apparent world demand for steel from 2000 to 2006. The annual worldwide consumption of steel has increased by 47% during this period with China emerging as the most dominant consumer. As an example of the magnitude of China's importance in this market, in 2000, the EU block and the NAFTA block of nations were the two largest consumers of steel followed by China. By 2006, the annual use of steel in China had tripled from its 2000 level and surpassed the total steel used in both EU and NAFTA nations collectively. The price of steel, buoyed primarily by the Chinese demand, has remained understandably very high in the new millennium and correspondingly, the price for scrap iron recycled from demolished ships.

Figure 5: Apparent world steel use, 2000-06 (in million metric tons)



Source: International Iron and Steel Institute Statistics, 2007

Table 1 provides an overview of the mean age, gross tonnage and scrapping price per lightship ton (LTD) of demolished ships per scrapping location of the dataset used for the econometric analysis. GRT is used in the table instead of LTD as this information was not known for all observations. Based on the descriptive statistics gathered, the average age of ships scrapped in Bangladesh is the highest followed by those scrapped in India and Turkey. Figure 6 shows the fluctuation in scrap prices in major ship demolition markets. As shown in the figure, the prices have escalated considerably in particular after 2003, showing a perfect correspondence with the freight market boom discussed earlier.

Table 1: Mean age, tonnage and scrap price per scrapping location (1978-2007)

Scrapping Location	Age	GRT	Scrap Price/LTD
Africa and Middle East	14.1	7312	240
Bangladesh	26.7	31094	299
China	25.0	29372	196
Europe	20.7	5160	223
India	25.9	16524	221
North America & Pacific	25.5	8615	214
Other Asia	15.9	7927	166
Pakistan	24.9	26501	214
South & Central America	21.9	11042	222
Turkey	25.9	7034	195
Unknown	15.3	11320	213
Average	**22.0**	**14718**	**218**

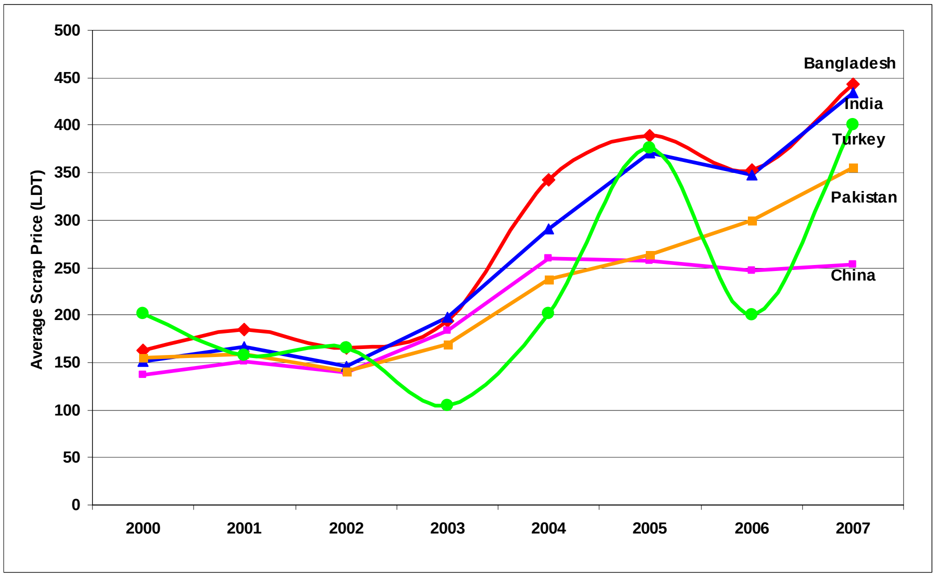
Note: The year 2007 end in October

4. ECONOMETRIC ANALYSIS

4.1. Explanation of Regression Models

The models are based on standard econometric techniques and produce the estimated probability of a ship being scrapped (*P*) based on binary logistic regression where a separate model is used for each major scrapping location (India, Bangladesh, China, Turkey, and Pakistan).

Figure 6: Average scrap price per LTD (2000 – 2007)



Note: The year 2007 end in October

The probabilities are produced on individual ship levels (i). Detailed descriptions on the construction of such models can be found in Franses and Paap (2001, Chapter 4) and is therefore not explained in detail here. The dependent variable (y) in this case is binary and can be either "scrapped" (1) or "not scrapped" (0). The model is presented in Equation 1 where the term $x_i\beta$ changes according to the model in question and is given in Equation 2. The variables are listed in Table 2 including the type of variable and following the abbreviations given in Equation 2 for further reference.

Equation 1: Probability of scrapping

$$P_{\mathrm{i}} = \frac{e^{(x_i\beta)}}{1 + e^{(x_i\beta)}}$$

The variables are based on an aggregated dataset per IMO number where the events represent averages over the ship's life history. We believe this is a better approach compared to only taking variables at the time of scrapping into account since the data at time of scrapping is not very accurate and complete information on flag and ownership at the time of scrapping could not be obtained from the data providers. By using variables which reflect inspection history as well as the history of standard ship particulars over its lifetime, we further believe that the variables, in particular flag and ownership can be interpreted to reflect the potential importance towards the probability of scrapping. The produced probability for any individual ship (i) and the rest of the notation is defined as follows:

ℓ represents the variable groups
n_ℓ is the total number of variables within each group of ℓ and
k is an index from 1 to n_ℓ.

Equation 2: Definition of term $x_i\beta$

$$x_i\beta = \beta_0 + \sum_{k=1}^{n_1-1}\beta_{1,k}\,ST_{k,i} + \beta_2\,DH_i + \beta_3\ln(AGE_i) + \beta_4\ln(SIZE_i) + \sum_{k=1}^{n_5-1}\beta_{5,k}\,CL1_{k,i}$$
$$+\beta_6\,CLChgd_i + \beta_7\,CLSurv_i + \beta_8\,CLWdr_i + \sum_{k=1}^{n_9-1}\beta_{9,k}OWN_{k,i} + \beta_{10}\,OWChgd_i$$
$$+\beta_{11}\,PSC_i + \beta_{12}\,Detained_i + \beta_{13}\,TotalDef_i + \beta_{14}\,SIRE_i + \beta_{15}\,RS_i + \beta_{16}\,CDI_i$$
$$+\beta_{17}\,ISM_i + \beta_{18}\,FLInsp_i + \beta_{19}\,FLChgd_i +_i \sum_{k=1}^{n_{20}-1}\beta_{20,k}\,FL_{k,i} + \beta_{21}\,CASVS_i$$
$$+\beta_{22}\,CASS_i + \beta_{23}\,CASLS_i + \beta_{24}\ln(EARN_i) + \beta_{25}\ln(SCRP_i)$$

Table 2: List of variables used

			Variable Type Total Number of Variables	Total n_ℓ
Variable	**ℓ**	**Demolition (India, Bangladesh, China, Turkey, Pakistan)**	**0/1**	**1**
ST	1	Ship Type	D(a)	6
DH	2	Double Hull	D	1
Ln(AGE)	3	Vessel Age at the time of demolition	C	1
Ln(SIZE)	4	Vessel Size in gross tonnage	C	1
CL1	5	Classification Societies Group	D(a)	3
CLChgd	6	Total changes of classification societies over time	D(s)	1
CLSurv	7	Total times classification survey was overdue	D(s)	1
CLWdr	8	Total number of classification society withdrawals	D(s)	1
OWN	9	Ship Owner Country Groups	D(a)	5
OWChgd	10	Indicates if ownership was changed over time	D(s)	1
PSC	11	Indicated total # of inspections by PSC	C(s)	1
Detained	12	Indicated total # of detentions by PSC of flag states	C(s)	1
TotalDef	13	Average number of deficiencies per inspection over time	C(a)	1
SIRE	14	Total # of inspections by SIRE (oil tankers)	C(s)	1
RS	15	Total # of inspections by Rightship (mainly dry bulk)	C(s)	1
CDI	16	Total # of inspections by CDI (oil and chemical tankers)	C(s)	1
ISM	17	Total # of ISM audits over time	C(s)	1
FSInsp	18	Total # of flag state inspections	C(s)	1
FSChgd	19	Indicator if flag changed over time	D(s)	1
FL	20	Individual Flags	D(a)	83
CASVS	21	Total number of very serious casualties	C(s)	1
CASS	22	Total number of serious casualties	C(s)	1
CASLS	23	Total number of less serious casualties	C(s)	1
LN(EARN)	24	Average earnings per day (based on Clarksons)	C	1
LN(SCRP)	25	Scrap Price on individual ship level or otherwise from Clarksons	C	1
		Total variables		**119**

C = continuous, D = dummy of categorical variables, s=sum, a=average

The economic variables were deflated using average inflation percentages for the USD for the time period 1978 to 2006 before aggregation per IMO. Second hand prices showed a relative high correlation with earnings (55%) and newbuilding prices with scrap prices (42%) and had to be excluded from the end models. which leaves scrap prices and earnings in the equation. The variables reflect ship particulars and their changes over time along with inspection variables for port state control inspections, vetting inspections, ISM audits and flag state inspections. The latter variables are expected to show a negative effect towards the probability of a ship being scrapped while the expected sign for the changes in ship particulars such as ownership (beneficial ownership as per Lloyd's Register Fairplay), class or flag is not defined. As explained earlier and since flag and ownership represent their history over a particular lifetime of a vessel, these variables are to be interpreted in showing their potential importance towards the probability of scrapping if the convention comes into force.

In order to keep the *ownership* component in the models manageable, owners were grouped together using the UNCTAD classification system as shown below:

- *Owners from Developing Countries (DEVC)*
- *Owners from Ex-Soviet Union and Non OECD Eastern Europe (EEUR)*
- *Owners from least developed countries (LSDC)*
- *Owners from industrialized countries (OECD)*
- *Unknown owners (Unknown)*

The most important variables are expected to be the age of the ship, the variables depicting ownership and other ship particulars which when combined with the shipping market data are expected to determine the dynamics of the recycling market. The owner makes the decision to scrap a ship taking into account the overall risk profile of the ship, current and anticipated earnings, and scrap prices all of which are directly related to the cash flow situation. The interaction between these variables is therefore important and must be included in the analysis.

The study uses quasi-maximum likelihood (QML) estimation based on Greene (2000, page 823) in order to give some allowance for a possible misspecification of the assumed underlying distribution function. The models were estimated for logit and probit specification and the key statistics can be found in Appendix 1 for further reference. The models give acceptable results for the number of observations in the models for logit and probit estimation. Although probit results give slightly better results, we use the logit model for the visualization of the results since the application of that model is more practical than that of the probit model.

4.2. Summary of Results

This section provides a summary of the variables of interest across the main demolition countries. It will also visualize the results by taking some relevant parts of the convention into account so as to see the likely effects of its possible implementation. In this case, we use the knowledge gained from the models based on historical data and present scenarios relevant to the ratification of the convention.

A summary of the partial effects of the coefficients of interest are presented in Tables 3, 4 and 5 at 1% significance level. The results show partial effects of the variables towards the probability of being scrapped. The coefficients are not to be interpreted as direct effects as in linear regression. It is merely the partial effect of a particular variable with all other variables remaining the same. The interesting part is not necessarily the coefficient but its significance and sign which determines the tendency of the effect towards the probability of being scrapped. A positive coefficient means an increase in the probability of the ship being scrapped and vice versa.

Table 3 shows that a ship's age is significant and positive towards its probability of being scrapped which is logical and intuitive. It follows that with the exception of Turkey, tonnage has a positive effect implying that smaller ships are most likely to be scrapped in Turkey. Earnings are all negative confirming the hypothesis that an increase in earnings decreases the probability of a ship being scrapped as owners would rather use it as a cash-cow if market permits. The positive sign for scrap prices is again intuitive as higher scrap prices enhance the probability of ships being scrapped.

Table 3: Results of demolition models – partial effects of variables of interest except flag

Variable of Interest	India Coefficient	Bangladesh Coefficient	China Coefficient	Turkey Coefficient	Pakistan Coefficient
Ln(Age)	1.174	1.035	1.037	1.122	0.740
Ln(Tonnage)	0.346	0.758	0.686	-0.237	0.211
Ln(Earnings per day)	-2.307	-1.338	-2.472	-1.475	-1.720
Ln(Scrap Prize)	2.58	3.514	1.938	1.636	1.951
Owner-OECD	benchmark	benchmark	benchmark	benchmark	benchmark
Owner-DEVC	n/s	n/s	n/s	n/s	1.219
Owner-EEUR	n/s	n/s	n/s	1.367	n/s
Owner-LSDC	n/s	n/s	-2.561	n/s	n/s
Owner-Unknown	1.257	n/s	0.456	n/s	1.316

Note: n/s = non significant, otherwise 1% significance level

With respect to ownership, one can see some different patterns across the demolition countries. The parameter for unknown ownership of a vessel is difficult to interpret but shows a positive effect for India, China and Pakistan based on the established benchmark, viz., owners from OECD countries while it is not significant for Bangladesh and Turkey. For owners from developing nations, ships are more likely to be scrapped in Pakistan while the same applies to Turkey for ships owned by owners from former Eastern block countries. Owners from least developed countries are less likely to recycle ships in China compared to owners from OECD countries. For Bangladesh, the study did not find significant difference for shipowner groups from the OECD.

Table 4 lists some of the flags which remain significant in either of the models. Due to the differences in the size of the dependent variable (scrapping), some flags drop out of the equation and cannot be used for the estimation process. For this reason, Pakistan is left with the least number of flags remaining in the model. For the flag variable, the benchmark for the interpretation is therefore not one particular flag but all other flags which dropped out of the equation. This variable represents the flag history of a vessel over its lifetime and can be interpreted as the potential effect of a flag towards the probability of being scrapped. We decided to use the flag history versus the flag at the time of scrapping for mainly two reasons: 1) the flag at the time of scrapping is difficult to obtain and 2) in this article, we are more interested in showing the potential importance of a flag towards the probability of scrapping since the registries are the signatories to the IMO convention. Flag further has an importance in indicating the overall safety quality of a vessel besides the owner. It is therefore preferable to include the flag history into the models since it reflects a ship's history. Most flags show either a positive or negative effect towards one country but few flags show significance across all countries. These flags are Cyprus (positive effect to all demolition countries with the exception of Turkey), Malta (positive effect, with the exception of China), Romania (positive effect with the exception of Bangladesh) and St. Vincent and the Grenadines (Turkey not significant, all others positive).

Table 4: Results of demolition models – partial effects of flags

Variable of Interest	India Coefficient	Bangladesh Coefficient	China Coefficient	Turkey Coefficient	Pakistan Coefficient
United Arab Emirates	1.113	n/s	not in model	not in model	not in model
Argentina	n/s	3.152	not in model	not in model	not in model
Bahamas	0.791	n/s	1.644	n/s	n/s
Bermuda	n/s	n/s	2.178	n/s	n/s
Belize	n/s	n/s	2.279	n/s	n/s
Canada	n/s	n/s	n/s	1.822	not in model
China	-3.210	n/s	n/s	n/s	not in model
Chile	n/s	n/s	2.337	not in model	not in model
Cyprus	1.057	1.511	1.490	n/s	1.607
Germany	-2.403	n/s	n/s	n/s	n/s
Georgia	n/s	n/s	n/s	n/s	2.736
Greece	n/s	n/s	1.165	n/s	1.700
Algeria	1.250	n/s	not in model	not in model	not in model
Estonia	n/s	n/s	not in model	not in model	not in model
Egypt	1.002	n/s	not in model	not in model	not in model
Hong Kong	n/s	n/s	2.494	not in model	not in model
Honduras	n/s	n/s	2.529	n/s	n/s
Indonesia	-4.138	2.618	n/s	not in model	not in model
India	1.724	1.610	n/s	not in model	not in model
Iran	1.177	n/s	not in model	not in model	not in model
Italy	n/s	n/s	n/s	3.076	n/s
Japan	-5.681	n/s	1.088	n/s	n/s
South Korea	-2.582	n/s	2.351	not in model	not in model
Kuwait	1.897	n/s	not in model	not in model	not in model
Liberia	n/s	n/s	1.852	n/s	n/s
Cambodia	n/s	n/s	2.737	n/s	2.284
Cayman Islands	1.959	n/s	n/s	n/s	not in model
Marocco	2.602	n/s	not in model	not in model	not in model
Malta	0.710	1.314	n/s	1.629	1.378
Malaysia	n/s	2.753	n/s	n/s	not in model
Marshall Islands	n/s	n/s	n/s	not in model	not in model
Myanmar	n/s	n/s	2.146	n/s	not in model
Netherlands	n/s	n/s	2.293	n/s	not in model
Norway	n/s	n/s	1.875	n/s	n/s
NIS	n/s	n/s	1.636	n/s	n/s
Panama	n/s	n/s	1.651	n/s	n/s
Philippines	-2.399	n/s	3.067	-4.794	n/s
Poland	n/s	n/s	4.224	not in model	not in model
Quatar	2.591	n/s	not in model	not in model	not in model
Romania	1.055	n/s	2.967	3.852	2.472
Russian Federation	n/s	1.128	1.892	n/s	n/s
Saudi Arabia	1.431	n/s	n/s	not in model	not in model
Singapore	n/s	2.238	n/s	-4.128	n/s
Spain	n/s	n/s	n/s	2.325	n/s
Thailand	n/s	1.488	n/s	not in model	not in model
Turkey	n/s	n/s	n/s	1.433	n/s
USA	n/s	n/s	1.433	not in model	not in model
United Kingdom	n/s	n/s	3.195	n/s	n/s
St. Vincent & Gren.	0.984	1.331	1.224	n/s	1.907
Vanuatu	n/s	n/s	2.505	n/s	not in model

Note: n/s = non significant, otherwise 1% significance level, NIS = Norwegian International Register

The top five flags with a strong positive effect towards the probability of being scrapped given its flag history over the ship's lifetime for India are the registries Morocco, Qatar, Cayman Islands, Kuwait and India. For Bangladesh, these are Argentina, Malaysia, Indonesia, Singapore and India. For China, the top five flags are Poland, the United Kingdom, the Philippines, Romania and Cambodia. For Turkey, the top three flags are Romania, Italy, Spain, Canada and Malta while for Pakistan, these are Georgia, Romania, Cambodia, St. Vincent and the Grenadines and Greece. From the main open registries, only Malta and Cyprus have a positive effect toward almost all scrapping locations while Panama, the Bahamas and Bermuda only show a positive effect towards China. For Turkey, one can easily see the importance of European flags.

Table 5 lists other variables which are of less interest for interpretation in the models but are nevertheless valuable findings based on the results. It seems India is not preferred for recycling double hull tankers. The probability of a general cargo vessel being scrapped is higher in Turkey (compared to all other ship types), India (compared to tankers), and Bangladesh (compared to passenger ships). China seems to scrap more container vessels and less tankers compared to general cargo ships. Pakistan and Bangladesh seems to scrap more tankers. Pakistan also seems to scrap more dry bulk carriers.

Table 5: Results of demolition models – partial effects of other variables

Other variables	India Coefficient	Bangladesh Coefficient	China Coefficient	Turkey Coefficient	Pakistan Coefficient
DH	-1.112	n/s	n/s	n/s	n/s
General Cargo	benchmark	benchmark	benchmark	benchmark	benchmark
Container Vessel	n/s	n/s	0.556	-1.799	n/s
Dry Bulk	n/s	n/s	n/s	-0.937	0.828
Other	n/s	n/s	n/s	-1.404	n/s
Passenger	n/s	-1.429	n/s	-0.874	n/s
Tanker	-1.226	0.534	-0.574	-0.804	1.507
Class Non IACS	benchmark	benchmark	benchmark	benchmark	benchmark
Class IACS	n/s	1.008	2.188	-0.956	n/s
Class Unknown	-0.883	n/s	1.408	n/s	n/s
Class changed	n/s	n/s	n/s	-0.651	n/s
Class survey overdue	-0.675	n/s	-1.351	n/s	n/s
Class withdrawal	0.277	n/s	0.741	n/s	n/s
Flag changed	0.202	n/s	0.148	n/s	n/s
Owner changed	n/s	n/s	n/s	n/s	n/s
PSC inspections	-0.233	n/s	-0.212	-0.225	-0.105
Detained	0.272	n/s	n/s	0.334	n/s
Total Deficiencies	n/s	n/s	n/s	n/s	n/s
Flag state inspections	0.026	n/s	n/s	n/s	-0.350
Vetting- (SIRE)	-0.978	-0.739	not in model	not in model	not in model
Vetting - (CDI)	0.361	-0.491	0.116	n/s	-0.397
Vetting- (Rightship)	n/s	n/s	-0.380	not in model	not in model
ISM audits	n/s	0.366	n/s	n/s	n/s
Less serious casualty	n/s	0.153	n/s	n/s	n/s
Serious casualties	n/s	n/s	n/s	n/s	n/s
Very serious casualty	n/s	n/s	0.296	0.562	n/s

Note: n/s = non significant, otherwise 1% significance level

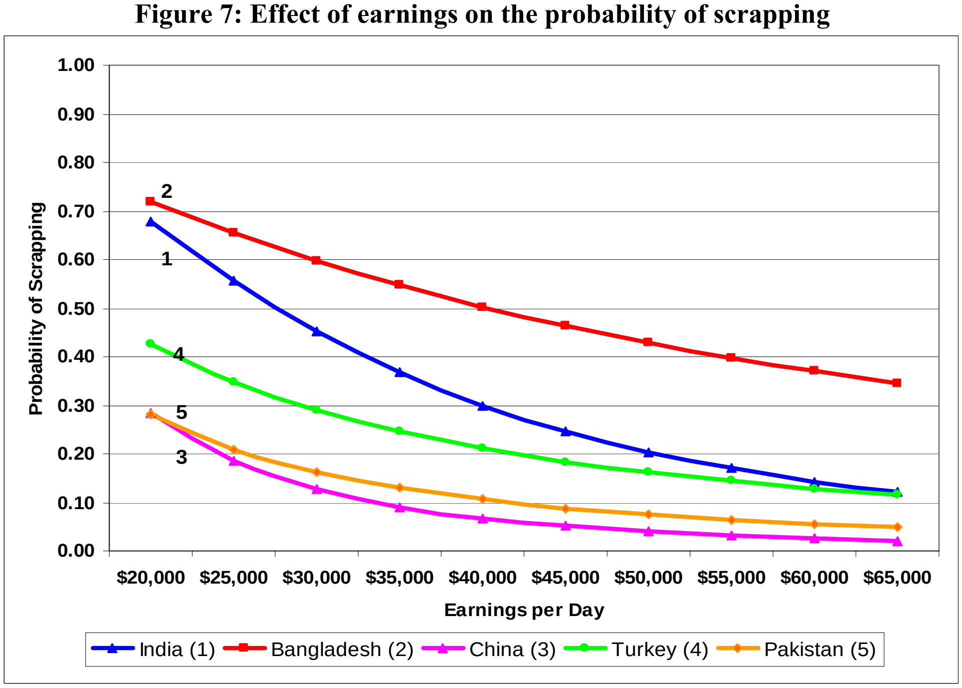
Most variables associated with changes in ship particulars such as a change of class show less of an importance, except for India, China and to a certain extent Turkey while these variables are not important for Bangladesh and Pakistan. The safety and vetting inspections give a mixed result across scrapping locations with the inspections showing mostly negative effects. This could be because some older and/or sub-standard ships may have been upgraded as a result of the inspection thereby prolonging the commercial use of those ships rather than their being recycled.

Detention on the other hand gives the expected result and indicates that detained ships are more likely to be scrapped in India and Turkey compared to other locations. The last group of variables showing the effect of casualties also give a mixed result which can be expected for less serious and serious casualties. Ships with very serious casualties are more likely to be scrapped in China and Turkey rather than in India, Bangladesh and Pakistan.

The following section will visualize some of the findings presented earlier. The partial effects with reference to the economic variables are visualized first, followed by graphs based on average probabilities of the 51,112 ships included in the dataset. Figures 7 and 8 are calculated using equations 1 and 2 and help visualize the effect of earnings and scrap prices on the probability of being scrapped at each scrapping location. The graphs are calculated based on an average ship profile for a tanker with the same ship particulars for each scrapping location and with the following particulars: 20 years old, 28,000 gt, Romanian Flag, Owner Unknown, Non-IACS Class, average scrap price and scrap prices for tankers as per dataset. The partial effect of the variables of interest is then visualized by calculating the probability of scrapping for several scenarios.

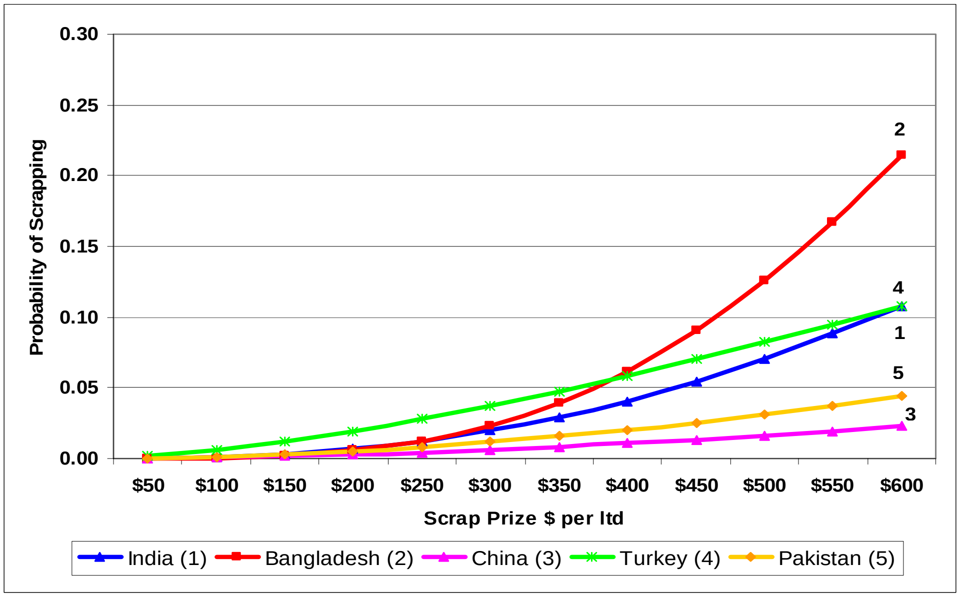
In Figure 7, earnings per day have a range from $20,000 to $65,000 while the price for scrap in Figure 8 ranges from $50.00 to $600/ltd. One can easily see the negative relationship between earnings and the probability of scrapping which is the weakest for Bangladesh followed by India, Turkey, Pakistan and China. Simultaneously, Figure 8 shows that an increase in scrap prices has a stronger effect on Bangladesh, followed by Turkey and India.

Figure 7: Effect of earnings on the probability of scrapping



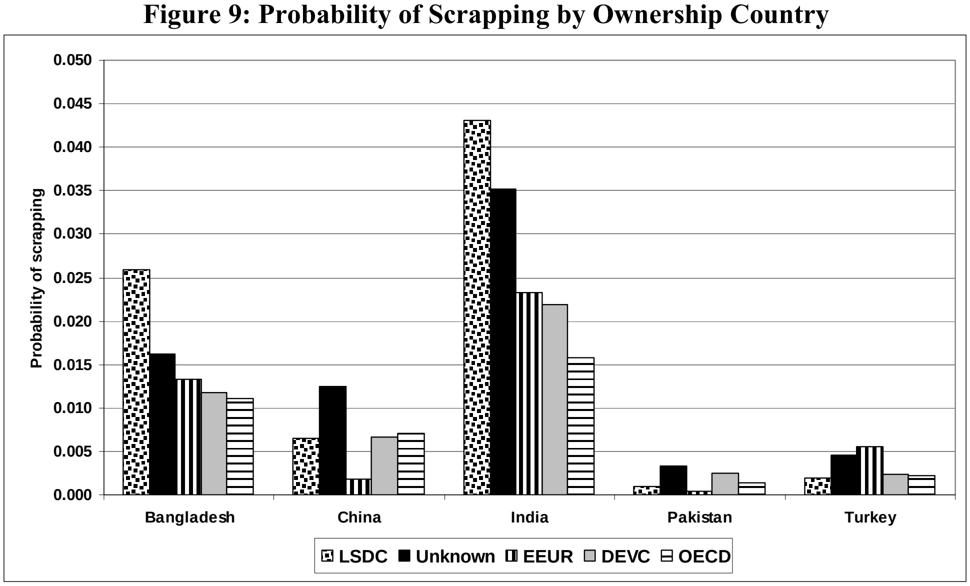
Thus graphs 7 and 8 clearly show that Bangladesh's status as a major location for ship recycling is more sensitive to the underlying market conditions compared the other four key nations considered in this study. This result is justified by the relatively late entry of the nation in ship scrapping and its build-up of a clientele most sensitive to fluctuations in scrap prices.

Figure 8: Effect of scrap prices on the probability of scrapping



Figures 9, 10 and 11 are based on average probabilities of 51,112 ships and should provide an overview of the probability of recycling per chosen location for ownership groups and flags. The average probabilities are calculated using Equations 1 and 2 and are then grouped into respective ownership groups and flags. This will help interpret the results and their usefulness in visualizing the impact of the proposed IMO Convention.

Figure 9: Probability of Scrapping by Ownership Country

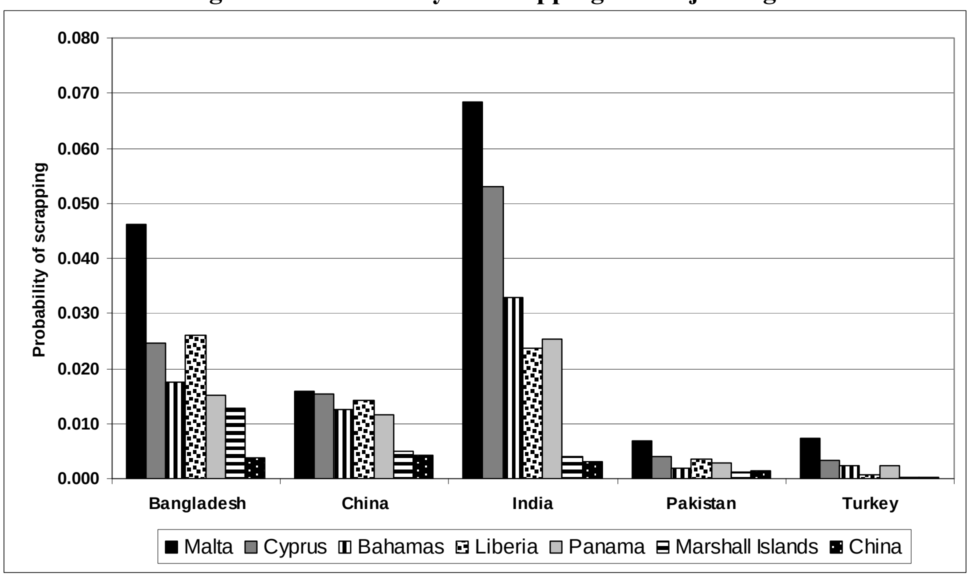


Note: Based on average probabilities of 51,112 vessels

With respect to ownership, one can easily notice from Figure 9 that owners from least developed countries have a higher probability of recycling ships in India and Bangladesh. For both these nations, the category of unknown shipowners have the next highest level of probability of scrapping followed by those from the former Soviet Union and Non OECD Eastern Europe. Owners from OECD countries show some importance in India, followed by Bangladesh and China.

Figure 10 visualizes the probability of recycling for some major flag states and China. Malta shows the highest average probability of ships being recycled in India and Bangladesh. Other flags with higher average probability of scrapping in India and Bangladesh include Cyprus and Liberia. Ships flagged in Bahamas and Panama also have a high probability of recycling in India. There is no significant difference among the major flags for China as a choice location for recycling.

Figure 10: Probability of Scrapping for major flags



Note: Based on average probabilities of 51,112 vessels

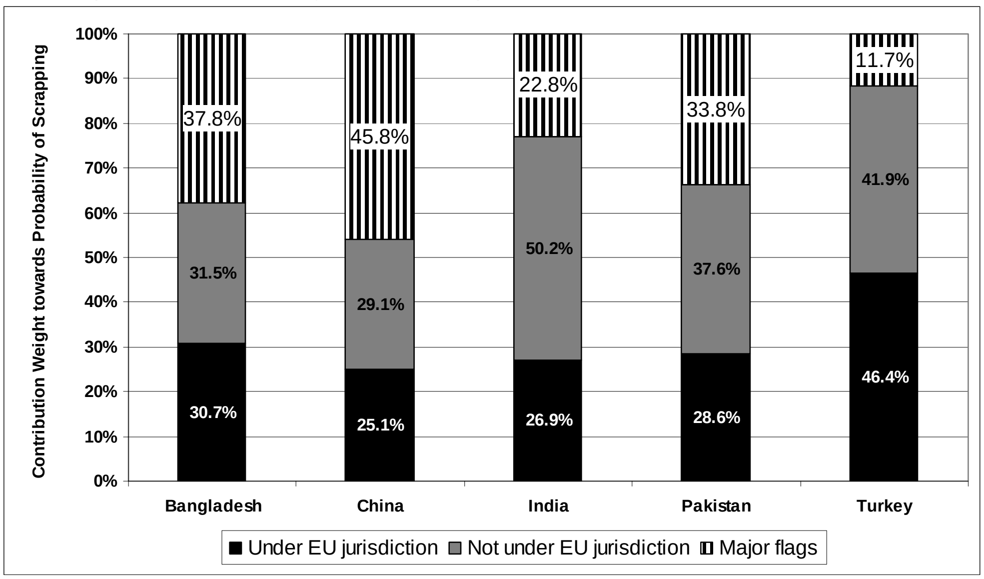
Figure 11 is helpful in understanding the possible impact on major ship recycling locations based on registry of ships to be recycled. It shows the contribution weight of the average probabilities of scrapping for various flag groups.

The development of the convention is an ongoing process and it is therefore difficult to put flags into a certain group. We assume that the EU Member States have a positive inclination in ratifying the convention since there is already a broad range of EU legislation which is applicable to end-of-life ships, setting up binding environmental and safety requirements related to the dismantling activities themselves as well as the transfer of end of life ships for dismantling from and to the EU.

It is most likely that the EU will encourage member states to ratify the convention and if this is the case, other registries under indirect influence of the EU will also follow suit (e.g. Norway and NIS). For other countries, it is difficult to classify them at this stage. We therefore choose a category for the EU registries including flags under EC jurisdiction (e.g. including flags of dependent territories for e.g the UK, France) and Norway and a category of flags which are not under EU jurisdiction. The latter category further indicates the portion of the major flag states which are not under EU jurisdiction of which some are already shown individually in Figure 10 (minus Malta and Cyprus.

The figures were calculated as follows. First, the average probability of the group was calculated and then brought in relation to the total probability of scrapping where the total is taken as 100%. The individual probabilities are then converted into a percentage contribution towards the total in order to visualize the importance of a certain group towards the probability of scrapping. The figure shows the relative importance for EU registries for Turkey with a contribution weight of 46% compared to around 30% ofr the rest of the scrapping locations. The highest contribution weight for the major flag states which are not under EU jurisdiction can be found for China (45%) while the lowest percentage of these flags are found for Turkey.

Figure 11: Probability of Scrapping per Implied Convention Ratification



Note: Based on average probabilities of 51,112 vessels

Given these findings, an implementation of the convention at EU level will most likely affect Turkey while a non ratification of one of the major flag states will most likely affect China.

5. CONCLUSIONS AND DISCUSSION

This study applies econometric modeling to an extensive dataset spread over a 29 year period and gathered from multiple sources. Its results provide a holistic insight into the dynamics of the ship recycling market and empirical support for interpreting the industry trends. This section summarizes the major contributions of the study.

With respect to the *economic* variables used in the study, the results show that *earnings* have a negative effect. This confirms the hypothesis that an increase in earnings decreases the probability of a ship being recycled as it is too hard to resist the temptation to enhance the cash-flow through commercial operations as long as the market permits. The positive effect of scrap prizes, another important finding, also validate the intuitive argument that an increase in the scrap price will lead to a higher probability of ships being scrapped.

Bangladesh seems to be most sensitive to changes in the market compared to the other scrapping locations which could be explained due to its new entry into the demolition market.

The *ownership* variables are particularly insightful and show different patterns across the recycling countries. For owners from developing nations, ships are more likely to be scrapped in Pakistan while ships owned by owners from former Eastern block countries prefer Turkey. Compared to the shipowners from OECD countries, the owners from former Eastern block countries and also the least developed countries are less likely to recycle ships in China. For Bangladesh and India, the study did not find significant difference for shipowner groups from the OECD benchmark with the sole exception of the category of unknown owners.

With respect to the *flag of registration*, the results show that while most flags show either a positive or negative effect towards each of the five major recycling countries considered in the analysis, a few flags show significance across all five countries. These flags are Cyprus (positive, with the exception of Turkey), Malta (positive, with the exception of China), Romania (Bangladesh not significant, rest positive) and St. Vincent and the Grenadines (Turkey not significant, all others positive). For Turkey, it is interesting to notice that European flags over the vessels history show a stronger positive effect towards the probability of scrapping compared to the other locations. Cyprus and Malta show a potential importance of the important registries towards the probability of scrapping while this is not necessarily the case for other major registries such as Panama, Bahamas, Liberia or the Marshall Islands.

With respect to other aspects of the *ship profile*, the probability of a general cargo vessel being scrapped is higher in Turkey (compared to all other ship types), India (compared to tankers), and Bangladesh (compared to passenger ships). China seems to scrap more container vessels and less tankers compared to general cargo ships. Pakistan and Bangladesh seems to scrap more tankers. Pakistan also seems to scrap more dry bulk carriers. Most variables associated with changes in ship particulars such as a change of class show less of an importance, except for India, China and to a certain extent Turkey while these variables are not important for Bangladesh and Pakistan. The safety and vetting inspections give a mixed result across scrapping locations with the inspections showing mostly negative effects. This could be because some older and/or sub-standard ships may have been upgraded as a result of the inspection thereby prolonging the commercial use of those ships rather than their being recycled. Detention on the other hand gives the expected result and indicates that detained ships are more likely to be scrapped in India and Turkey compared to other locations.

The analysis further reveals the relative importance for EU registries for Turkey compared to the rest of the scrapping locations. An implementation of the convention at EU level will most likely affect Turkey while a non ratification of one of the major flag states will most likely affect China. The authors believe that the study has made a useful contribution in maritime economics based on extensive empirical data and that the results will help shape the ongoing ship recycling discussions at IMO and EU level.

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APPENDIX 1: Summary of Key Statistics

	Per Country					
	India		Bangladesh		China	
# observations in final model	0 =	49747	0 =	50457	0 =	50622
	1 =	1365	1 =	655	1 =	490
	Total =	51112	Total =	51112	Total =	51112
# outliers (twins)	none		none		none	
Cut Off	0.0267		0.0128		0.0095	
	LOG	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**
Mc Fadden R2	0.549	0.559	0.589	0.5969	0.432	0.439
% Hit Rate y=0	91.78	91.80	94.05	93.99	90.15	90.15
% Hit Rate y=1	96.78	97.73	97.56	97.86	92.04	93.67
% Hit Rate Tot	91.91	91.95	94.09	94.04	90.15	90.18
p-value of HL-Stat.	0.000	0.000	0.017	0.668	0.326	0.934
	Turkey		Pakistan		Remarks	
# observations in final model	0 =	50919	0 =	50981	*LOG = logit model*	
	1 =	193	1 =	131	*PRO = probit model*	
	Total =	51112	Total =	51112		
# outliers (twins)	none		none			
Cut Off	0.0037		0.0025			
	LOG	**PRO**	**LOG**	**PRO**		
Mc Fadden R2	0.393	0.396	0.342	0.358		
% Hit Rate y=0	88.03	88.61	88.85	89.63		
% Hit Rate y=1	93.26	94.30	97.71	97.71		
% Hit Rate Tot	88.05	88.63	88.87	89.65		
p-value of HL-Stat.	0.973	0.770	0.218	0.731		