Econometric Analysis of Ship Life Cycles – are safety inspections effective?

Govert E. Bijwaard[1] and Sabine Knapp

Econometric Institute, Erasmus University Rotterdam[2]

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Abstract

Due to the shipping industry's international legal framework and the existence of loopholes in the system, an estimated 5-10 percent of substandard ships exist which are more likely to have incidents with high economic cost. This article uses ship life cycles to provide insight into the effectiveness of inspections on prolonging ship lives. We account for fluctuations in the relevant economic environment and the (possible time-varying) ship particulars. We use a unique dataset containing information on the timing of accidents, inspections, ship particular changes of more than fifty thousand ships over a 29 year time period (1978-2007). The results of our duration analysis reveal that the shipping industry is a relative safe industry but there is a possible over-inspection of vessels. It also reveals the need to improve transparency related to class withdrawals and changes of classification of the vessel. Another interesting finding is that for the majority of ship types an increase in earnings decreases the incident rate. This is in contrast to the industry perception of the impact of earnings. The effect of inspections vary across ship types and the prevention of incidents with high economic costs can be improved by better coordination of inspections, data sharing and a decrease in the number of inspections . Further, more emphasis should be placed on the rectification and follow up of deficiencies.

[1] Bijwaard is financially supported by the Netherlands Organization for Scientific Research (NWO) nr. 451-04-011.

[2] Econometric Institute, Erasmus Univ., P.O. Box 1738, NL-3000 DR, Rotterdam, The Netherlands, knapp@few.eur.nl or bijwaard@few.eur.nl

Introduction

The development of the world economy is closely related and influenced by the commercial shipping industry. Today 90 percent[3] of global trade is carried by sea. The shipping industry provides the basis for economic growth since it facilitates the distribution of resources and manufactured goods. According to the United Nations Conference on Trade and Development (UNCTAD)[4], total world seaborne trade reached 7.11 billions of tons (goods unloaded) in 2005, an increase of 284 percent compared to 1970. In terms of total activity of the sector measured in ton-miles[5], this accounts to 29,045 billion ton miles in 2005 compared to 10,654 billion ton-miles in 1970. Besides the contribution of shipping to the global economy, UNCTAD further estimates an additional economic contribution to the global economy of USD 380 billion in freight rates deriving from the operation of ships. Most cargo carried by sea is crude oil and oil products which amount to 65.9 percent of the total cargo carried or 11,705 ton miles. Other important cargoes are dry bulk general cargo and container trade. The latter remains the fastest growing segment within the shipping industry due to the fast economic development of China. Regardless of this importance of the shipping industry as a prime user of the oceans, not much has changed amongst policy makers of ocean governance since the 1970's. Wilkinson (1979) already pointed out that most effort of policy makers is geared towards fisheries and little towards shipping and pollution. Integrated maritime and marine policies on areas related to ocean governance do not exist.

Compared to the total amount of freight or passengers which are carried each year, the shipping industry is a very safe industry. However, ship accidents occur and they may have a significant economic impact on the coastal state, the fisheries, the environment or lead to loss of life. It is very hard to measure the economic cost of incidents[6]. For instance, consider in the case of oil spills. The cost of such an incident depends on the type of oil spilled, oceanographic conditions, the regional location and the efficiency of the oil response. Notwithstanding the estimation of socio-economic factors (Grigalunas et al, 1988). In the case of passenger vessel incidents the number of people onboard is often unknown and the value associated with the loss of life varies. For dry bulk carrier incidents, very little is reported in the media and economic loss is mostly associated with the value of the vessel and its cargo.

This article provides insight into the effectiveness of inspections in preventing accidents. It builds on the dataset originally used by Knapp and Franses (2007b) and complements it with additional data for a extended time period. It exploits a unique, global dataset combining various types of safety inspections of ships over a time period of 29 years. We also account for the economic shipping cycles to reflect the changes of the economic condition of the shipping industry on the ship incident rate.

For a comprehensive analysis of the effect of inspections and the economic shipping cycle on ship incidents the full history of this information should be exploited including

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[3] International Maritime Organization
[4] UNCTAD, Review of Maritime Transport, 2006
[5] Tonnage of cargo shipped times average distance transported
[6] We use the term incidents to cover accidents, casualties as per the definition of the International Maritime Organization (IMO) and total loss of a vessel excluding constructive total loss for insurance purposes

general ship particulars[7] and changes thereof during its economic life. One approach for inference could be to apply a logit or probit model on the probability of a ship incident. In such a model, the dynamics are discarded because it only considers whether a ship had an accident at fixed points in time. The choice of these fixed points has a big impact on the estimation results. It is also not straightforward to include time-varying covariates into such a model. We have information on daily basis and therefore use duration analysis on the length of the ship's economic life is the natural approach for this dynamic framework. It enables us to measure the effect of inspections on the incidence rate of a vessel.

Table 1 lists some of the major maritime incidents for oil tankers and passenger vessels starting in 1912 with the *Titanic* claiming 1,517 lives to one of the most recent passenger vessel accident claiming 1,000 lives (*Al Salam Boccachio 98,*2006). According to the International Oil Pollution Claim Fund (IOPCF) and the International Tanker Owners Pollution Federation (ITOPF), the associated costs can vary from USD 9.5 billion (*Exxon Valdez*, 1989) to USD 37 million (*Sea Empress*, 1996) where the size of the vessel or oil spill is not directly related with the associated economic costs (ITOPF, 2007). According to Grey (1999), accident costs translated to USD/tons of oil spilled reveals a wide range from as little as USD 667/tons of oil spilled (*Haven*, 1991) to USD 180,000/tons of oil spilled (*Shinryu Maru No 8*, 1995) This further demonstrates the difficulty in estimating the true economic cost associated with an oil spill. For most incidents, an estimated cost figure could not be found, especially for some of the older incidents.

Very often the shipping industry triggers legislative reactions after incidents. For the US, the *Exxon Valdez* incident triggered the creation of the Oil Pollution Act (OPA90) while for the European Union (EU), the two latest incidents at the coast of France and Spain, the *Erika* (1999) and *Prestige* (2002) triggered a full revision of the EU maritime legislative framework dealing with all aspects of the shipping industry – the so called EU Third Maritime Safety Package.

Despite the development of a complex legislative framework in the shipping industry, parts of the enforcement remain weak. This is due to the fact that the industry is very global and its regulatory framework is based on international law. The loopholes in the enforcement create a market for substandard ships which is estimated by the OECD to comprise 5-10 percent [8] of the world fleet. These substandard ships distort competition to prudent ship owners since costs are saved to cut the edges on what would otherwise be acceptable. Following a series of major oil tanker accidents in the 70's, the concept of port state control (PSC) evolved which allows port states to conduct safety inspections on foreign flagged vessels entering its ports. The countries grouped themselves into PSC regimes based on Memoranda of understanding and today, there are currently 10 such regimes in force covering most of the port states.

From a public perspective, the desired situation is to promote safe, secure and environmentally friendly maritime transportation and to decrease the number of

[7] Ship particulars is a standard term used in the shipping industry and contain the description of physical characteristics of a vessel such as ship type, hull type, gross tonnage and operational items such as ownership, safety management or the registry of a vessel.
[8] Peijs, K. (2003). Ménage a trois. Speech at *Mare Forum* (November 2003: Amsterdam)

substandard vessels in order to prevent the likelihood of a maritime incident bearing substantial economic costs.

Table 1: Major Shipping Incidents of Oil Tankers and Passenger Ships

Ship Name	Year	Location	Spill Size (tonnes)	Economic Costs
Titanic	1912	North Atlantic		1,517 lives
Torrey Canyon	1968	Scilly Isles, UK	119,000	No estimate
Sea Star	1972	Gulf of Oman	115,000	No estimate
Metula	1974	Magellan Street, Chile	47,000	No estimate
Jakob Maersk	1975	Oporto, Portugal	88,000	No estimate
Urquiola	1976	La Coruna, Spain	100,000	No estimate
Argo Merchant	1976	Nantucket Sound, USA	28,000	No estimate
Hawaiian Patriot	1977	300 nautical miles off Honolulu	95,000	No estimate
Amoco Cadiz	1978	Off Brittany, France	223,000	US$ 282 million
Independenta	1979	Bosphorus, Turkey	95,000	No estimate
Atlantic Empress	1979	Off Tobago, West Indies	287,000	No estimate
Irenes Serenade	1980	Navarino Bay, Greece	100,000	No estimate
Castillo de Bellver	1983	Off Saldanha Bay, South Africa	252,000	No estimate
Nova	1985	Off Kharg Island, Gulf of Iran	70,000	No estimate
Herald of Free Enterpr.	1987	Off coast of Belgium		193 lives
Dona Pax	1987	Philippines		4,000 lives
Odyssey	1988	Off Nova Scotia, Canada	132,000	No estimate
Khark 5	1989	Off Atlantic coast of Morocco	80,000	No estimate
Exxon Valdez	1989	Prince William Sound, USA	37,000	US$ 9.5 billion
Scandinavian Star	1990	Baltic Sea		158 lives
ABT Summer	1991	700 nautical miles off Angola	260,000	No estimate
Haven	1991	Genoa, Italy	144,000	US$ 96 million
Aegean Sea	1992	La Coruna, Spain	74,000	US$ 60 million
Katina P	1992	Off Maputo, Mozambique	72,000	No estimate
Braer	1993	Shetland Islands, UK	84,700	US$ 83 million
Estonia	1994	Baltic Sea		852 lives
Sea Empress	1996	Milford Haven, UK	72,000	US$ 62 million
Nakhodkha	1997	Japan	17,500	US$ 219 million
Erika	1999	Off Coast of France	20,000	US$ 180 million
MV Joola	2002	West Africa		1,863 lives
Prestige	2002	Off the Spanish coast	77,000	Euro 778 million
Tasman Spirit	2003	Pakistan	30,000	US$ 291 million
Al Salam Boccachio 98	2006	Red Sea		1,000 lives

Source: compiled by authors from various sources, (spill size is in tonnes of oil spilled)

On a regional scale and based on data from one country, Cariou et all (2007a,b) touch upon the topic of effectiveness of PSC inspections and concludes that some of the ship characteristics appear to be significant predictors for risk. Talley et al (2005) look at the probability of a vessel being inspected by the United State Coast Guard for a safety inspection versus a pollution inspection. They recommend a revision of the targeting of ships for inspection in order to enhance their effectiveness. Knapp and Franses (2007a,b,c) look at various aspects of safety inspections using binary logistic regression on combined datasets. They estimate that a port state control inspection leads to a 5 to 10 percent decrease in the probability of a very serious casualty. They recommend that targeting of ships for inspections can be enhanced by using data from various port state control regimes and industry inspections and by taking inspections of other regimes into account. Another policy recommendation is to revise the release of a vessel from detention. Furthermore, their analysis shows the importance of ownership versus registry to define the risk profile of a vessel.

The paper is organized as follows. In Section I we explain the combination of datasets and variables used in this article. To obtain a general impression of the data some descriptive statistics are given. Section II explains the construction of the variables and models used for duration analysis. It also presents its results including the visualization thereof by taking policy implications into account. In Section III we discuss the results and present our conclusions.

I. The Datasets and Variables

A. Combination of Datasets to create ship life cycles

The dataset used in this analysis is compiled from several sources which will be explained in this section in detail. Particular care was placed on the creation of the data with respect to the choice of the data sources which are limited in the shipping industry due to its secretive and political nature. The final data comprises of information on 52,130 ships over 100 gross tonnage and contains 748,621 events, ships incidents, inspections and changes in ship particulars, over a 29 year time period (1978-2007). The information in the data can be split into four main groups:

1. possible time-varying *ship particular data* (e.g. ship type, ship yard country, beneficial ownership of a vessel, DoC Company[9], flag and classification society[10])
2. *economic data* representing the shipping markets influencing the shipping economic cycles (on a monthly basis)
3. *information on safety inspections*
4. *data on the timing of incidents and regular death of a vessel (demolition of a vessel)*

To create the dataset, we combine data from the three major data providers[11] in the shipping industry. Due to the nature of the shipping industry, it is difficult to obtain raw data on ship inspections, in particular from port state control regimes (PSC), or industry inspections. We have to our disposal information on safety inspections from six PSC regimes. However, the data could not be obtained from all regimes for the whole time period. The data was further complemented by data from industry inspection systems[12] and safety management audits (ISM[13] audits). For each vessel we have a number of ship related information: the flag state, the classification society, the ship yard country,

[9] Document of Compliance Company, the company which is responsible for the safety management on commercial vessels trading internationally and according to international requirements
[10] Classification societies are companies who deal with the technical aspect of shipping and sometimes also conduct inspections on behalf of the flag state. In this case, they are called recognized organization (RO). This article will not emphasize on the role of RO's.
[11] Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit and Clarkson's Shipping Intelligence Network
[12] CDI, SIRE, RigthShip, Greenaward Foundation
[13] Audits performed under the International Safety Management Code (ISM Code)

the owner and the DoC company. Many ships change their flag, class society, owner or DoC company during their life. We have information when such a change occurs.

To account for the differences in the types of cargo markets we divide the dataset into datasets per ship type. The main cargo markets are dry bulk, liquid bulk (tanker) and general cargo. We further distinguish the container vessels from the rest of general cargo vessels. We also identify passenger vessels. Finally, all other ship types[14] are aggregated to the other ship type category.

The data on safety inspections include port state control inspections, ISM audits, detention[15] of a vessel and the number of deficiencies found during a port state control inspection. Furthermore, three industry inspections performed primarily on oil tankers and dry bulk carriers are included. The industry inspections are called vetting inspections and are performed by the Chemical Distribution Institute (CDI) on chemical tankers and oil tankers, by RightShip[16] primarily on dry bulk carriers and by the Oil Companies International Marine Forum (OCIMF) on oil tankers. The inspection system of OCIMF is called SIRE which is used in this article.

There are currently ten port state control regimes operating worldwide and we have data from about 60 countries or six regimes including the most important regimes. Port state control inspections are neither cross-recognized amongst regimes nor do they recognize industry inspections. This implies that a possible selection bias due to the targeting criteria is negligible.

Furthermore, the dataset contains information on the timing of various ship incidents such as the total loss of a vessel and casualties. It also contains information on the timing of regular death (demolitions) of a vessel which indicates the regular end of a ship's economic life. It is very difficult to obtain accurate information on ship demolitions and three data sources[17] were combined to create the best possible dataset. Casualties are divided according to seriousness into very serious, serious and less serious casualties based on the International Maritime Organization (IMO) MSC Circular 953 of 14th December 2000. The total loss of the vessel implies the loss of a vessel either because it is completely destroyed or because it has submerged[18]. Usually the IMO includes a total loss of a vessel in the category of very serious casualties. In some cases we can distinguish a total loss from a very serious casualty. In such occasion we treat a total loss of a vessel separately. The dataset used for this analysis can be seen as a representative dataset of the world fleet under the jurisdiction of the international conventions.

B. Economic data

According to Stopford (2003) four markets determine the shipping cycles and influence the cash flow: 1) the freight market, 2) the sales and purchase market of vessels, 3) the

[14] Other ship types are e.g. research vessels, offshore vessels, dredgers, training vessels, etc.
[15] A vessel is detained when it is found in severe violation of the international conventions and is only released after the rectification of its deficiencies.
[16] RightShip is an independent vetting inspection system located in Melbourne, Houston and London and performs inspections on all ship types but primarily dry bulk carriers
[17] Data from Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit and Clarksons
[18] Lloyd's Maritime Intelligence Unit and Lloyd's Register Fairplay, definitions received with the casualty data

new building market and 4) the demolition market. Since this cash flow influences the amount of money that is available for the maintenance of the vessel and the safety quality, it is important to include economic data that reflects these four markets. The Shipping Intelligence Network from Clarkson's, which is one of the main ship brokers in the shipping industry, provided the relevant economic data.

For the freight rate market, we use *earnings per day* (in USD) as defined by Clarksons[19], for the sales and purchase market of vessels, we use the *second hand price of vessels* (USD per deadweight[20] - DWT), for the new building market, we use the *new building prices of vessels* (USD per DWT) and for the demolition market, we use the *scrap price of a vessel* (USD per lightweight[21] ton - LTD). For container vessels, the DWT is replaced by TEU[22] for earnings and new building prices. In constructing the variables, we account for inflation rates[23] for the USD for the time frame on hand and deflate the nominal values. Missing values were replaced with average values of changes in the ship cycles based on Stopford (2003).

A summary of the development of the variables presented as real values and converted to an index for earnings, new-building prices and second hand prices is given in Figure 1, 2 and 3. Figure 4 visualizes the development of scrap prices. The figures give the development of the variables for the last 17 years (1990 to 2007) where most data was available. One can easily observe the steady increase in real earnings per day since 2002, especially for tankers and dry bulk carriers. The same development can be seen for new-building prices and scrap values.

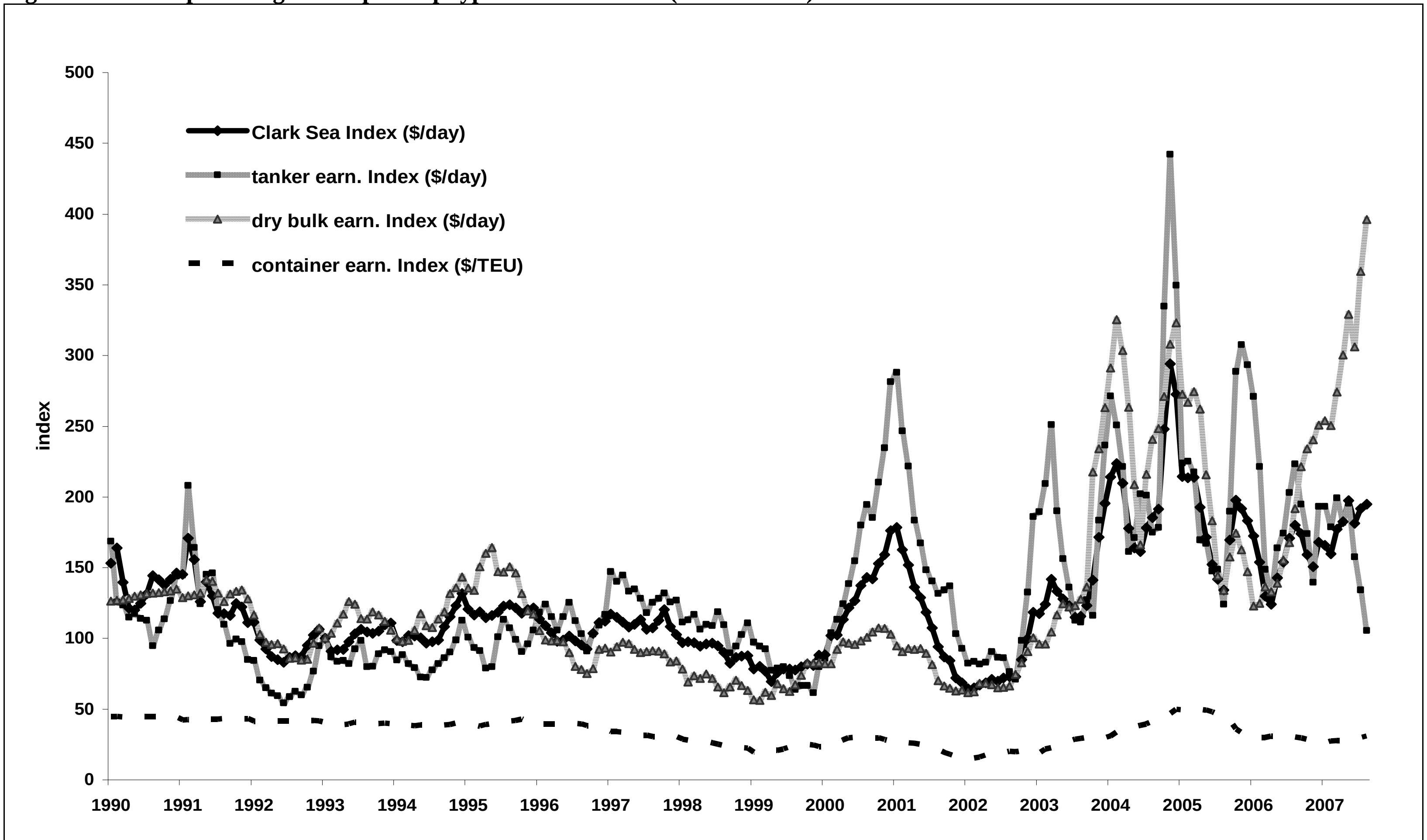
C. Descriptive and nonparametric analysis

To get an idea of the data we start with a nonparametric comparison of the different ship types. Table 2 provides an overview of the dataset. The table lists general ship particular information along with a summary of the changes of such particulars (averages and total) and a summary of time varying variables.

More than one-third of the vessels in our sample data are general cargo vessels (34 percent; 17,879 vessels). We also have many tankers (24 percent; 12,533 vessels) and dry bulk carriers (14 percent; 7,264 vessels). The average number of port state control inspections per vessel is the highest for dry bulk carriers (9.68) followed by container vessels (6.66) despite the fact that these two ship types are not defined as high risk vessels by the various MoU's. General cargo vessels show the highest detention rate (15.1 percent), the highest average number of deficiencies per inspection (2.03) and a slightly higher average number of very serious casualties than all other ship types while dry bulk carriers show a slightly higher number of changes of the main ship particulars than all other ship types.

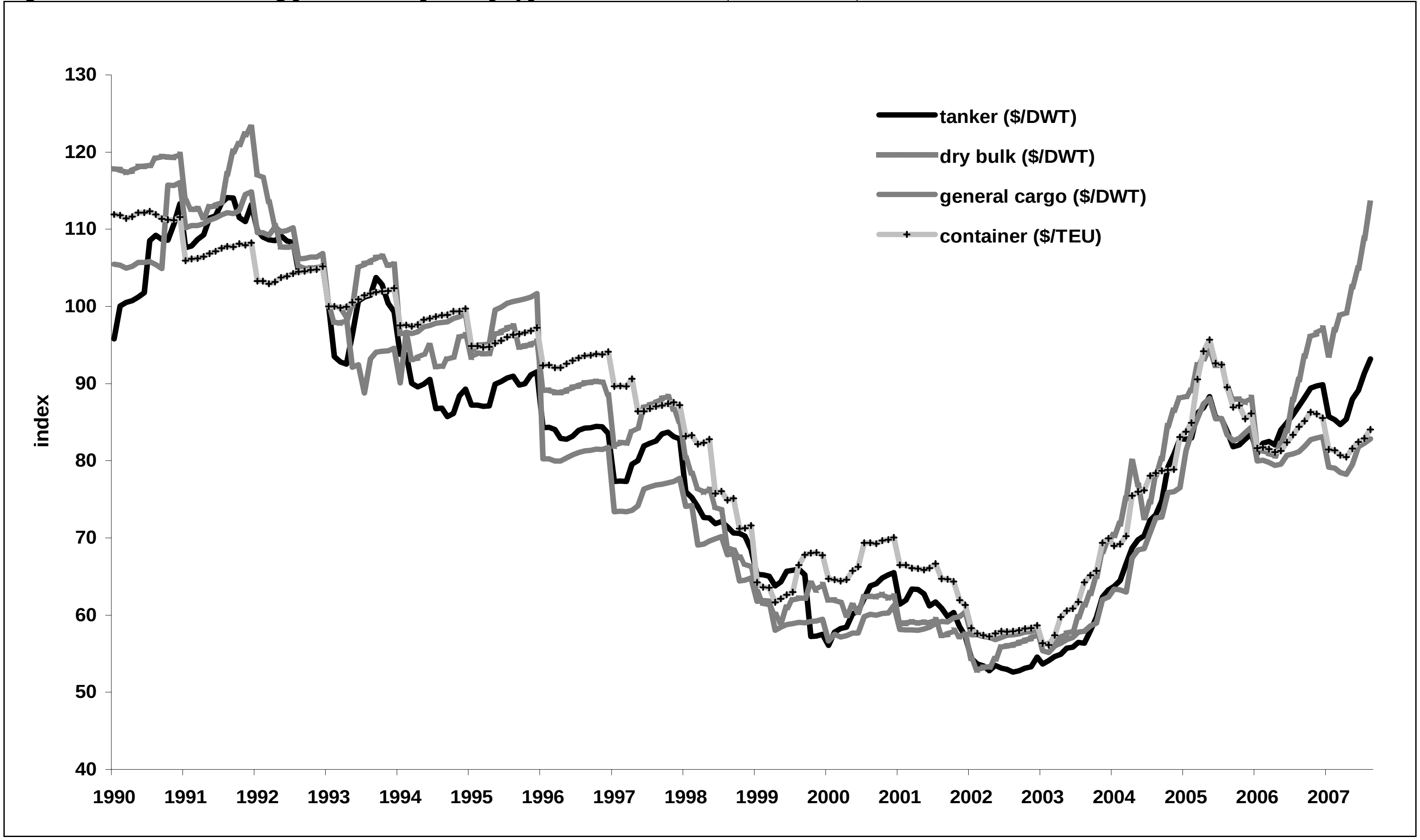
[19] Clarksons Research Studies: Sources and Methods for the Shipping Intelligence Weekly, http://www.clarksons.net
[20] Deadweight is a measurement of how much weight of cargo, equipment, provisions the ship can carry
[21] Lightweight ton is a measurement used in the demolition market to define the weight of a ship ready for sea but without fuel, fresh water and stores
[22] TEU is the abbreviation for "twenty-foot equivalent unit", the measurement used in the container trade
[23] Historical monthly inflation rates can be obtained from http://www.inflationdata.com

Figure 1: Real ship earnings index per ship type from 1990-2007 (1993/01=100)



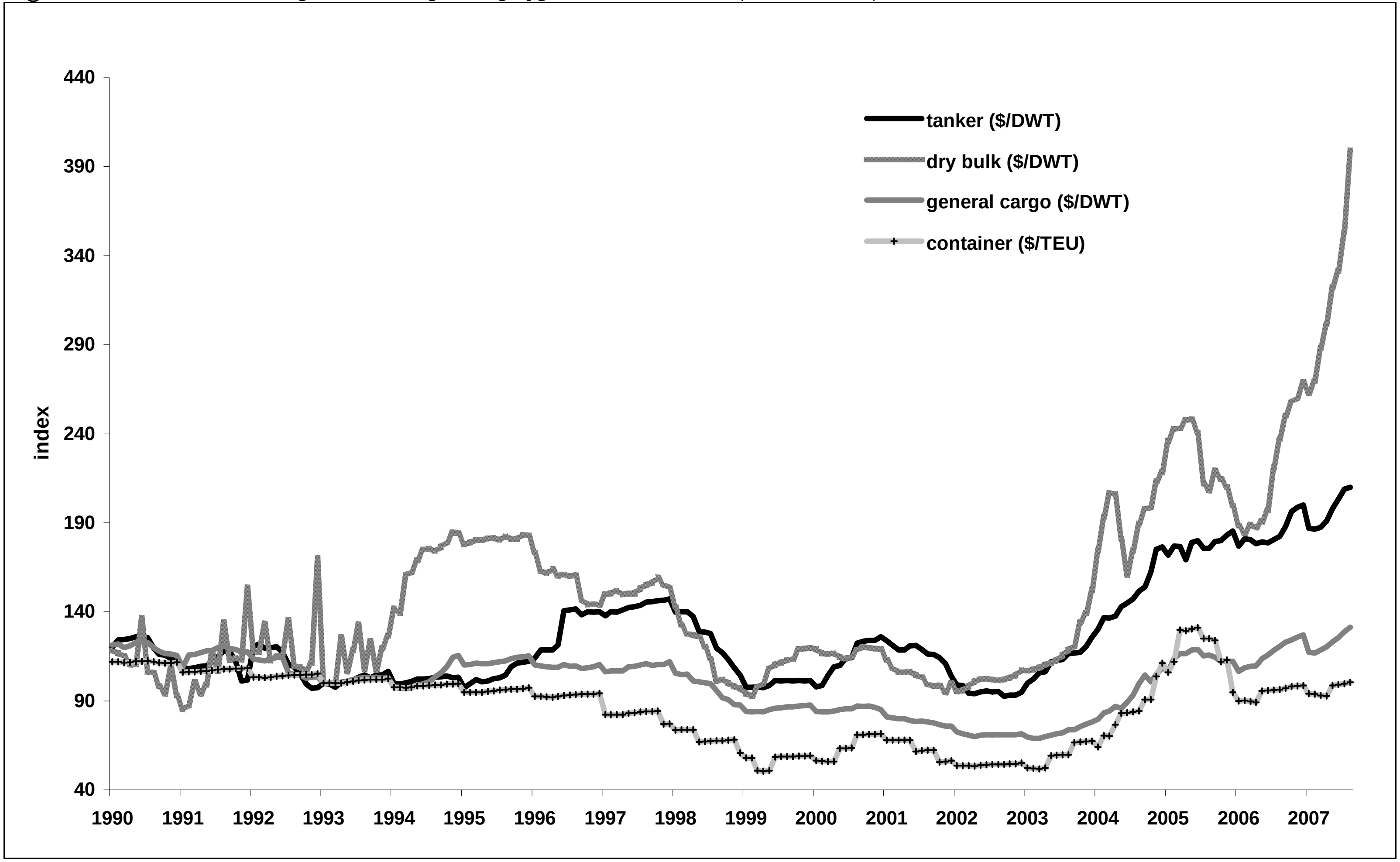
Note: 2007 is only covered until October

Figure 2: Real new-building prices index per ship type from 1990-2007 (1993/01=100)



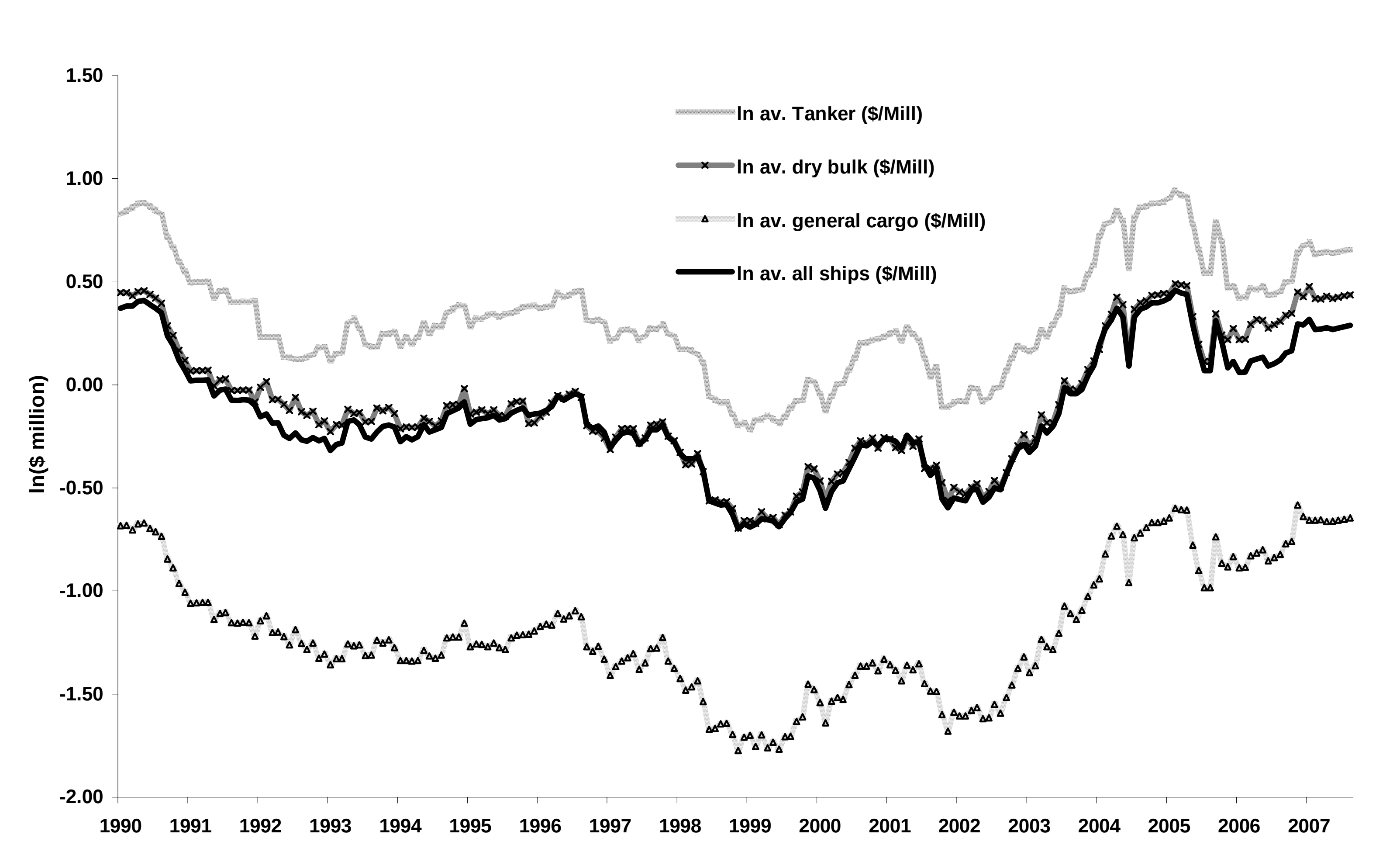
Note: 2007 is only covered until October

Figure 3: **Real second hand prices index per ship type from 1990-2007 (1993/01=100)**



Note: 2007 is only covered until October

Figure 4: Logarithm of real scrap prices per ship type for 1990-2007 (1993/01=100)



Note: 2007 is only covered until October

Table 2: Descriptive Statistics

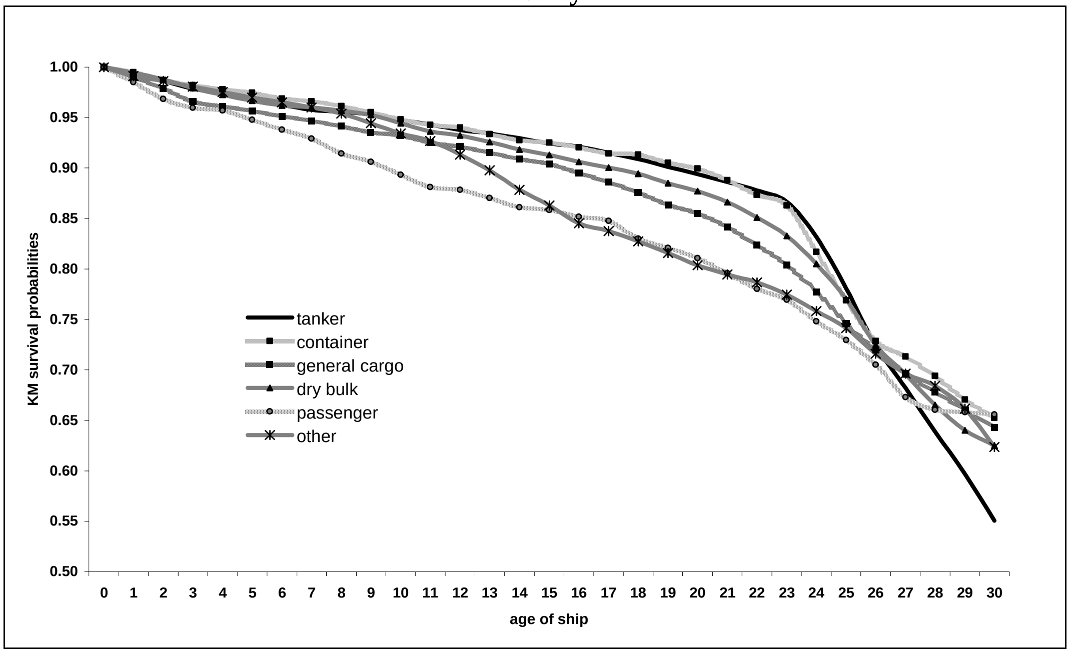
	Container	Tanker	Dry Bulk	General Cargo	Passenger	Other ST
# of vessels	5063	12533	7264	17879	2637	6754
Av. Gross Tonnage (grt)	25926	26567	30882	10639	15496	4262
Percentage double hull	2.8%	4.7%	3.6%	6.1%	4.6%	6.5%
Inspections/Detention						
Total PSC inspections	33,721	49,408	70,334	100,159	7,170	5,492
Total ISM audits	3,596	8,870	5,770	13,931	2,081	3,202
Total RightShip inspections	n/a	517	31,986	2,747	n/a	n/a
Total CDI inspections	n/a	10,785	n/a	n/a	n/a	n/a
Total SIRE inspections	n/a	15,169	n/a	n/a	n/a	n/a
Av. # PSC per vessel	6.66	3.94	9.68	5.60	2.72	0.81
Av. # ISM audit per vessel	0.71	0.71	0.79	0.78	0.79	0.47
Av. # RightShip per vessel	n/a	0.04	4.40	0.15	n/a	n/a
Av. # CDI per vessel	n/a	0.86	n/a	n/a	n/a	n/a
Av. # SIRE per vessel	n/a	1.21	n/a	n/a	n/a	n/a
Percentage detained	5.9%	6.5%	9.4%	15.1%	2.1%	5.1%
Av # deficiencies found	0.95	0.86	1.46	2.03	1.47	1.50
Changes of Ship Particulars						
Total flag changes	7,631	19,561	14,564	26,646	2,359	6,006
Total DoC changes	5,564	12,334	7,998	15,535	1,795	768
Total Owner changes	7,319	19,236	14,732	22,633	1,874	775
Total Class changes	6,416	17,211	12,150	21,793	2,228	4,849
Total Class withdrawals	782	2,617	1,710	3,802	458	2,922
Av. # flag state changes	1.51	1.56	2.00	1.49	0.89	0.89
Av. # DoC changes	1.10	0.98	1.10	0.87	0.68	0.11
Av. # Owner changes	1.45	1.53	2.03	1.27	0.71	0.11
Av. # Class changes	1.27	1.37	1.67	1.22	0.84	0.72
Av. # Class withdrawal	0.15	0.21	0.24	0.21	0.17	0.43
Casualties and Regular Death						
Total # death	228	1,295	510	1,350	142	555
Total # Total loss	24	112	103	677	49	256
Total # very serious accidents	533	1,271	947	2,732	316	197
Total # serious accidents	630	4,093	1,254	1,849	483	263
Total # less serious accidents	533	1,271	947	2,732	316	197
# Very serious/ship	0.11	0.10	0.13	0.15	0.12	0.03
# Serious/ship	0.06	0.04	0.07	0.06	0.13	0.05
# Less serious/ship	0.12	0.33	0.17	0.10	0.18	0.04

n/a = not applicable

Simple Kaplan Meier survival curves of the accident free life of a vessel, that is the time till a ship experiences a very serious accident, a total loss or a demolition, give a first impression of how the probability of ship accidents changes over the lifetime of a vessel. These survival curves are depicted in Figure 5. Separate survival curves are produced for each ship type. The survival of a vessel without any major accident gradually decreases until the vessel is 23 years old, after which it decreases sharply, especially for tankers. A reason for this strong decrease in survival could be the phase out of single hull tankers due to international requirements of Marpol 73/78 (International Convention for the Prevention of Pollution from Ships). Very few alternatives are available for these tankers. It is therefore understandable to see less tankers older than 30. All these tankers have to be scrapped by 2010, the latest, depending on the type of trade and year built.

Comparison of the survival of the different ship types reveal that container vessels and passenger ships show a slightly higher survival probability than general cargo vessels, dry bulk and other ship types. Note that around 65% of the vessel does not experience any (very serious) accidents till they have reached 30. Thus, our data on ship life time duration is heavily censored, in the sense that all is known that they survived more than 30 years. The Kaplan-Meier curves only provide an indication of the survival probability. Kaplan-Meier survival curves ignore the dynamic selection inherent to ship characteristics.

Figure 5: Kaplan Meier Survival (till 1999) for event death, total loss and very serious casualty



To proceed, in the next section we estimate duration models where the individual incidence rate of ships is allowed to depend on the timing of inspections, changes of ship characteristics and on the economic conditions. The duration analysis also controls for time-invariant ship characteristics.

II Duration Analysis

A. Models for the Ship incident rate

We are interested in the effect of safety inspections on ship survival. The ship specific incidence rate is therefore the natural starting point of the specification of the model. We take the time till death, total loss or a very serious accident of the vessel as the duration of interest. The first two events are terminal events, that is, the ship has reached its economic life or is lost, while the very serious accidents can be recurrent. As the age of the ship is measured in days, we assume it is a continuous random variable. Let the variable τ denote current calendar time. We express the incident rate λ of an individual ship at a given point in time in terms of the age of the vessel t, (possibly time-varying) ship particular characteristics $X(t)$, time-intervals (6 or 12 months) since an inspection or ship particular change $Y(t)$ and the current value of some economic indicators $Z(\tau)$. The economic indicators are measured on a monthly basis, the other variables are available on a daily basis. We assume that the incidence rate has a proportional hazard specification.

$$\lambda(t \mid X,Y,Z,\tau) = \lim_{dt \downarrow 0} \frac{\Pr(t \le T < t + dt \mid T \ge t, X(s), Y(s), 0 \le s \le t, Z(\tau))}{dt}$$
$$= \lambda_0(t;\alpha) e^{X(t)'\theta + Y(t)'\beta + Z(\tau)'\gamma},$$

where λ_0 represents the baseline incidence rate, that is the age dependence. We adopt a piecewise constant specification six different intervals (0-4, 5-10, 11-15, 16-20, 21-25, 25+) for the age dependence. For identification we fix the incidence rate of the first interval to one. Thus, the parameters of the age dependence are the difference of the incidence rate at a particular age of a ship compared to a recent built ship (0-4 years old). The three different types of covariates affect the incidence rate proportionally.

To emphasize the different nature of the incorporated covariates we use a notation *x*, *y* and *z*. Concerning *x,* we include ship characteristics that are determined at the moment the ship is built and that remain constant, like the tonnage, the primary ship yard where the vessel was built and whether the ship is a double hull. Some of the ship characteristics change over time. For example, the flag and owner of a vessel change frequently (see Table 2). The effect of the economic environment on the incidence rate is captured by the *economic variables* $z(\tau)$ that were discussed in detail in section I.B. The economic variables change on a monthly basis, in calendar time. We center these variables by their temporal mean and take the logarithm.

The specification of the $y(t)$ variables requires some discussion. These variables are all interval indicators starting from an event that may affect the ship incidence rate. We distinguish three types of such variables: time since an inspection, time since a ship particular change and time since a minor incident. The reason why we construct the variables in such a way is that we believe that these events all have a temporal effect on the incidence rate. We expect that after an inspection the vessel is safer. However, this effect on the incidence rate fades out as the time since the inspection progresses. We decided to allow for a one-year lasting effect of an inspection on the incidence rate.[24] Similarly, we allow for a one-month lasting effect of a class survey overdue, a one-year effect of a class change and, a six-month effect of class withdrawal. For changes in flag, ownership, DoC Company and minor incidences we allow for a two period effect; one (immediate) effect in the first six months after the change and another effect from six to twelve months.

Table 3 provides an overview of the variables included in the model. The variables describe ship life cycles and can be grouped into *ship related variables*, *inspection related variables and*, *economic variables*.

[24] A one-year period seems rather arbitrary. We also estimated a two interval, 6 months and 6-12 months, effect and a linear effect restricted on a one-year time period. The one-year constant effect gave the best interpretable results. A continuous, say log-linear, inspection-effect may lead to the ridiculous result that ten years after the inspection we have a huge effect of this inspection on the incidence rate.

Table 3: Summary of Variables used for ship life cycles

X-variables: ship characteristics	**#**	**Duration interval/Remarks**	**Reason for including in the model**
Ship Yard country	18	individual countries and groups	Reflects construction quality of vessel, important countries are kept individual
Tonnage	1	gross tonnage (logarithm)	To distinguish between trade routes within each market segment
Double Hull	1	Binary variable (0/1)	To reflect type of vessel
Flag	187	individual flag	Reflects legislative enforcement – individual flags
Classification Society	28	individual class	Reflects type of class of vessel and survey quality – individual class societies
DoC Company	5	Grouped into 5 variables	Reflects level of safety management
Ownership	5	Grouped into 5 variables	Reflects level of safety culture
Y-variables: interval variables			
Change of flag	2	6 months and 12 months	Reflects entry of ship into a different market
Change of class	5	12 months includes type of change	Reflects possible technical problem with vessel
Class survey overdue	1	1 month	Reflects technical problem of vessel
Withdrawal of class	1	6 months	Reflects action taken by class in case surveys are overdue
Change of DoC	2	6 months and 12 months	Reflects change of safety management
Change of Ownership	2	6 months and 12 months	Reflects possible transition to a different market
Port State Control	6	1 year	Enforcement of intern. conventions on the port state level
Detained	1	1 year	To account for detention of a vessel and rectification of deficiencies
Total Deficiencies	1	Continuous variable	Total deficiencies at time of inspection
ISM audits	1	1 year	To account for ISM audits which audit the safety management system
CDI inspections	1	1 year	To account for industry inspections – mainly for tankers and dry bulk carriers
SIRE inspections	1	1 year	To account for industry insp. performed by oil majors on oil and chemical tankers
RightShip inspections	1	1 year	To account for industry insp. performed on dry bulk carriers for charterer
Greenaward certified	1	Interval when ship was certified	To account for certification of tankers to be environmentally friendly and safer
Very serious casualty	2	6 month and 1 year	As per IMO definition
Serious casualty	2	6 month and 1 year	As per IMO definition
Less serious casualty	2	6 month and 1 year	As per IMO definition
Z variables: Economic variables			
Earnings or Clarkson's Index	2	$/day or $/TEU for container ships	To account for the economic situation of the shipping market
Second Hand Prices or Ship's Value	2	$/DWT or Value in Mil. $	To account for the second hand market of ships
New-building Prices	2	$/DWT or $/TEU for container ships	To account for the new building market of ships
Demolition Prices or Value	2	$/LDT or value in Mil. $	To account for the demolition market of ships
Total Variables	**296**	**Total possible variables**	**The number of variables varies in each ship specific model**

The *ship related variables* provide the basic risk profile of a vessel. We use the ship specific flag state and classification societies in the model. We include dummies for the shipyard country, the country in which the vessel was primarily built. The important shipyard countries are included while minor ship yards are grouped into regional dummies. For beneficial ownership and the DoC Company, we use a grouping of countries based on UNCTAD and the UN system as follows: OECD countries, developing countries, least developed countries, former east block countries and unknown owners.

Of the many classification societies, which exist today, only 10 are member of the International Association of Classification Societies (IACS). The shipping industry considers IACS as the club of the best societies who developed common implementation rules on structural issues. Recognition of class societies is very important for their role as inspectors on behalf of a flag state. This role is not analyzed in this article. The main reason is that due to confidentiality it is very difficult to obtain data for classification societies when they act as recognized organizations. However, their traditional role as class society responsible for the retaining of the "class" of the vessel and construction is taken into consideration. This is an important role with respect to the safety aspect of a ship. For the variable change of class, we therefore further indicate the type of change (eg. IACS to IACS, Non IACS to IACS, etc.).

The *inspection information* is grouped into port state control inspections, ISM audits, detention[25] of a vessel and the number of deficiencies found during a port state control inspection. Furthermore, three industry inspections, primarily performed on oil tankers and dry bulk carriers, are taken into consideration (CDI, RightShip and SIRE).

A well know issue in duration models is that neglecting unobserved heterogeneity in proportional hazards models leads to spurious negative duration dependence and attenuation bias in the regression coefficients (see e.g. Lancaster (1990) and van den Berg (2001)). We attempted to fit a gamma mixed proportional hazard, but in none of the models this lead to an indication of unobserved heterogeneity or a change in the parameters and, therefore, we do not present the details of the models with unobserved heterogeneity.

To account for the ship-specific economic conditions of each market segment, we estimate separate models for each main ship type, namely general cargo vessels, dry bulk carriers, container vessels, tankers, passenger ships and other ship types.

B. Estimation Results

In principle the duration of interest is the time until the end of a ship's life. Both death and total loss of a vessel indicate the end of a ship's life. In the shipping terminology death of a ship is the end of the ship's economic life, which implies it is considered not profitable to continue to let it float and subsequently the ship is demolished. Death of a ship can be due to economic conditions or due to an accident. Total loss of a ship implies it is destroyed or it has submerged. However, sometimes a very serious casualty implies a total loss. Due to the difficulty to obtain accurate data on the demolition of

[25] A vessel is detained when it is found in severe violation of the international conventions and is only released after the rectification of its deficiencies.

vessels, necessary to make a clear distinction between demolition of a vessel due to total loss and demolition due to a very serious accident, we present two models. First, a model in which we use total loss and death (model type 1) as the event of interest and, second, a model in which we also include, the possibly recurrent, very serious casualties (model type 2) in the incident-event indicator. Both models are estimated for each ship type separately.

An issue is that some of these economic variables are highly correlated. We excluded economic variables with high correlations (> .5), especially second and prices and new-building prices. Most emphasis is given on earnings since this variable is viewed as the most important factor in determining the cash flow that is available to the ship owner, besides the cash flow generated by the other markets. The next important factors are the second hand market and the scrap market. For container vessels, the correlation[26] of all other economic variables with real earnings was more than 90 percent and therefore only real earnings are used.

Table 4 provides the estimates of the hazard coefficients for selected variables for each ship type.[27] A negative coefficient indicates that an increase in the variable reduces the incidence rate, and therefore it is associated with a longer ship life. The time unit is one year.

The most striking result is that the effect of the inspections differs substantially across the ship types and that this effect changes when very serious casualties are included in the incident-event indicator. For dry bulk carriers most port state inspections lead to a decrease in the incidence rate in the year after the inspection, although this is less pronounced when the incident-event indicator includes very serious incidents. Port state inspections also decrease the incidence rate for tankers (only for death and total loss) and for general cargo vessels. For container vessels we only find a significant negative effect of inspections performed by the Viña del Mar. Neither for passenger nor for other ships have we found any significant effect of the port state control inspections on the incidence rate.

A possible explanation why the effect is less pronounced when very serious casualties are added to the models is that neither there cross-recognition across port state control regimes nor industry inspections exits. Therefore ships get over inspected and the effect is becomes less pronounced as we would expect. In addition, every inspection place a time burden on the crew during the time the ship is in a port. Time is critical for port operations. An overload of inspections also cuts into the resting hours of crew and it can therefore have a negative effect on the safety performance. Fatigue of the crew is a known problem in the shipping industry. Unfortunately, little has been achieved to monitor the fatigue problem. A possible remedy is to coordinate inspections accordingly.

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[26] The high correlation of the other economic variables could be partly explained due to the different scaling, namely \$/TEU or \$/mTEU compared to \$/day or \$/DWT for the other ship types. This is due to the different characteristics of the container trade.

[27] The estimated effects of all other variables included, such as flags, classification societies, ownership and the DoC company are listed in Appendix 1 for further reference

Table 4: Main Estimation Results for the Parameters of the Proportional Hazard Models of the Ship Incidence Rate (1=death and total loss, 2=death, total loss and very serious casualty)

Variable	tanker1	tanker2	dry bulk1	dry bulk2	gen. cargo1	gen. cargo2	container1	container2	other ST1	other ST2	passenger1	passenger2
Inspections (PSC, Flag state, Vetting and ISM audits)												
PSC: Paris MoU	-0.392**	-0.027	-0.651**	-0.317*	-0.583***	-0.053	-0.575	0.053	0.078	0.087	-0.417	-0.180
	(0.144)	(0.104)	(0.204)	(0.133)	(0.119)	(0.072)	(0.323)	(0.156)	(0.204)	(0.228)	(0.482)	(0.232)
PSC: Vina del Mar	-0.256	-0.230	-1.106**	-1.166***	-0.605**	-0.707***	-0.978	-1.040*	-0.122	0.098		
	(0.275)	(0.244)	(0.395)	(0.299)	(0.210)	(0.194)	(0.778)	(0.516)	(0.396)	(0.363)		
PSC: Indian Ocean MoU	0.151	0.274	-0.134	-0.220	0.234	0.202	0.603	0.162	0.804*	0.976*		
	(0.214)	(0.182)	(0.321)	(0.247)	(0.175)	(0.148)	(0.436)	(0.325)	(0.394)	(0.405)		
PSC: USCG	-0.594***	-0.143	-1.026**	-0.015	-1.341***	-0.233	0.213	-0.080	0.355	0.567		-0.018
	(0.178)	(0.127)	(0.348)	(0.149)	(0.356)	(0.165)	(0.431)	(0.236)	(0.283)	(0.299)		(0.317)
PSC: AMSA	-1.038	-0.503	-0.970*	-0.570**	0.022	-0.027	-0.369	-0.178	-0.820	-0.415		0.851
	(0.553)	(0.337)	(0.418)	(0.203)	(0.320)	(0.221)	(0.738)	(0.446)	(0.858)	(0.825)		(0.542)
PSC: Caribbean MoU		0.364		0.023	0.358	-0.330						
		(1.018)		(1.253)	(0.908)	(0.908)						
PSC: Detention	0.522	0.264	0.766*	0.533	0.083	0.004	1.106	0.375	-0.026	-0.739	1.992**	0.372
	(0.356)	(0.325)	(0.338)	(0.281)	(0.248)	(0.187)	(0.760)	(0.535)	(0.853)	(1.135)	(0.652)	(0.992)
PSC: # of deficiencies	0.312	0.415**	0.045	0.038	0.332***	0.246***	0.208	-0.104	-1.259	-0.956	-0.241	0.370
	(0.181)	(0.152)	(0.135)	(0.116)	(0.083)	(0.067)	(0.392)	(0.318)	(1.070)	(1.007)	(0.208)	(0.419)
ISM audits	0.284*	0.243*	0.593**	0.437**	0.555***	0.380***	0.265	0.542**	-0.446	-0.516	0.091	0.208
	(0.127)	(0.109)	(0.221)	(0.151)	(0.141)	(0.107)	(0.354)	(0.179)	(0.353)	(0.404)	(0.418)	(0.278)
CDI inspections	-0.644**	-0.054										
	(0.209)	(0.137)										
RightShip inspections	-0.336	-0.097	-0.958**	-0.147								
	(1.013)	(0.580)	(0.362)	(0.150)								
SIRE inspections	-0.832**	-1.494***										
	(0.291)	(0.284)										
Greenaward certified		-0.272										
		(0.699)										
Changes in flag, DoC company, owner and classification society												
Flag changes 6m	-0.615**	-0.318*	-0.725*	-0.669**	-0.625**	-0.164	-0.855	-0.118	0.726**	0.716**	0.665	0.544
	(0.212)	(0.156)	(0.288)	(0.206)	(0.193)	(0.128)	(0.676)	(0.249)	(0.221)	(0.232)	(0.434)	(0.294)
Flag changes 12m	-0.376	-0.325	-0.819*	-0.462*	-0.216	0.001	0.362	0.010	0.660**	0.735**	0.270	0.608
	(0.218)	(0.166)	(0.390)	(0.227)	(0.171)	(0.121)	(0.369)	(0.242)	(0.255)	(0.257)	(0.631)	(0.327)
DoC com. changes 6m	-0.533**	-0.503***	-1.505**	-0.780***	-0.684***	-0.605***	-0.419	-0.272	-0.035	-0.812	-0.369	-0.630
	(0.193)	(0.150)	(0.511)	(0.223)	(0.195)	(0.133)	(0.462)	(0.236)	(0.479)	(0.746)	(0.753)	(0.377)
DoC com. changes 12m	-0.167	-0.231	-1.932**	-0.883***	-0.610**	-0.621***	-0.691	-0.521	-0.136	-0.021	-0.978	-0.983*
	(0.160)	(0.135)	(0.705)	(0.253)	(0.192)	(0.132)	(0.508)	(0.273)	(0.549)	(0.574)	(1.009)	(0.444)
Owner changes 6m	-0.933***	-0.717***	0.290	0.230	-0.490*	-0.081	-0.632	-0.212	-0.230	-0.294	-0.252	-0.570
	(0.253)	(0.184)	(0.271)	(0.193)	(0.193)	(0.125)	(0.442)	(0.240)	(0.463)	(0.528)	(0.804)	(0.361)

Table 4 cont.: Variable	**tanker1**	**tanker2**	**dry bulk1**	**dry bulk2**	**gen. cargo1**	**gen. cargo2**	**container1**	**container2**	**other ST1**	**other ST2**	**passenger1**	**passenger2**
Owner changes 12m	-0.976***	-0.399*	0.160	0.025	-0.056	0.068	-0.410	-0.012	-0.078	-0.534	0.521	-0.438
	(0.256)	(0.161)	(0.296)	(0.218)	(0.160)	(0.115)	(0.393)	(0.214)	(0.430)	(0.521)	(0.539)	(0.350)
Class withdrawals 6m	3.838***	3.611***	3.769***	3.286***	3.401***	3.118***	2.964***	2.729***	2.452***	2.531***	3.388***	2.872***
	(0.081)	(0.070)	(0.134)	(0.107)	(0.077)	(0.066)	(0.216)	(0.170)	(0.150)	(0.154)	(0.223)	(0.170)
Class overdue 1m	1.063***	0.997***	0.169	0.220	1.583***	1.501***	1.345*	0.929	0.890*	0.934**	0.467	0.201
	(0.280)	(0.272)	(0.483)	(0.455)	(0.194)	(0.182)	(0.560)	(0.571)	(0.354)	(0.359)	(1.047)	(1.015)
Changes in class												
IACS to IACS 12m	0.279**	0.263**	0.280	0.562***	0.451***	0.626***	1.078***	0.909***	1.008***	1.045***	0.207	0.882***
	(0.096)	(0.086)	(0.167)	(0.133)	(0.086)	(0.073)	(0.264)	(0.197)	(0.166)	(0.178)	(0.372)	(0.188)
IACS to NIACS 12m	-0.206	-0.216	-0.326	0.196	0.445	0.581**	0.028	0.193	-0.110	0.119		
	(0.337)	(0.288)	(0.657)	(0.396)	(0.253)	(0.202)	(0.480)	(0.466)	(0.905)	(0.810)		
NIACS to NIACS 12m	1.077***	0.901***	0.386	0.772**	0.995***	0.935***	0.612	0.447	1.314*	1.510*		-1.001
	(0.213)	(0.210)	(0.366)	(0.291)	(0.144)	(0.135)	(0.642)	(0.554)	(0.668)	(0.684)		(1.083)
NIACS to IACS 12m	0.022	0.452		0.616	0.119	0.335	0.659	1.330*				
	(0.496)	(0.325)		(0.436)	(0.336)	(0.305)	(1.141)	(0.554)				
Class change unknown 12m	0.122	-0.101	0.624**	0.377	0.461***	0.478***	1.270***	0.782**	-0.022	0.195	-0.151	-0.201
	(0.131)	(0.119)	(0.230)	(0.207)	(0.106)	(0.090)	(0.347)	(0.280)	(0.123)	(0.132)	(0.352)	(0.241)
Economic variables												
Earnings (in logs)	-0.232*	-0.154	-1.068***	-1.311***	-0.027	-0.023	0.474	0.953***	-0.758***	-0.689***	n/a	n/a
	(0.098)	(0.081)	(0.291)	(0.211)	(0.137)	(0.118)	(0.276)	(0.184)	(0.126)	(0.130)		
New-building prices (in logs)	0.688	1.250*	n/a	n/a	n/a	n/a	n/a	n/a	0.628*	0.642*	n/a	n/a
	(0.835)	(0.597)							(0.276)	(0.287)		
Second hand prices (in logs)	0.608	0.380	n/a	n/a	0.229	1.253***	n/a	n/a	-0.859**	-1.022**	n/a	n/a
	(0.690)	(0.486)			(0.219)	(0.168)			(0.298)	(0.315)		
Scrap prices (in logs)	n/a	n/a	1.713***	2.131***	0.093	-0.107	n/a	n/a	n/a	n/a	n/a	n/a
			(0.392)	(0.295)	(0.159)	(0.140)						
Previous accidents												
less serious 6m	-1.030	0.083	-0.522	0.723*	-0.477	0.580		-0.016	0.703	0.453		0.909**
	(1.037)	(0.487)	(0.660)	(0.324)	(0.714)	(0.348)		(0.522)	(0.643)	(0.790)		(0.340)
less serious 12m	0.052	0.576	-0.522	0.142	-0.675	-0.533		-0.016	0.611	0.859		0.111
	(0.621)	(0.454)	(0.660)	(0.485)	(0.627)	(0.444)		(0.522)	(0.649)	(0.684)		(0.605)
serious 6m	-1.420	-1.676*	0.422	0.084	-0.691	-1.321*	-1.131*	-0.392	0.321	0.644	0.608	0.918
	(0.753)	(0.812)	(1.004)	(0.686)	(0.592)	(0.548)	(0.466)	(0.951)	(0.560)	(0.565)	(1.065)	(0.487)
serious 12 m	0.944*	0.709*	-0.076	0.295	-0.846	-0.308	-1.131*	1.158*	-0.130	0.031	0.608	0.883*
	(0.425)	(0.320)	(1.033)	(0.524)	(0.605)	(0.367)	(0.466)	(0.559)	(0.620)	(0.645)	(1.065)	(0.440)
very serious 6m	-0.984	n/a	0.612	n/a	1.100*	n/a		n/a	2.250***	n/a		n/a
	(1.041)		(0.995)		(0.435)				(0.662)			
very serious 12m	1.251**	n/a	-0.207	n/a	1.285***	n/a		n/a	0.772	n/a		n/a
	(0.472)		(0.777)		(0.321)				(0.898)			

Table 4 cont.: Variable	**tanker1**	**tanker2**	**dry bulk1**	**dry bulk2**	**gen. cargo1**	**gen. cargo2**	**container1**	**container2**	**other ST1**	**other ST2**	**passenger1**	**passenger2**
Duration dependence, tonnage and double hull												
Tonnage (ln)	0.258***	0.192***	0.367***	0.314***	0.135***	0.077***	0.337***	0.227***	-0.122***	-0.104***	-0.070	-0.016
	(0.026)	(0.023)	(0.053)	(0.043)	(0.022)	(0.020)	(0.069)	(0.049)	(0.030)	(0.030)	(0.060)	(0.045)
Double Hull	-0.471**	-0.303	-0.457	0.127	-0.542***	-0.432***	-1.493*	-0.974*	0.051	0.027	0.029	-0.551
	(0.174)	(0.158)	(0.333)	(0.191)	(0.148)	(0.125)	(0.635)	(0.402)	(0.155)	(0.153)	(0.486)	(0.357)
5 to 10 years	-0.598*	-0.467**	-0.852*	-0.243	-0.858***	-0.365*	-1.565*	0.048	0.259	0.202	-1.157*	0.475*
	(0.234)	(0.160)	(0.367)	(0.209)	(0.218)	(0.149)	(0.777)	(0.209)	(0.216)	(0.235)	(0.555)	(0.237)
11 to 15 years	-0.365	-0.192	-1.087*	0.026	-0.750***	-0.148	-1.619	0.085	0.691***	0.619**	-0.180	0.171
	(0.239)	(0.160)	(0.434)	(0.206)	(0.195)	(0.140)	(1.042)	(0.261)	(0.192)	(0.208)	(0.431)	(0.262)
16 to 20 years	-0.309	0.146	-0.256	0.156	0.111	0.415***	0.576	0.499	0.662***	0.687***	-0.081	0.391
	(0.240)	(0.159)	(0.263)	(0.194)	(0.161)	(0.125)	(0.545)	(0.287)	(0.186)	(0.200)	(0.401)	(0.257)
21 to 25 years	1.622***	1.145***	1.152***	1.049***	1.040***	0.999***	2.524***	1.695***	0.808***	0.855***	0.613	0.923***
	(0.172)	(0.128)	(0.209)	(0.159)	(0.149)	(0.117)	(0.380)	(0.204)	(0.178)	(0.190)	(0.350)	(0.237)
> 25 years	2.231***	1.731***	1.339***	1.303***	1.088***	1.056***	3.030***	2.031***	1.565***	1.707***	1.190***	1.124***
	(0.189)	(0.138)	(0.237)	(0.180)	(0.156)	(0.124)	(0.406)	(0.224)	(0.174)	(0.184)	(0.289)	(0.212)
Constant	-9.530***	-8.024***	-9.615***	-8.186***	-8.365***	-7.262***	-12.344***	-8.768***	-5.030***	-5.921***	-7.799***	-6.086***
	(0.534)	(0.420)	(0.679)	(0.530)	(0.411)	(0.342)	(0.848)	(0.593)	(0.506)	(0.561)	(0.983)	(0.703)
Log-likelihood	662.787	-189.879	213.223	-474.869	-521.089	-1834.959	-6.540	-584.243	-776.823	-627.112	-103.164	-479.445

*Note: * p<0.05, ** p<0.01, *** p<0.001, n/a=not applicable*

A counterintuitive result seems the positive effect of detention on the incidence rate (model 1) for dry bulk carriers and passenger vessels. One would expect that detaining a ship is a very strong remedy to rectify deficiencies, because it prevents a substandard vessel from continuing operating. However, our results indicate that the timing of the release from detention is perhaps not correct and subsequently a substandard vessel is released too early from detention. Another reason for the positive effect could be that deficiencies are not followed up correctly – in particular if they are not serious enough to be detainable deficiencies. The positive effect of the number of deficiencies for tankers (model 2) and general cargo (model type 1 and 2) supports this interpretation and applies to all types of deficiencies found. One could improve the release from detention by establishing a system which evolves the flag state administrations. This puts more pressure on flag states to react because a ship owner only chooses a flag which reacts on a detention. Detention can mean a substantial loss of revenue of a ship owner.

For all ships, except for passenger and other ships, the coefficients for the ISM audits are positive which implies that the incidence rate increases in the year after inspection. This might be caused by an improper implementation of the ISM code or due to a selection of bad ships. Industry inspections (vetting inspections) performed on oil tankers, chemical tankers and dry bulk carriers show the expected negative effect on the incidence rate.

The variables indicating the changes of ship particulars over its lifetime give mixed results. A change of flag decreases the incidence rate for tankers, dry bulk carriers and general cargo while it increases the incidence rate for other ship types. The effect of a flag change seems to be confined to the first half a year after the flag has changed. A change of DoC company also decreases the incidence rate within a period of six months for tankers, dry bulk carriers and general cargo vessels for both model types while it is not significant for any other ship types. For the period of 6 months to 1 year, a change of DoC company decreases the incident rate for dry bulk carriers, general cargo vessels and passenger vessels (type 2 model only). A change of ownership decreases the incidence rate for tankers (for 6 and 6-12 months) and general cargo vessels (only within 6 months) but is insignificant for any other ship type.

At first impression the decrease in the hazard with respect to the DoC company seems rather odd. The DoC company is the technical manager of the vessels and responsible for the safety quality. If a ship owner decides to change the respective company but remains to hold the vessel, some additional costs are associated with this change in the form of an investment. It could mean that the owner wants to continue to trade and therefore makes an investment in the ship – hence the negative effect. For the change of ownership of a vessel, the negative effect is more difficult to explain. A possible explanation can be found in the characteristics of the tanker market, in which a certain standard needs to be maintained at all levels. This does not apply to the general cargo market which shows the worst safety record of the commercial fleet. For the other ship types, e. g. dry bulk, we would expect to see a positive relationship between the change of ownership and the incidence rate. The entry of the vessel into the second hand market could imply that less money is spent by the owner to maintain the vessel. However, for none of the other ship types, this variable is significant. This finding, that a change in ownership decreases the incidence rate, is new and contradicts to the findings of previous studies.

A class withdrawal is a very important indicator for a substandard vessel as it leads to a big increase in the incidence rate for all ship types and both model types. The same applies for overdue conditions of class with the exception of dry bulk carriers, passenger vessels and container vessels (type 2 models). For class changes we also take the type of change into account. Most class changes lead to an increase in the incidence rate within a time period of 6-12 months.

The effect of a NIACS to NIACS (non IAICS) society change is generally the highest. Note that, contrary to the effect of inspections, the effect of changes in ship particulars hardly differ between model 1 and model 2. This indicates that changes of ship particulars have a similar effect on the incidence rate of the terminal events, death and total loss, as on the incidence rate of the recurrent very serious accidents, while inspections mainly influence the incidence rate of terminal events.

An important contribution of our paper is that we measure the effect of the economic environment on the ship incidence rate. For that purpose we merged the relevant economic indicators on a monthly basis (1978 to 2007) to the shipping data (see section 1.B). For passenger vessels, we do not use any economic variables because for this ship type different market dynamics apply. For some economic variables we do not have the information for all ship types. For these missing variables we use the averages for other ship types. The logarithms of the following economic variables (in real terms, centered by their mean) are used in the models:

- *general cargo ships:* earnings (ClarkSeaIndex), second hand prices, scrap prices (average of all ships);
- *container ships:* earnings;
- *dry bulk ships:* earnings, scrap prices;
- *tankers:* earnings, new-building prices, second hand prices;
- *other ship types:* earnings (ClarkSeaIndex), new-building prices (Average of all ships), second hand prices (average of all ships).

The estimated effects of these economic variables on the ship incidence rate are shown in Table 4. First we discuss the effect of the earnings level on the incidence rate. The earnings per day give an indication of the freight rate market for ships. An increase in earnings for tankers, dry bulk and other ship types decreases the incidence rate while it increases the incidence rate for container vessels (type 2 model). This implies that more money is available for maintenance and improved safety management. This can further imply that substandard ships are not driven from the market at low earnings but that there is always a certain part of the fleet which operates at substandard level. These results do not confirm the the shipping industry and regulators hypothesis that a good market brings more substandard ships into trade. However, this hypothesis seems to hold for container vessels.

The second economic variable is the new-building price of ships, which is an indicator of the new building market for ships. New-building prices evaluated for tankers and other ship types have a positive effect on the incidence rate. The third economic variable, the second hand price of vessels, provide an indication of the sales and purchase market for ships. The results for second hand prices give mixed effects on the incidence rate. For general cargo vessels the effect is positive while for other ship types the effect is negative. The final economic variable we included in our models is the scrap price of ships, which is an indicator for the demolition market. Scrap prices have a positive effect on the incidence rate for dry bulk carriers. This might reflect the specific market characteristics. If demand for vessels is high and ship yards have limited capacity, new building prices rise and waiting periods are extended for the delivery of a new vessel. The owner might be more reluctant in scrapping the vessel until the new vessel has been delivered and might, therefore, invest less in the current vessel's maintenance, thereby slowly degrading its safety quality. In addition, tight supply will make it also more difficult to obtain a vessel on the second hand market. These two combined might explain the positive effect of new-building prices (tankers, other ship types) and second hand prices (general cargo) on the incidence rate.

It is more difficult to explain the negative effect of second hand prices (other ship types) and the positive effect of scrap prices (dry bulk carriers) on the incidence rate. Under normal conditions, this would not be expected since high scrap prices will help the cash flow of the owner. A tentative explanation is that, due to shortage of vessels caused by high freight rates, the owner prefers to keep the vessel in trade and to extend its economic life. For the dry bulk market, earnings (freight rate) and scrap prices have an opposite effect on the incidence rate. An interesting finding is that general cargo vessels seem to be less influenced by the economic situation of the market, especially for the type 1 models.

The effect of previous (very) serious accidents[28] on the incidence rate display mixed results. We allow for an effect on the incidence rate in the first six months after the accident and for a, separate, effect six to twelve months after the accident. The occurrence of a very serious accident (for model 1) leads to strong positive effects for tankers (6-12 months), general cargo and other ship types (first six months). A recent serious accident leads for tankers to first decrease and later, six months after the accident, to an increase in the incidence rate. The initial decrease in the incidence rate, also observed for general cargo and container vessel, may be explained by an initial extra caution after the accident. After six months the cautiousness is loosened and because an accident is an indicator of a substandard ship the incidence rate rises again. A minor, less serious accident only has a positive significant effect for dry bulk carriers and passenger ships for a time period of 6 months.

The two final important variables we discuss are tonnage and whether a ship has a double hull. With respect to tonnage, the results show that larger vessels have a higher incidence rate. This does not hold for other ship types and passenger vessels, which is a surprising result. Normally, smaller vessels are perceived to be more substandard than larger vessels. Double hull ships have a lower incidence rate for tankers (model type 1), general cargo and container vessels (model type 1 & 2).

The duration dependence, the effect of the age of the vessel on the incidence rate, as implied by the estimated piecewise constant baseline hazard shows a similar pattern for all ships (only other ships show a slightly different pattern). In Figure 6 we display the baseline hazard for the type 1 model (death and total loss). A repetitive discussion in the shipping industry is the age dependence of risk. The baseline hazard tells the story. For tankers, dry bulk, general cargo container and passenger vessels, the baseline hazard first decreases until approximately age 15 when it starts to increase in large steps.

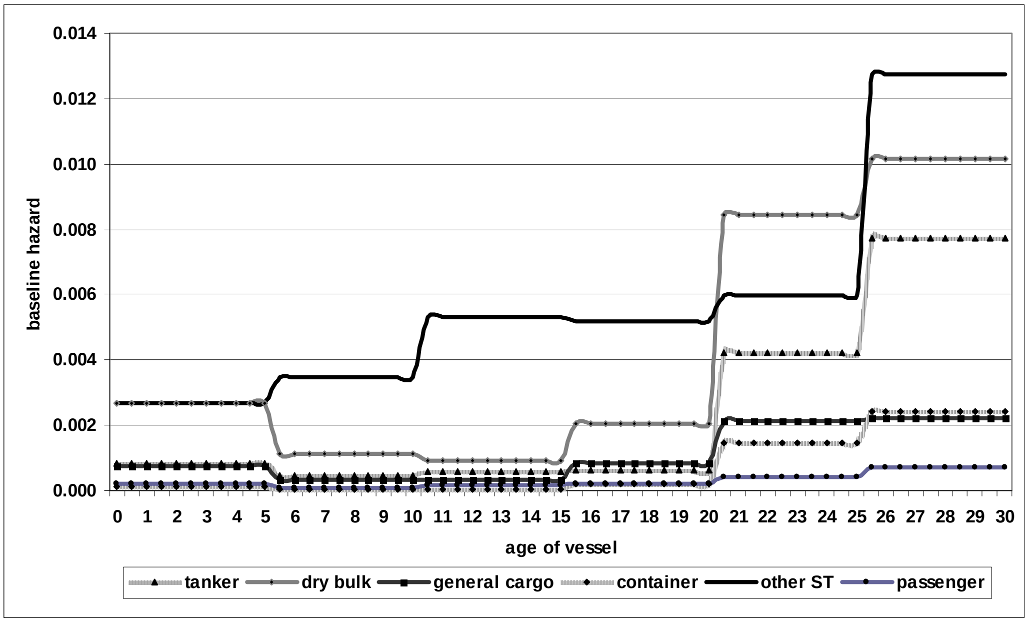
We end with a short discussion on the effect of the remaining variables listed in Table 5 in Appendix A. Note that there is less difference in the results between the type 1 and type 2 models, than for the variables we have discussed so far. The results further show that unknown DoC company locations increase the incidence rate for all ship types and models (except other ship types and passenger ships type 2 models) compared to DoC companies from OECD countries. The same applies for tankers for DoC companies from the former Eastern European countries and for DoC companies from least developed countries for general cargo vessels. DoC companies from developing countries decrease the hazard for general cargo ships (type 2 model).

Beneficial ownership of a vessel shows a similar pattern for unknown owners compared to owners from OECD countries for dry bulk, general cargo and container vessels. Owners from least developed countries also increase the incidence rate for tankers and dry bulk carriers while

[28] Of course, the effect of very serious accidents on the incidence rate is not estimated when we consider model 2 in which very serious casualties are included in the incident-event indicator.

they decrease the incidence rate for general cargo vessels. An interesting result is the negative effect on the incidence rate for owners from former East European countries and developing countries for tankers and other ship types. For passenger vessels, no significant difference was found for ownership compared to OECD countries.

Figure 6: Change in baseline hazard (death and total loss)



The included flag states have mainly a positive effect on the incidence rate. The reference flag are all other flags not in the model. Flags which decrease the incidence rate are China (dry bulk, general cargo and container), Denmark (other ST), Indonesia (general cargo, passenger), Japan (general cargo, passenger), Marshall Islands (other ST), Philippines (general cargo), Singapore (other ST), Sweden (general cargo), South Korea (tanker, general cargo, other ST), US (dry bulk, general cargo and passenger) and Vietnam (general cargo). Important flags such as Panama, Cyprus, Malta, Bahamas, Liberia or the Marshall Islands (except other ST) mainly show a positive effect on the incidence rate. In addition, some of the traditional maritime nations also show a positive effects such as Germany (dry bulk, general cargo and container), Greece (tanker, other ST), Italy (tanker, passenger), Netherlands (general cargo, container), Norway and NIS (tanker), Russian Federation (tanker, general cargo, other ST) and the UK (other ST and passenger).

With respect to the classification societies the impact of class are found both positive and negative can change from positive to negative (or vice versa) per ship type. It reflects the various specializations into ship types of the classification societies compared to the reference category. For tankers, RINA, ABS and Lloyd's Register increase the hazard compared to the reference category NKK while for dry bulk carriers, Germanischer Lloyd, Croatian Register of Shipping, ABS, China Classification Society and Lloyd's Register decrease the hazard compared to NKK. For general cargo vessels, only DNV shows a decreased hazard compared to NKK for type 1 model while Lloyd's shows an increased hazard for type 2 models.

No significant difference could be found for container vessels with the reference category. For other ship types, Lloyd's Register, DNV, Bureau Veritas, the Russian Maritime Register of Shipping and the Korean Register of Shipping (KRS) show an increased hazard compared to the benchmark Germanischer Lloyd. Finally, for passenger vessels, only the KRS show a decreased hazard compared to Germanischer Lloyd.

C. Policy Simulations

This section will provide some graphs to visualize some of the effects on survival of a vessel. In visualizing these effects, we will emphasize on the most important variables, see Table 4. For the construction of the figures we use the following basic ship profile: double hull, tonnage (ln 10.4), flag (Panama), classification society (Lloyd's Register), changes in ship particulars (3 flag changes, DoC company changes and ownership changes at age 10, 15 and 20), 4 class withdrawal and class change (IACS-IACS) at age 5, 10, 15 and 20, 1 less serious casualty at age 5, 1 serious casualty at age 10 and 1 very serious casualty at age 15, DoC company and Owner country of location is a country belonging to the OECD. For the economic variables, averages have been used. In each of the next figures the survival probability for this basic ship profile (denoted by basic survival) is compared to the survival of an alternative scenario.

We start with PSC inspections scenario. Figure 7 visualizes the change in the survival probability for a policy regime with an annual PSC inspection (Paris MoU) compared to the basic survival for dry bulk carriers. For basic ship profile the survival probability gradually decreases over its life cycle to about 55%. When we add an annual Paris MoU inspection to the profile, the survival probability increases, up to a 10%-point when the vessel is aged 35. As the vessel gets older, the effect becomes more pronounced.

Figure 7: Effect of PSC inspections on the survival probability (dry bulk, type 2)

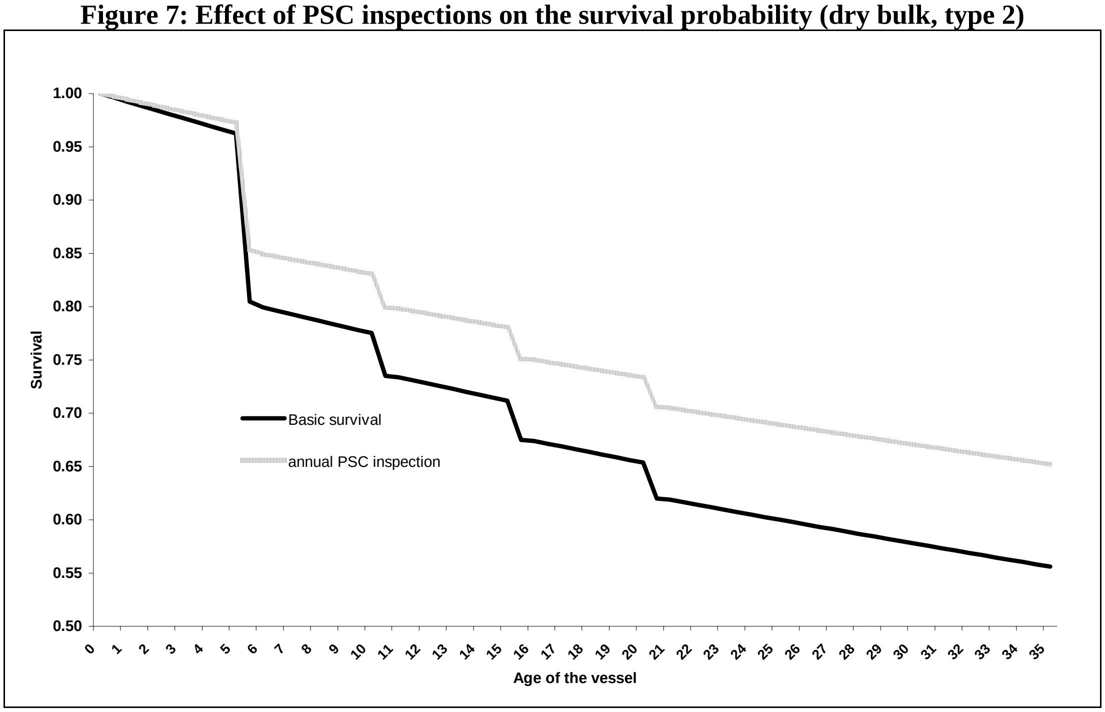


Figure 8 and 9 demonstrate the effect of annual industry vetting inspections on the survival. These SIRE and CDI inspections are only performed on tankers. The effects of these inspections are similar to the PSC inspections depicted in the previous picture. Again the effect of the inspection increases with age.

Figure 8: Effect of SIRE vetting inspections on the survival probability (tanker, type 1)

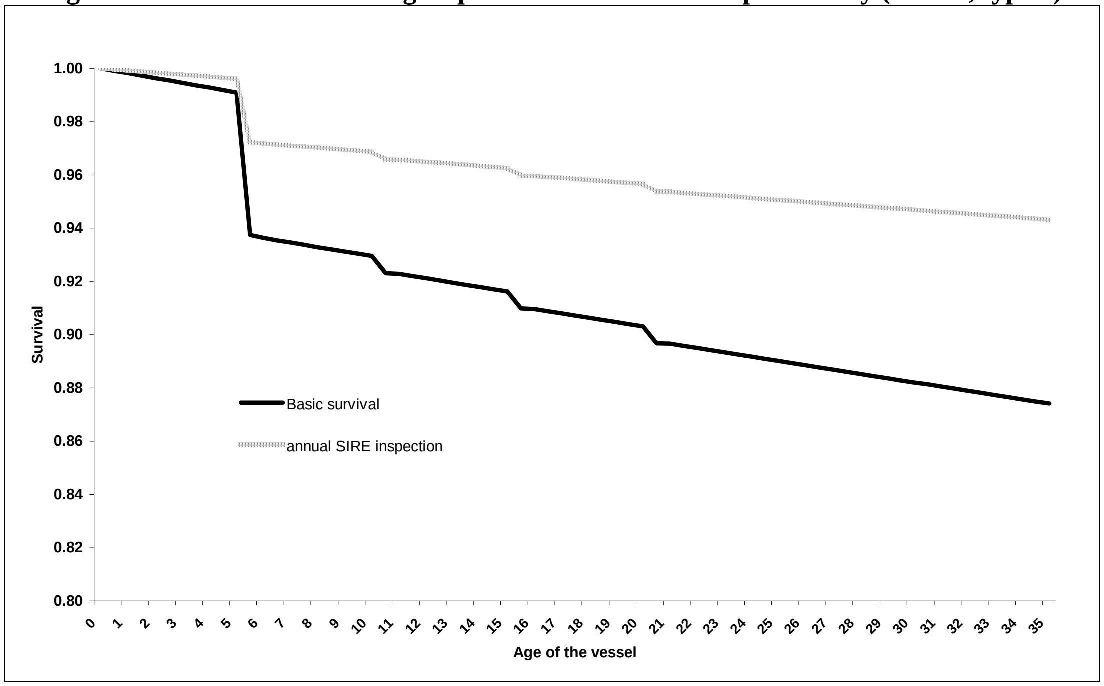


Figure 9: Effect of CDI vetting inspections on the survival probability (tanker, type 1)

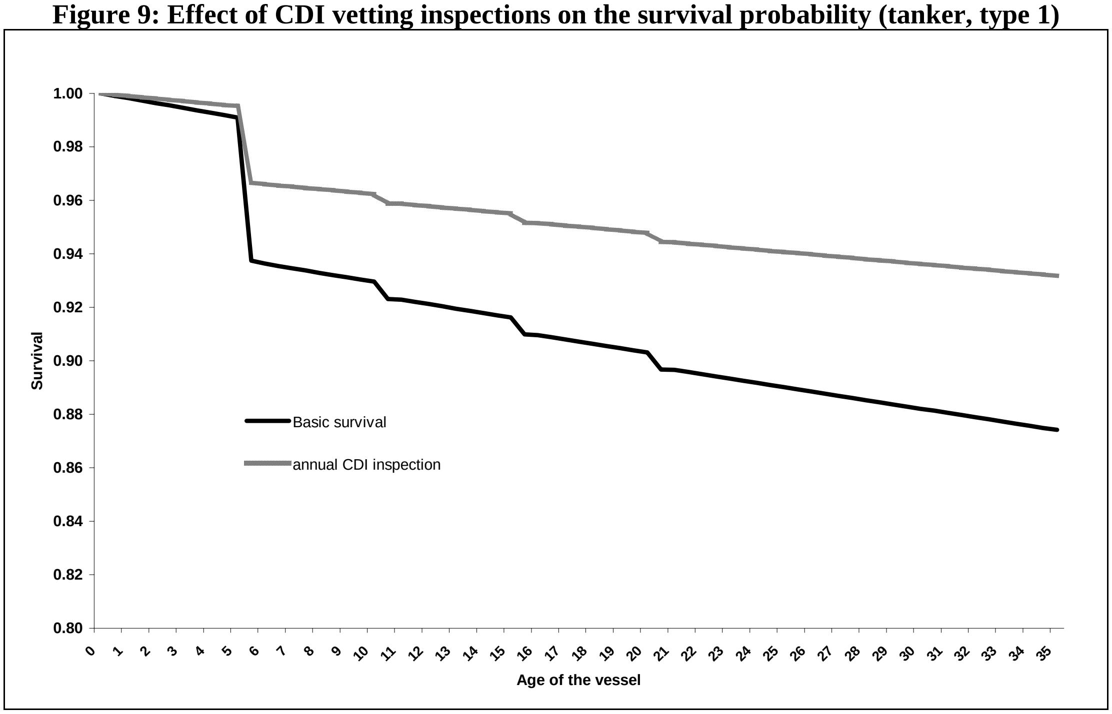
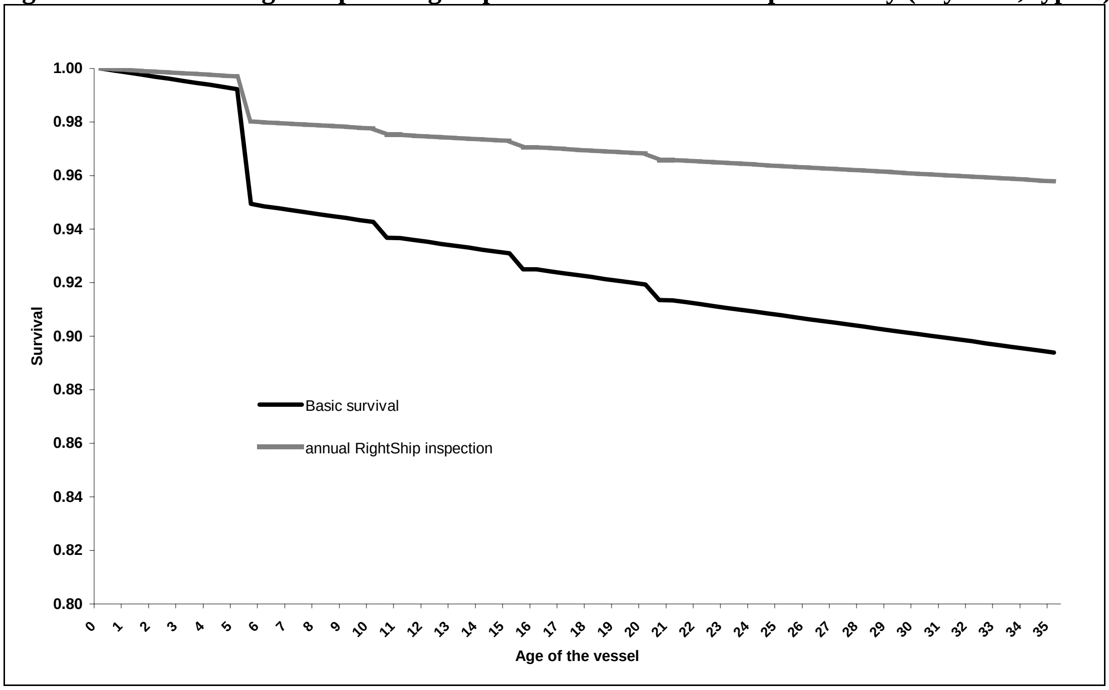


Figure 10 demonstrate the effect of annual RightShip inspections on the survival, an industry inspection only performed on dry bulk vessels, for the type 1 model. The survival curve is similar to the survival curve for CDI and SIRE inspected tankers. The result is interesting as one would expect to see a stronger effect of vetting inspection on dry bulk carriers than of vetting inspections on tankers. The concept of performing inspections on dry bulk carriers only started in 2001 compared to the 70's and 80's for tanker inspections. The two segments of the industry are very different and currently only one type of industry inspection is performed on dry bulk carriers compared to the double inspections performed on tankers.

Figure 10: Effect of RightShip vetting inspections on the survival probability (dry bulk, type 1)



The results show that the risk of death or total loss for tankers and dry bulk carriers is low and that the shipping industry is a relatively safe industry. Inspections decrease the risk based on annual inspections.

Figure 11 shows the combined effect of all types of annual inspections - port state control, vetting inspections and ISM audits, on the survival of tankers. The survival probability is calculated for both types of models and the difference in survival compared to the basic ship profile is shown. The survival probability decreases faster for the type 2 models (total loss, death and very serious casualty) compared to the type 1 models (only total loss and death). The effect of the combined inspections on the survival probability is about 11% (type 1) and 19% (type2) at age 30. This is an accumulation of the effect over the lifetime of a ship.

However, when we compare these results with the inspection effects in the previous graphs we see that the effect of the combined inspections hardly change if more inspections are performed. This is further visualized in Figure 12 for the type 1 model. This graph combines the basic survival with survival probabilities of annual PSC inspections and annual industry inspections (both types are considered: CDI and SIRE). If the ship is not inspected, the survival probability decreases gradually to 0.87 at age 35. With annual PSC inspections, survival increases to 0.91 at age 35, a difference of 4%. With the addition of each of the industry inspections (annually), the marginal increase in survival is 2% and 1%, respectively. Hence, each additional inspection type only adds a small effect in decreasing the risk of an accident for a vessel.

We conclude that these results indicate that too many inspections are performed on ships (in particular tankers) and that the benefit of an additional inspection is negligible. This further reflects the lack of cross-recognition and coordination of inspection efforts amongst port state control inspections and with industry inspections. The inspections are not coordinated and only limited consultation on the outcome of other inspections is made. While industry inspections do consult the outcome of port state control inspections, if the data is readily available, port state control inspections do not consult the outcome of industry inspections. As a result a vessel could easily be inspected several times within a short time period.

Figure 11: Combined effect of inspections on the survival probability (tanker, model type 1&2)

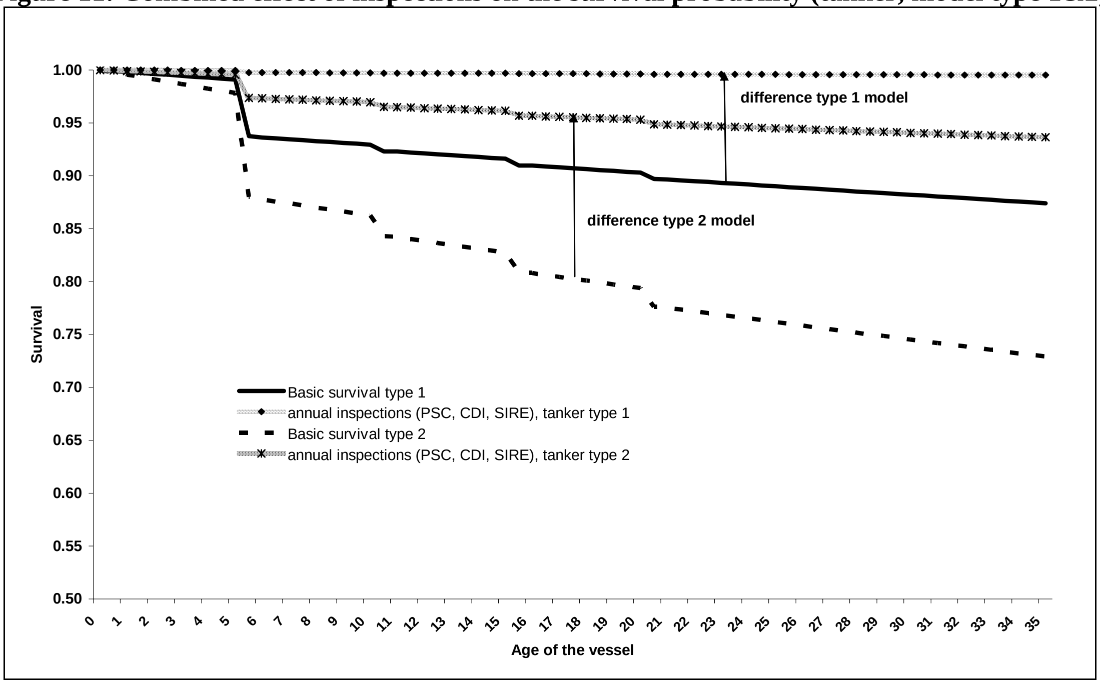
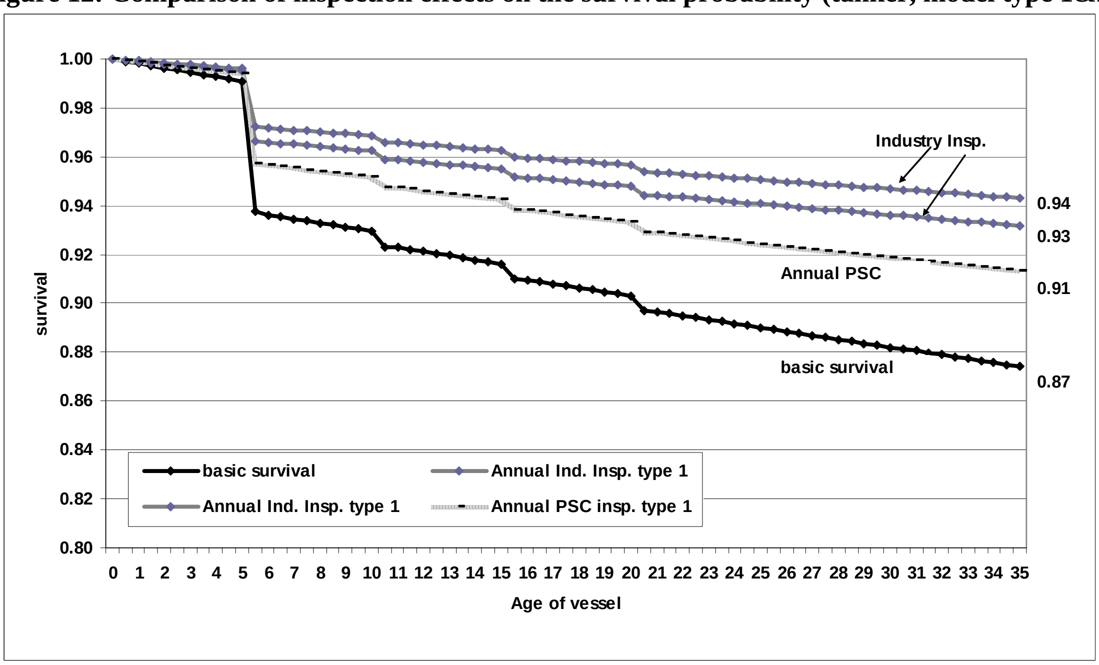


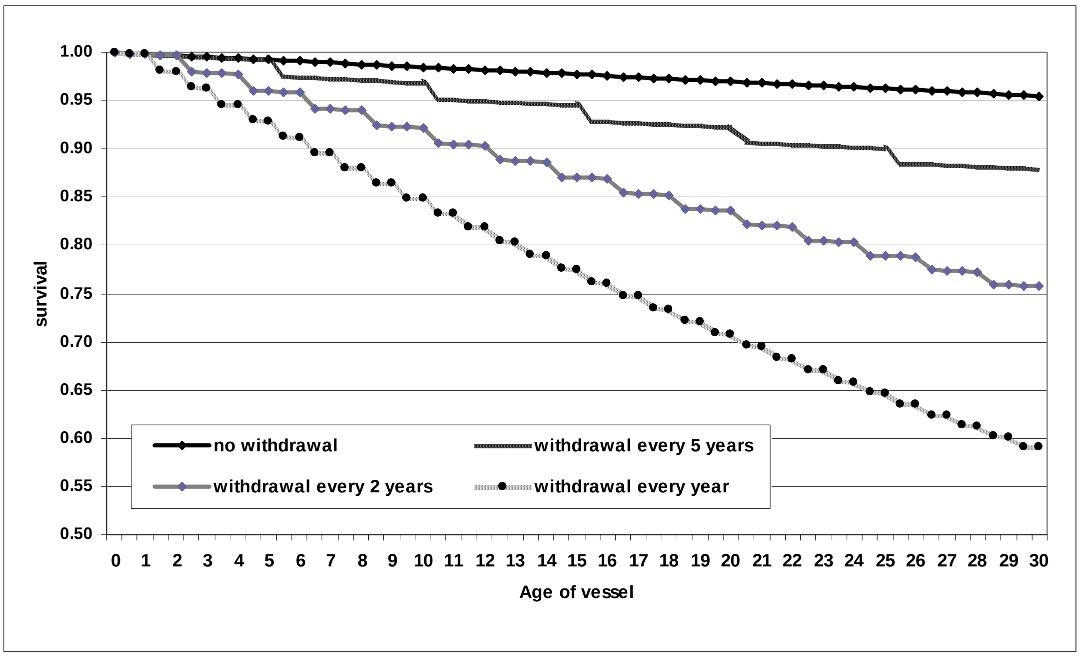
Figure 12: Comparison of inspection effects on the survival probability (tanker, model type 1&2)



Figures 13 and 14 visualize the effect of class withdrawals and type of classification societies changes (e.g. IACS to IACS, NIACS to IACS etc.) over the ships life cycle. We slightly adjust our basic ship profile. For the class withdrawals, depicted in Figure 13, the reference category is now without class withdrawals while for class changes, depicted in Figure 14, the reference category is now without class changes. In both cases we assume that no changes in the other ship particulars occur. The other aspects of the basic ship profile remain the same.

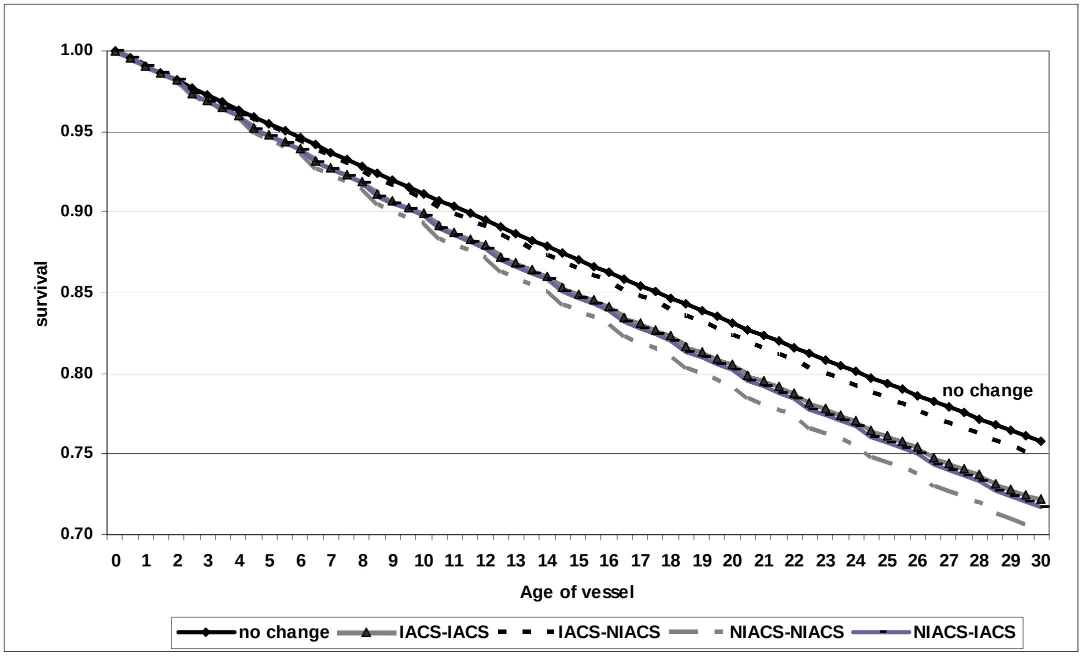
Figure 13 clearly demonstrate the effect of a class withdrawal on the survival probability for a general cargo vessel (type 2 models). Four different scenarios are presented – no class withdrawals, a withdrawal every 5 years, a withdrawal every 2 years and a withdrawal every year. The gap in the survival probability between the no withdrawal scenario and the other scenarios gradually increases. Class withdrawal can be seen as a strong indicator of a substandard vessel. A policy implication for this finding is the need to develop legislation which enhances transparency and the reporting requirements of classification societies when classification is withdrawn. The European Union (EU) in its recast directive has this requirement for classification societies which are recognized by the EU. But it currently lacks enforcement since the information on class withdrawals is not readily made available in a combined format for the regulators, this holds in particular for port state control officers and industry inspections.

Figure 13: Effect of class withdrawals on the survival probability for general cargo (type 2)



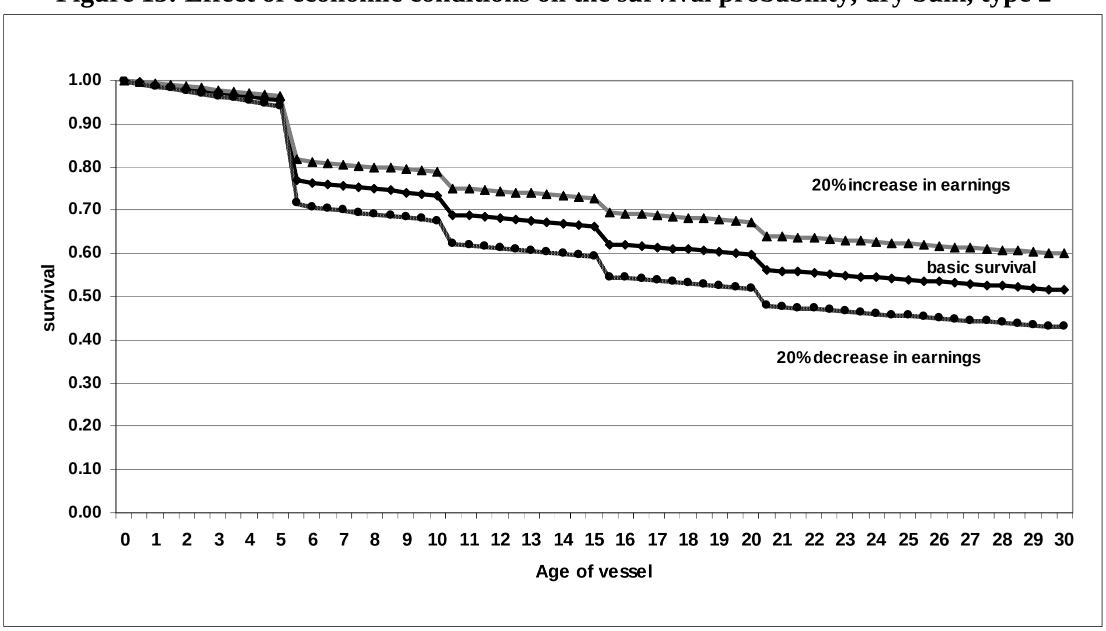
All type of class changes, either within IACS or between IACS and Non-IACS classification societies, clearly decrease the survival probability (see Figure 14). This is consistent across ship types. The effect is the strongest for changes within the NIACS class. An interesting finding is that the effect of a change from IACS to NIACS class is the smallest. This is in contrast with the industry perception. They perceive the group of IACS classification societies as the best class societies. A direct policy implication is to enhance transparency amongst class societies with reference to transfer of class, not just within IACS but also amongst all types of class transfers. Similar to the information available on class withdrawals, the change or transfer of class from one society to another is not readily available in combined format. It is therefore difficult to include these data in the risk profiling of vessels to target for inspections.

Figure 14: Effect of changes in ship particulars on the survival probability, dry bulk, type 2



The last graph in this section visualizes the effect of the ship earnings on the survival probability. Again as reference scenario we apply the basic ship profile as used in construction of Figures 7 to 10. Thus, the basic survival represents the survival for a ship with the averages economic data. Two alternative scenarios are considered: an increase- and a decrease in earnings, both by 20%, Figure 15 shows the effect on the survival probability for a dry bulk carrier.

Figure 15: Effect of economic conditions on the survival probability, dry bulk, type 2



An increase in earnings increases the survival probability and vice versa. This finding, as already explained before, contradicts to industry believes. Although earnings are not under direct control of the regulatory framework for safety measures, the results are still of interest to the regulators.

On several occasions, the industry postulated that changes in freight rates explain changes in incident rates. The common perception was that an increase of freight rates brings more substandard vessels into the market and therefore leads to more detentions and incidents. However, we cannot confirm this for most ship types. Only for container vessels this perception seems true. We therefore conclude that other factors than an increase in earnings has induced the increase of incident rates.

III Discussion of Results and Conclusions

This article has investigated the effect of inspections on survival of ships for various types of inspections. It is based on a unique and comprehensive dataset which allows the creation of ship life cycles and the measurement of changes of ship particulars, inspections and economic cycles over the life cycle of a vessel.

The results show that the shipping industry is a relative safe industry and that the incident rate of total loss and death is not very high. Despite the fact that the risk is low, the high economic costs associated with an incident should underline the importance of improving the effectiveness of inspections to prevent such incidents. The results indicate that there is room for improvement in targeting ships for inspections since there is little cooperation amongst port state control regimes and industry inspections. There are too many inspections with little added benefit for certain vessels (e.g. tankers). The positive effect of detention and the number of deficiencies found during an inspection on the survival probability also indicates a lack of rectification of deficiencies and a imperfect follow up. This is also caused by the lack of cross-utilization of inspection data. A direct policy implication is to enhance inspection efforts across the various types of inspection regimes – be it the port state control regimes or industry inspections and to promote data-sharing to improve the targeting of vessels for inspections.

Another interesting finding is that changes of ship particulars have a similar effect on the incidence rate of the terminal events, death and total loss, as on the incidence rate of the recurrent very serious accidents, while inspections mainly influence the incidence rate of the terminal events. In addition, class withdrawal and change of class are strong indicators of substandardness for all ship types. A direct policy implication is to enforce the legal framework to enhance transparency in disclosing information on class withdrawals and changes of class.

With respect to the impact of economic environment, the results show that an increase in earnings for tankers, dry bulk and other ship types decreases the incidence rate while it increases the incidence rate for container vessels (type 2 model). This implies that more money is available for maintenance and improved safety management. This can further mean that substandard ships are not driven from the market at low earnings but that always a certain part of the fleet operates at substandard level. These results do not confirm the hypothesis believed by the shipping industry and regulators that a good market brings more substandard ships into trade. However, this hypothesis seems to hold for container vessels.

As a future research topic, the authors recommend the inclusion of the role of classification societies as recognized organizations. Another path for future research is the inclusion of the ISM auditor into the analysis. The results show a positive effect of ISM audits on the hazard which indicates that there is a lack of implementation of the ISM code. A direct policy implication is a revision of the code and adaptation to the various ship types.

As a final recommendation, the prevention of incidents with high economic costs can be improved by a better coordination of inspections, data sharing and a decrease the number of inspections. More emphasis should be placed on the rectification and follow up of deficiencies.

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Appendix A

Table A1: Estimation Results for the Parameters of the Proportional Hazard Models of the Ship Incidence Rate of Covariates Flag, Class, Ownership and DoC company (1=death and total loss, 2=death, total loss and very serious casualty)

Variable	tanker1	tanker2	dry bulk1	dry bulk2	gen. cargo1	gen. cargo2	container1	container2	other ST1	other ST2	passenger1	passenger2
DoC Company (Reference: DoC Companies from OECD countries)												
Former East European	1.960***	1.653***	0.185	-0.714	-0.232	-0.357			0.829	1.348*	0.195	-0.327
	(0.385)	(0.295)	(0.780)	(0.626)	(0.348)	(0.224)			(0.587)	(0.605)	(0.727)	(0.669)
Developing Countries	-0.046	-0.174	0.015	-0.122	0.057	-0.463***	0.687*	0.253	-0.342	-0.437	0.280	-0.715
	(0.149)	(0.127)	(0.288)	(0.169)	(0.176)	(0.129)	(0.351)	(0.239)	(0.422)	(0.561)	(0.569)	(0.392)
Least Developed Countries	0.560	0.290		-0.275	1.026*	0.500	0.067	0.077				
	(0.475)	(0.456)		(0.750)	(0.399)	(0.323)	(1.017)	(0.903)				
DoC Company unknown	0.667***	0.445***	1.295***	0.540***	1.072***	0.374***	1.022***	0.494***	0.192	0.506*	1.001*	0.309
	(0.094)	(0.076)	(0.167)	(0.101)	(0.126)	(0.075)	(0.261)	(0.137)	(0.204)	(0.251)	(0.391)	(0.222)
Owner (Reference: Owners from OECD countries)												
Former East European	-0.877**	-1.160***	0.696	0.379	-0.262	-0.177	-0.246	-0.741	-0.914**	-0.983**	0.316	-0.499
	(0.340)	(0.304)	(0.507)	(0.398)	(0.181)	(0.158)	(0.537)	(0.625)	(0.345)	(0.302)	(0.510)	(0.440)
Developing Countries	-0.091	-0.175*	-0.114	-0.118	-0.069	-0.118	-0.323	-0.389*	-0.389*	-0.359*	0.023	0.146
	(0.094)	(0.084)	(0.153)	(0.121)	(0.083)	(0.071)	(0.248)	(0.187)	(0.156)	(0.161)	(0.292)	(0.204)
Least Developed Countries	0.714*	0.619*	1.640***	1.279***	-0.571*	-0.531*	0.935	0.243	-0.008	-0.135	0.732	-0.192
	(0.302)	(0.289)	(0.334)	(0.326)	(0.235)	(0.224)	(0.971)	(0.815)	(0.594)	(0.551)	(0.631)	(0.543)
Owner unknown	0.021	-0.041	0.372**	0.395***	0.247**	0.187**	0.941***	0.699***	0.021	0.131	0.467	0.090
	(0.079)	(0.073)	(0.125)	(0.116)	(0.075)	(0.067)	(0.234)	(0.182)	(0.103)	(0.110)	(0.242)	(0.168)
Classification society (Reference: Nippon Kaiji Kyokai/Germanischer Lloyd)												
Registro Italiano Navale (IT)	0.379**	0.342**	0.151	0.265	-0.077	-0.037		-0.559	0.330	0.131	0.169	0.244
	(0.137)	(0.123)	(0.294)	(0.269)	(0.156)	(0.137)		(0.670)	(0.493)	(0.484)	(0.365)	(0.247)
Other Class	0.307	0.283	0.910***	0.943**	0.521	0.455	0.966	0.610	0.382	0.491		
	(0.458)	(0.421)	(0.276)	(0.293)	(0.290)	(0.285)	(0.951)	(0.866)	(0.419)	(0.432)		
Nippon Kaiji Kyokai (JP)	reference	reference	reference	reference	reference	reference	-0.250	0.033	0.011	-0.380	-0.112	-0.189
							(0.326)	(0.237)	(0.298)	(0.283)	(1.188)	(0.766)
Germanischer Lloyd (DE)	-0.255	-0.085	-0.836*	-0.580*	-0.043	0.043	reference	reference	reference	reference	reference	reference
	(0.215)	(0.176)	(0.356)	(0.266)	(0.109)	(0.094)						
Croatian Register of Shipping	0.435	0.699	-1.481*	-1.756*	0.543	0.362						
	(0.688)	(0.502)	(0.627)	(0.788)	(0.350)	(0.295)						
Lloyd's Register (UK)	0.223*	0.208*	-0.543***	-0.298*	0.107	0.216**	-0.269	-0.072	0.926***	0.756***	0.253	0.200
	(0.102)	(0.092)	(0.147)	(0.118)	(0.088)	(0.077)	(0.230)	(0.174)	(0.170)	(0.173)	(0.293)	(0.198)
Det Norske Veritas (NO)	0.200	0.179	-0.331	-0.072	-0.337*	-0.033	-0.861	-0.509	0.500*	0.472*	-0.005	0.161
	(0.117)	(0.104)	(0.190)	(0.150)	(0.148)	(0.124)	(0.624)	(0.390)	(0.217)	(0.227)	(0.443)	(0.242)
No Class Recorded	-0.304	-0.396	-0.365	-0.489	-0.243	-0.197	-0.716	0.177	1.034***	1.063***	0.574	-0.092
	(0.357)	(0.307)	(0.518)	(0.509)	(0.172)	(0.158)	(0.820)	(0.489)	(0.140)	(0.142)	(0.359)	(0.301)

Classification society	tanker1	tanker2	dry bulk1	dry bulk2	gen. cargo1	gen. cargo2	container1	container2	other ST1	other ST2	passenger1	passenger2
Bureau Veritas	0.192	0.098	-0.207	-0.096	-0.156	0.082	-0.073	0.045	0.509**	0.548**	-0.509	-0.112
	(0.119)	(0.109)	(0.155)	(0.127)	(0.100)	(0.088)	(0.267)	(0.194)	(0.192)	(0.202)	(0.319)	(0.220)
American Bureau of Shipping	0.308**	0.272**	-0.800***	-0.486***	-0.134	0.058	-0.585	-0.327	-0.163	-0.221	0.082	0.208
	(0.115)	(0.103)	(0.161)	(0.131)	(0.152)	(0.130)	(0.349)	(0.245)	(0.196)	(0.206)	(0.464)	(0.303)
Russian Mar. Reg. of Shipping	-0.004	-0.044	-0.259	-0.270	-0.154	0.017	-0.148	-0.075	1.688***	1.620***	0.811	0.114
	(0.215)	(0.205)	(0.239)	(0.195)	(0.110)	(0.101)	(0.493)	(0.401)	(0.167)	(0.166)	(0.482)	(0.421)
Korean Reg.of Shipping (KR)	0.014	0.256	-0.254	0.059	0.405*	0.509***	-0.911	-0.353	1.318***	1.373***	-1.700*	-0.245
	(0.366)	(0.282)	(0.286)	(0.227)	(0.187)	(0.152)	(0.692)	(0.410)	(0.374)	(0.395)	(0.716)	(0.750)
China Classification Society	-0.445	-0.395	-0.755**	-0.523*	0.059	0.194	-0.109	-0.220	-0.386	-0.361		-1.367
	(0.256)	(0.230)	(0.283)	(0.231)	(0.184)	(0.173)	(0.340)	(0.281)	(0.587)	(0.582)		(1.196)
Bulgarski Koraben Register	-0.744	-0.611	-0.105	-0.107	-0.580	-0.460	0.356	0.411	0.770	0.893	1.054	0.570
	(0.435)	(0.472)	(1.885)	(1.694)	(0.443)	(0.424)	(0.767)	(0.660)	(0.513)	(0.532)	(0.573)	(0.467)
Flags (Reference: all other flags not in the model)												
Antigua		0.597	1.138*	0.993*	0.075	0.622***	0.349	0.697*	1.039*	0.231		
		(0.934)	(0.549)	(0.433)	(0.270)	(0.150)	(0.427)	(0.272)	(0.521)	(1.024)		
Azerbaijan	-1.643	-0.589				-1.274						
	(1.152)	(0.661)				(1.027)						
Bahamas	1.008***	0.916***	0.521	0.254	-0.005	0.110	0.537	0.471	0.057	0.078	1.206***	0.513*
	(0.173)	(0.152)	(0.320)	(0.246)	(0.161)	(0.123)	(0.408)	(0.319)	(0.265)	(0.275)	(0.320)	(0.239)
Brazil	-0.515	-0.858	1.107***	0.782**	1.328**	0.981*			0.426	0.473		
	(0.630)	(0.622)	(0.295)	(0.278)	(0.409)	(0.383)			(1.434)	(1.524)		
Belize	0.940***	0.822***	-0.118	-0.927	-0.195	-0.166	0.237	0.107	-0.282	-0.127	2.432**	1.277
	(0.196)	(0.197)	(0.939)	(1.019)	(0.190)	(0.178)	(0.602)	(0.538)	(0.427)	(0.419)	(0.913)	(0.806)
Bermuda	0.091	0.283	-0.292	0.163	0.225	-0.074	0.185	-0.391	-0.219	0.064		0.626
	(0.437)	(0.386)	(0.603)	(0.529)	(0.230)	(0.236)	(0.598)	(0.448)	(0.889)	(0.858)		(0.477)
Cayman Islands	-0.330	0.278		-0.380	0.129	0.280	1.464*	1.512*	-0.091	0.093		
	(0.530)	(0.409)		(0.741)	(0.366)	(0.278)	(0.693)	(0.602)	(0.531)	(0.476)		
China	-0.534	-0.519	-1.181**	-1.006**	-1.111***	-1.076***	-1.136	-1.242*	-0.984	-0.822	0.863	0.414
	(0.356)	(0.320)	(0.398)	(0.325)	(0.243)	(0.219)	(0.629)	(0.609)	(0.767)	(0.766)	(0.561)	(0.634)
Cyprus	1.099***	1.072***	0.115	0.083	0.337**	0.305**	0.364	0.527*	0.236	0.160	0.895*	0.246
	(0.186)	(0.172)	(0.210)	(0.164)	(0.113)	(0.102)	(0.344)	(0.257)	(0.242)	(0.242)	(0.400)	(0.343)
Danish Intern. Register					-0.220	-0.364						
					(0.717)	(0.501)						
Denmark	0.695	0.172			0.213	0.140		-0.147	-1.451*	-1.873		-1.038
	(0.457)	(0.438)			(0.362)	(0.288)		(0.857)	(0.724)	(1.029)		(1.035)
France	-0.251	0.155			0.059	-0.224			0.279	0.391		
	(0.432)	(0.383)			(0.434)	(0.407)			(0.364)	(0.393)		
French Territory of the Afars		0.897										
		(0.719)										

Flag	tanker1	tanker2	dry bulk1	dry bulk2	gen. cargo1	gen. cargo2	container1	container2	other ST1	other ST2	passenger1	passenger2
Gibraltar	1.024	1.107*			-0.695	0.515						
	(0.591)	(0.445)			(1.028)	(0.380)						
Germany	0.805	0.741	1.094*	1.426**	1.654***	1.280***	1.846***	1.280***	-1.125	-0.979	0.431	0.795
	(0.793)	(0.648)	(0.430)	(0.445)	(0.279)	(0.226)	(0.367)	(0.251)	(0.748)	(0.750)	(0.335)	(0.452)
Greece	1.051***	0.998***	0.208	0.186	-0.236	-0.132	0.501	-0.243	0.733**	0.763**	0.603	0.271
	(0.168)	(0.146)	(0.290)	(0.210)	(0.310)	(0.286)	(0.719)	(0.715)	(0.251)	(0.255)	(0.384)	(0.248)
Hong Kong	0.777*	0.338	0.137	0.102	0.491*	0.247	0.655	0.684*	-0.609	-0.577	0.270	-0.190
	(0.306)	(0.301)	(0.369)	(0.238)	(0.240)	(0.242)	(0.405)	(0.338)	(1.029)	(1.081)	(1.101)	(0.756)
India	0.669**	0.772***	0.515	0.226	0.352	0.339	2.736***	2.286***	0.395	0.599	0.669**	0.772***
	(0.215)	(0.194)	(0.301)	(0.301)	(0.235)	(0.199)	(0.555)	(0.344)	(0.517)	(0.527)	(0.215)	(0.194)
Indonesia	0.136	0.214	-0.116	-0.544	-0.759*	-0.870*	-0.036	-0.438	-0.604	-0.487	-1.832	-1.878**
	(0.330)	(0.300)	(1.410)	(1.240)	(0.376)	(0.354)	(0.576)	(0.517)	(0.419)	(0.439)	(1.073)	(0.718)
Iran	0.888*	0.871**	1.181**	1.047***	0.355	0.369	1.821***	1.448***			2.984***	1.856*
	(0.353)	(0.328)	(0.382)	(0.298)	(0.199)	(0.195)	(0.432)	(0.350)			(0.670)	(0.802)
Isle of Man	-0.842	0.004		-0.482	-0.578	0.428	-0.667	0.484	0.499	0.238		
	(0.828)	(0.495)		(0.951)	(0.840)	(0.456)	(0.669)	(0.635)	(0.730)	(1.033)		
Italy	0.932***	0.845***	-0.653	-0.449	0.327	0.288		-0.189	-0.575	-0.731	1.462**	0.448
	(0.204)	(0.179)	(0.819)	(0.540)	(0.258)	(0.216)		(0.969)	(0.564)	(0.551)	(0.456)	(0.323)
Japan	-0.161	-0.021	-0.346	-0.528	-1.168***	-1.257***	0.617	-0.461	0.157	0.205	-0.876	-0.899*
	(0.291)	(0.227)	(0.539)	(0.457)	(0.194)	(0.171)	(1.108)	(1.032)	(0.193)	(0.197)	(0.752)	(0.456)
Liberia	0.998***	0.907***	0.280	0.279	0.245	0.177	-0.484	0.278	0.867**	0.928**	0.459	0.195
	(0.143)	(0.123)	(0.241)	(0.184)	(0.186)	(0.158)	(0.554)	(0.296)	(0.302)	(0.320)	(0.520)	(0.485)
Luxembourg		1.306*										
		(0.554)										
Madeira	1.953***	1.611***			0.335	0.301		1.745			0.715	-0.592
	(0.350)	(0.358)			(0.347)	(0.307)		(1.238)			(0.439)	(0.719)
Malaysia		-0.777	1.673**	0.693	-0.207	-0.328	0.554	0.435	-1.257	-0.898		
		(0.563)	(0.566)	(0.700)	(0.316)	(0.334)	(0.537)	(0.432)	(0.924)	(0.918)		
Malta	0.813***	0.787***	0.225	0.065	0.082	0.253**	-0.067	0.090	-0.168	-0.244	0.928*	0.257
	(0.133)	(0.121)	(0.173)	(0.147)	(0.122)	(0.098)	(0.395)	(0.312)	(0.425)	(0.431)	(0.392)	(0.376)
Marshall Islands	0.466	0.483*	0.203	0.036	1.198**	0.741*	0.461	-0.138	-1.389*	-1.243*		
	(0.262)	(0.207)	(0.567)	(0.367)	(0.396)	(0.357)	(0.765)	(0.529)	(0.547)	(0.491)		
Netherlands		-0.642		1.716	1.008***	0.799***	0.251	0.819*	-0.001	-0.029	0.048	-1.167
		(1.018)		(1.203)	(0.184)	(0.142)	(1.011)	(0.398)	(0.388)	(0.397)	(1.107)	(0.956)
Norway	0.845***	0.653***	1.114	0.453	0.222	0.223			0.510	0.479		
	(0.216)	(0.195)	(1.000)	(0.848)	(0.231)	(0.230)			(0.335)	(0.341)		
Norwegian Intern. Register	1.262***	1.058***	0.756	0.327	-0.292	0.233		0.113	-1.240	-0.949		0.780
	(0.214)	(0.183)	(0.455)	(0.422)	(0.327)	(0.243)		(1.076)	(0.829)	(0.769)		(0.719)

Flag	tanker1	tanker2	dry bulk1	dry bulk2	gen. cargo1	gen. cargo2	container1	container2	other ST1	other ST2	passenger1	passenger2
Panama	0.781***	0.694***	0.322*	0.217	0.239**	0.258**	0.289	0.456*	-0.076	0.093	1.205***	0.318
	(0.118)	(0.108)	(0.161)	(0.132)	(0.085)	(0.080)	(0.270)	(0.211)	(0.176)	(0.181)	(0.281)	(0.216)
Philippines	0.145	0.167	-0.872	-0.857	-1.044***	-1.049***	0.191	0.471	0.011	0.142	0.996*	0.777**
	(0.338)	(0.330)	(0.532)	(0.476)	(0.225)	(0.216)	(0.394)	(0.331)	(0.260)	(0.265)	(0.426)	(0.300)
Portugal		0.419			0.782*	0.322		1.463				
		(0.846)			(0.360)	(0.374)		(0.914)				
Russian Federation	1.117***	0.935***	0.752	0.689	0.366**	0.157	0.251	-0.006	0.412*	0.517**	0.277	0.046
	(0.248)	(0.240)	(0.683)	(0.473)	(0.131)	(0.125)	(0.643)	(0.574)	(0.204)	(0.199)	(0.699)	(0.541)
Singapore	0.700***	0.513***	1.446***	0.837**	0.096	0.360*	0.633	0.819**	-0.895*	-1.438**		
	(0.138)	(0.135)	(0.340)	(0.286)	(0.236)	(0.166)	(0.385)	(0.293)	(0.419)	(0.547)		
Spain	-0.072	-0.766			0.159	0.339		-0.937	0.337	0.681	1.586***	0.503
	(0.821)	(0.781)			(0.377)	(0.307)		(1.083)	(0.516)	(0.560)	(0.425)	(0.391)
Sweden	-0.231	0.757			-1.293*	-0.051			-1.719	-1.628		
	(0.773)	(0.392)			(0.628)	(0.359)			(1.150)	(1.168)		
South Korea	-0.713	-0.692*	1.022*	0.070	-0.616**	-0.490*	0.915	0.672	-1.353***	-1.398***	2.466***	-0.398
	(0.452)	(0.348)	(0.455)	(0.391)	(0.234)	(0.205)	(0.811)	(0.503)	(0.372)	(0.414)	(0.669)	(0.968)
St. Vincent & Grenadines	0.725***	0.767***	0.150	0.137	0.180	0.087	-0.272	-0.160	0.342	0.494*	1.354**	0.318
	(0.196)	(0.186)	(0.242)	(0.192)	(0.108)	(0.099)	(0.385)	(0.361)	(0.230)	(0.240)	(0.415)	(0.396)
Thailand	-0.802	-0.778	0.473	0.351	0.173	0.152	0.001	-0.323	-0.554	-0.394	1.099	0.549
	(0.461)	(0.421)	(0.597)	(0.475)	(0.186)	(0.171)	(0.354)	(0.483)	(0.962)	(0.966)	(0.680)	(0.789)
Turkey	0.872***	0.750***	-0.022	-0.083	-0.344	-0.479			0.163	0.564		
	(0.233)	(0.218)	(0.252)	(0.222)	(0.268)	(0.245)			(0.662)	(0.555)		
United Kingdom	0.242	0.463	1.142	0.156	0.352	0.230	0.311	0.565	0.505**	0.631***	0.089	0.764*
	(0.285)	(0.238)	(0.623)	(0.667)	(0.309)	(0.237)	(0.431)	(0.303)	(0.186)	(0.192)	(1.019)	(0.326)
United States of America	-0.272	-0.229	-1.782*	-1.029*	-2.269***	-1.728***	-0.537	-0.452	0.611***	0.578**	-1.503	-1.008*
	(0.171)	(0.159)	(0.727)	(0.430)	(0.493)	(0.345)	(0.878)	(0.662)	(0.173)	(0.190)	(0.974)	(0.505)
Vietnam	-1.597	-0.613			-0.753*	-0.698*	2.055***	1.391	0.341	0.379		
	(1.069)	(0.640)			(0.304)	(0.284)	(0.553)	(0.725)	(0.849)	(0.878)		

*Note: * p<0.05, ** p<0.01, *** p<0.001, n/a=not applicable*