Does ratification matter and do major conventions improve safety and decrease pollution in shipping?

Sabine Knapp[1], Philip Hans Franses

Econometric Institute, Erasmus University Rotterdam[2]

Econometric Institute Report 2009-03

Abstract

We develop a method which measures the effect of the major international conventions in the area of safety, pollution, search and rescue and work related measures. We further distinguish between the effect of entry into force and the status of ratification of a convention by its parties. We use standard econometric models and base our analysis on a unique dataset of 30 years of monthly data where we correct for other factors which can influence safety such as safety inspections and ship economic cycles. The results show a complex picture where the average time between adoption and entry into force was calculated to be 3.1 years. Overall, the more parties ratify a convention, the more likely safety is improved and pollution is decreased although one can detect a certain level of non compliance. The immediate effect of entry into force presents a mixed picture where most negative effects can be found with legislation in the area of safety management and pollution, followed by technical areas. The effect of legislation in the areas related to working and living conditions and certification and training is smallest. Seasonality can be found with peaks in December and January for all conventions but are less important for pollution.

Acknowledgments

We would like to acknowledge Lloyd's Register Fairplay (LRF) for proving casualty and pollution data and the Paul Scherrer Institute (PSI) for providing oil pollution data. Furthermore we would like to thank Clarksons for providing data on ship economic cycles. Finally we would like to thank Mr. Gangcan Rao for his very helpful insight into the development of the legislative framework and the identification of milestones relevant for this analysis.

[1] Disclaimer: The views expressed in this article represent those of the author and do not necessarily represent those of the International Maritime Organization (IMO)

[2] Econometric Institute, Erasmus School of Economics., P.O. Box 1738, NL-3000 DR, Rotterdam, The Netherlands, knapp@ese.eur.nl or franses@ese.eur.nl

1. Introduction and formulation of research question

In the shipping industry the legislative framework is complex, and, due to its international nature, enforcement can be weak. The legislative framework of about 50 conventions is developed by the International Maritime Organization (IMO) who is the regulator of the shipping industry but lacks enforcement powers and does not directly monitor performance of its member states. Preventive actions, despite some effort made by IMO's member states to change this process, are still uncommon. This results in the creation or amendment of legislation being reactive, and typically following the outcome of a major disaster (oil tanker disaster, ferry disaster).

Action is usually taken after major disasters. After a negotiation process, the measures are agreed upon and the convention is adopted. After adoption, it normally will then take two to five years until it enters into force. Another important aspect of the regulatory process is the establishment of a system which compares the costs associated with the development of a measurement with the benefits so as to *maximize social welfare* (see Goulielmos and Giziakis [1]). According to these authors and in the context of preventing accidents, the "*optimum level of acceptable accidents*" should be determined. This level is determined by finding the minimum of the total costs associated with accidents where total costs is the total of the costs related to the accident and the accident prevention costs.

Following this concept, IMO, in the years 2001 and 2002, approved guidelines for the application of *Formal Safety Assessment (FSA)* for use in the IMO rule-making process. FSA is a rational and systematic process for assessing the risks relating to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks. Application of FSA is limited to major changes in the regulative framework but its concept is to provide a proactive versus a reactive approach. Some of the major drawbacks of FSA studies are the lack of adequate data for proper analysis of risk factors and different applications of the guidelines.

Besides the development of FSA and its shortcomings, and notwithstanding the lack of enforcement, IMO through its technical cooperation committee (TCC) provides training and support to its member states. In this respect, IMO also developed the Voluntary Member States Audit Scheme (VMSAS) which should provide a better mechanism to foster compliance.

IMO's latest developments at council level come in the form of the Strategic Plan for the Organization, of which the latest for the period 2008-2013 is based on Assembly Resolution A.989(25) [2] and sets out 13 broad strategic directions. Resolution A.990(25) [3] then provides the corresponding High Level Action Plan (HLAP) for the 2008-2009 biennium. Along with the strategic directions, IMO developed a set of 42 performance indicators (PI) to measure progress made in achieving its strategic directions.

Despite the various measures to identify potential weaknesses in the legislative framework, no methods have been developed to provide any bore defined insight into the effectiveness of legislation in force, irrespective of the level of enforcement. It is generally assumed that a stricter level of enforcement of legislation will achieve what legislation wanted to obtain in the first place but the effect itself has not been measured using proper econometric techniques for various types of conventions in shipping. We present both aspects in which we use the level of ratification of a certain convention by its parties and the timing of the entry into force of the legislative framework including relevant amendments over the given time period.

Alternative attempts were made to provide insight into the effect of legislation related to the environment such as Young [4] who investigates the effectiveness of international environmental regimes by looking at causal connections and behavioral mechanisms. Eliopoulou and Papanikolaou [5] and Delautre et al. [6] provide some insights into the influence of regulations on the safety records of tankers.

There are however currently 50 conventions at IMO level and various ILO[3] conventions, and hence a partial analysis will not allow for an understanding of the full process. In this article, we therefore develop a method which measures the effectiveness of all relevant IMO and ILO conventions in the area of safety, the environment, search and rescue and work related measures. We further aim to provide an answer to the question of the level of enforcement, and we thereby correct for variables which can also have an effect on safety such as safety inspections and ship economic cycles (see Bijwaard and Knapp [7] for both aspects). In section 2, we provide an introduction to regime design and present our underlying concepts along with a description of the dataset used in this analysis. In section 3, we develop the model, apply it to the data and present a discussion of the results. Section 4 provides a high level summary and some recommendations for the policy maker.

2. Underlying concepts and dataset to measure effectiveness of conventions

2.1. Main underlying concepts

In regime design, Mitchel [8] distinguishes between three phases, and these are the creation of the measures, the compliance to it and the measures taken in case of non-compliance. The compliance phase in some circumstances starts prior to enforcement while in other cases it will only start after some time after enforcement. The degree of compliance will depend on the measures that are taken for non-compliance which also determines the effectiveness.

Despite the fact that the adoption/entry into force in normal circumstances will only apply to new ships, for some measures it applies to all ships or is staggered depending on the date of construction and ship type. Two types of measures can therefore be identified, that is, first, measures which take effect prior to entering into force and, second, measures which only become relevant after they are entered into force. An example for the first would be physical requirements with respect to the construction or conversions of vessels (e.g. single hull tanker phase out, Crude Oil Washing, Segregated Ballast Tank) while a classic example for the second would be the implementation of the ISM code or anything related to operational changes of the vessel.

In the long run, the effect of certain measures of a convention can be grouped into measuring the effect on certain types of casualties. Vessels with good safety management are expected to have less serious casualties or casualties with less pollution.

2.2. Dataset created for our analysis

The underlying dataset for the analysis follows the concepts above and is based on 50,367 casualties for a time period 1977 to 2007 of monthly data from IMO, Lloyd's Register Fairplay (LRF) and Lloyd's Maritime Intelligence Unit (LMIU) where only the whole time

[3] ILO = International Labor Organization

period is covered by LRF data. The dataset was also extended by including detention information from six port state control regimes when data was available.

Casualties can either be split up into the seriousness of the casualty (very serious, serious, less serious) or by casualty category (e.g. collision, contact, fire, hull related failures, pollution, loss of life and so on). For the classification of seriousness, we use IMO definitions according to MSC/Circ. 953, MEPC/Circ. 372 [9] and MSC Resolution MSC.255(84) [10][4]. Pollution data was combined by using data from LRF, the International Tanker Owners Pollution Federation (ITOPF) and the Energy Related Safety Accident Database (ENSAD). For the classification of the casualty types, the data was reclassified whenever the first event could be identified. It is worth noticing at the classification of seriousness can be interpreted with more confidence in comparison to the casualty types.

In addition, the dataset also accounts for ship economic cycles based on data received from Clarksons which is one of the main brokers in the shipping industry. In constructing the variables, we follow the methodology explained in Bijwaard and Knapp [7] and account for inflation rates[5] for the USD for the time frame on hand and deflate the nominal values. We then complement the time series with ship particular information from LRF and information on the adoption and ratification of flags to the international conventions and protocols from the IMO and ILO home pages [11]. The various types of variables and derivation of dependent variables for the econometric analysis will be explained in detail in section 3.

2.3. The creation of milestones of the legislative framework

Appendix 1 provides an overview of the development of the legislative framework in the shipping industry along with a link to some of the major disasters which triggered legislation. The types of events can be classified as follows:

- Type 1: International conventions with their respective amendments
- Type 2: Unilateral legal instruments (e.g. EU regulations, US law)
- Type 3: Creation of port state control regimes who perform inspections
- Type 4: Creation of industry driven inspections (SIRE, CDI, RightShip)

One can observe various phases in the development of the framework. Initially, more emphasis was given to technical issues which were then expanded to pollution topics after a series of oil tanker disasters in the 70's. Only in recent years other pollution areas are considered (e.g. air pollution). Safety management and human-related issues only obtained the attention of regulators in recent years. The average time between adoption and entry into force is given by 3.1 years for all legal instruments listed in Appendix 1.

The conventions and amendments are linked to casualty areas and the aim is to filter out the effect of the convention corrected by other factors that could have an effect (e.g. other safety inspections or the economic situation of the shipping markets – in particular earnings). We also account for the different time periods from adoption to entry into force and the number of flags which have ratified conventions of interest.

[4] The Maritime Safety Committee (MSC84) adopted MSC Resolution 255(84) on 16 May 2008 where the definitions were slightly changed and no longer distinguish between serious and less serious casualties. The definition for very serious casualty remains however unchanged. The reporting requirements will also change in the future.
[5] Historical monthly inflation rates can be obtained from http://www.inflationdata.com

Important amendments to legislation and other events which can influence the level of safety and pollution prevention are identified and a set of *milestones (MS*) are identified [12] which forms the basis of the econometric analysis which we will perform in section 3. The 45 milestones are listed in Table 1 with their respective adoption and entry into force dates. We also show starting dates of other events as well as a miles stone areas which will be used in the evaluation of the effects when we present our policy recommendations.

Table 1: Summary of Milestones used in the analysis

Nr.	Main Events of interest	in response to	Adoption date	Entry into force date	Mile stone area
1	LOAD LINES 66 Conv.		05/04/1966	21/07/1968	Technical
2	TONNAGE 69 Conv.		23/06/1969	18/07/1982	Technical
3	COLREG 72 Convention		20/10/1972	15/07/1977	Navigation
4	SOLAS 74 Convention	Titanic (1912)	01/11/1974	25/05/1980	Technical
5	ILO147 MinSt 1976		29/10/1976	28/11/1981	human related
6	MARPOL 73/78 AI	Torrey Can. (1968)	17/02/1978	02/10/1983	Pollution
7	MARPOL 73/78 AII	Torrey Can. (1968)	17/02/1978	06/04/1987	Pollution
8	MARPOL 73/78 AIII		17/02/1978	01/07/1992	Pollution
9	SOLAS Protocol 78		17/02/1978	01/05/1981	Technical
10	STCW 78 Convention		07/07/1978	28/04/1984	human related
11	SAR Convention.		27/04/1979	22/06/1985	search & rescue
12	SOLAS 81-11 Amend	Amoco Cadiz (1978)	20/11/1981	01/09/1984	technical
13	Paris MoU starts	Amoco Cadiz (1978)	26/01/1982	01/07/1982	safety/pollution
14	IBC Code mandatory		05/12/1985	06/04/1987	technical/pollution
15	SOLAS 88-11 Amend		11/11/1988	01/02/1992	search &rescue
16	SOLAS 88-Protocol		11/11/1988	03/02/2000	safety mgtm
17	LOAD Line 88-Protocol		11/11/1988	03/02/2000	safety mgtm
18	OPA 90	Exxon Valdez (1989)	01/08/1990	01/08/1990	pollution
19	MARPOL 92 Amend	Exxon Valdez (1989)	06/03/1992	06/07/1993	pollution
20	Viña del Mar starts		05/11/1992	05/11/1992	technical/pollution
21	SIRE starts	Exxon Valdez (1989)	n/a	01/01/1993	technical/pollution
22a	SOLAS 93-11 Amend1	Herald of FE (1987)	01/11/1993	01/07/1998	safety mgtm
22b	SOLAS 93-11 Amend2	Herald of FE (1987)	01/11/1993	01/07/2002	safety mgtm
23	Tokyo MoU starts		01/12/1993	01/01/1994	technical/pollution
24	USCG emphasis on PSC		n/a	01/01/1994	technical/pollution
25	CDI starts inspections		n/a	10/01/1994	technical/pollution
26	SOLAS 94-05 Amend		01/05/1994	01/01/1996	technical
27	STCW 95 Amend	Estonia (1994)	07/07/1995	01/02/1997	safety mgtm
28	SOLAS 95-11 Amend	Estonia (1994)	29/11/1995	01/07/1997	technical
29	SOLAS 96-06 Amend		04/06/1996	01/07/1998	safety/technical
30	SOLAS 96-12 Amend		06/12/1996	01/07/1998	safety/technical
31	Caribbean MoU starts		09/02/1996	09/08/1996	technical/pollution
32	ILO 147 Prot 1996		22/10/1996	10/01/2003	human related
33	Mediterranean MoU starts		11/07/1997	23/02/1998	technical/pollution
34	SOLAS 97-11 Amend	Derbyshire (1980)	27/11/1997	01/07/1999	technical
35	Indian Ocean MoU starts		05/06/1998	22/01/1999	technical/pollution
36	MARPOL 99 Amend		01/07/1999	01/01/2001	technical/pollution
37	STCW White List published		n/a	06/02/2000	human related
38	Black Sea MoU start s		07/04/2000	07/10/2000	technical/pollution
39	MARPOL 01 Amend	Erika (1999)	27/04/2001	01/09/2002	pollution
40	RightShip starts vetting		n/a	01/10/2001	technical
41	EC Regulation 417/2002	Erika (1999)	18/02/2002	01/09/2002	pollution
42	SOLAS 02-12Amend	Derbyshire (1980)	12/12/2002	01/07/2004	technical
43	EC Regulation 1726/2003	Erika, Prestige (2002)	22/07/2003	21/10/2003	pollution
44	MARPOL 03 Amend	Erika, Prestige (2002)	04/12/2003	05/04/2005	pollution
45	SOLAS 04-12 Amend		01/12/2004	01/07/2006	technical

Source: compiled from various sources by authors

The milestones are briefly explained in the paragraphs that follow in chronological order and by types of events. We start with the international conventions and their respective amendments followed by unilateral regional measures, port state control and industry inspections and exclude security related measures.

International Convention on Load Lines (1966) and Protocol (1988): The load line convention deals with limitations on draught (freeboards) up to which a ship can be loaded as well as external weather tight and watertight integrity of the vessel. As such, the convention tries to eliminate excess stress on the hull of the ship and tries to ensure adequate stability of the ship. The 1988 Protocol provides harmonized certification and survey requirements between the load line convention and other conventions (SOLAS and MARPOL) so that the time a ship needs to spend out of service due to a mandatory survey is reduced.

International Convention on Tonnage Measurement of Ships (TONNAGE 69)
It took considerable time for the Tonnage convention to come into force which reflects the complexity to develop a system to calculate the gross and net tonnage of a ship. These items needed harmonization on an international level due to the fact that both tonnages are used to calculate harbor dues. The new system had to be adopted so that it did not interfere too much with the old system. It is assumed that the convention also has an effect on safety due to the influence it had on the design on ships to reduce tonnage and associated harbor dues. We will test this in our models for the three major ship types.

Convention on the International Regulations for Preventing Collisions at Sea (COLREG 72): COLREG provides a set of rules in order to prevent collision at sea. It covers rules and regulations in any condition of visibility which states the rules the ships have to comply to prevent collision. The convention has four annexes dealing with technical details for lightening positioning, sound and signal appliances and distress signals.

International Convention for the Safety of Life at Sea (SOLAS 74) and Protocols (1978 and 1988): The creation of the SOLAS convention is partly influenced by the *Titanic (1912)* incident and is one of the most important conventions and contains twelve chapters specifying minimum standards for the construction, equipment and operation of ships. The convention itself has been amended numerous times and we take several of such amendments into account. We focus on safety-related measures and exclude security-related measures and the adoption of the IMO voluntary member state audit scheme which was adopted in 2005 where the period is too short to measure the effect. The identified milestones are as follows:

- *1978-Febr. Protocol:* deals with several amendments for tankers and strengthens the surveys and the port state control requirements.
- *1981-Nov. Amendment*: in response to the *Amoco Cadiz (1978)* incident, this amendment introduces improved requirements for fire safety, machinery and electrical installations as well as additional requirements concerning the carriage of navigational equipment.
- *1988-Nov. Protocol*: the 1988 links up with the Load Line Protocol of 1988 to facilitate harmonized surveys for all ships under SOLAS, MARPOL and the Load Line Convention.
- *1988-Nov Amendment:* introduction of the Global Maritime Distress and Safety System (GMDSS) to improve search and rescue.
- *1993-Nov. Amendment*: influenced by the *Herald of Free Enterprise (1987),* IMO adopts the International Safety Management Code by Assembly Resolution

A.741(18). The ISM code establishes a safety management system for all ship types with two different entries into force dates.

- *1994-Apr. Amendment*: the amendment introduces the Enhanced Survey Program (ESP) by adoption of Assembly Resolution A.744(18) and makes the ISM Code mandatory. ESP should ensure better hull integrity by paying attention to corrosion and thickness of hull plates.
- *1995-Nov. Amendment*: in response to the *Estonia (1994)* accident, improved stability requirements, lifesaving appliances and communication systems for passenger ships were adopted.
- *1997-Nov. Amendment:* in response to the *Derbyshire (1980)* accident, additional safety measures for bulk carriers are adopted via a new chapter in SOLAS (chapter XII), adoption of the Code of Practice for the Safe Loading and unloading of bulk carriers (BLU Code, Assembly Resolution A.862(20))
- *1996-June and Dec Amendments:* The amendments introduce a revised chapter on life-saving appliances and a new International Life-Saving Appliance Code (LSA) is introduced. The December Amendments introduce new fire safety measures and make the International Code for Application of Fire Test Procedures mandatory.
- *2002-Dec. Amendment:* influenced by the Derbyshire accident, further amendments are made for additional safety measures for bulk carriers (high level alarms and water ingress systems based on MSC Resolution MSC.145(77), additional measures for the construction, fire protection and life saving appliances for other ship types.
- *2004-Dec. Amendment:* improve bulk carrier safety, new requirements related to double side skins, free fall lifeboat mandatory for bulk.

Merchant Shipping (Minimum Standards) Convention (ILO Convention No. 147, 1976) and Protocol 1996: The Merchant Shipping (Minimum Standards) Convention from the ILO applies to seafarers on foreign flagged vessels. Its primary concern is to ensure safe working conditions and a minimum standard of onboard living conditions in order to ensure the safety of life onboard the vessel. The protocol of 1996 extends the coverage of the original convention including updated conventions on accommodation for crews, working hours, workers representation and health protection and medial care. The 2006 Maritime Labor Convention will replace the old system once it comes into force and it is not taken into consideration in our analysis.

International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) with Annexes I-VI: MARPOL's creation was influenced by the *Torrey Canyon (1968)* incident and its prime aim is to prevent pollution from ships either caused due to an accident or due to normal operations. The convention is split into six relevant Annexes of which only the first three are taken into consideration in our analysis and they are as follows: Annex I: Prevention of Pollution by Oil, Annex II: Control of Pollution by Noxious Liquid Substances in Bulk (NLS), Annex III: Prevention of Pollution by Harmful Substances in Packaged Form, Annex IV: Prevention of Pollution by Sewage from Ships, Annex V: Prevention of Pollution by Garbage from Ships and Annex VI: Prevention of Air Pollution from Ships.

Annex I was amended by the Protocol of 1978 which introduced the SBT, COW and CBT[6] requirements. Annex II provides a list of dangerous substances and their discharge criteria and makes the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) mandatory.

[6] SBT: segregated ballast tanks, COW: crude oil washing, CBT: clean ballast tanks

MARPOL has been amended many times but the most important amendments are the ones in response to the *Exxon Valdez (1989)* incident, the *Erika (1999)* incident and the *Prestige (2002)* incident. The amendments starting in 1992 up to 2003 deal with the phasing out of single hull tankers. Depending on the size and age of the vessel, the last amendment of 2003 provides a time table for this process. By 2010 at the latest, all single hull oil tankers have to be phased out. For the purpose of this article, we concentrate on the overall effect of MARPOL Annex I, II, III, the IBC[7] Code, the phase out of single hull tankers and the establishment of the condition assessment program (CAS).

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 78): This convention tries to ensure a minimum standard for training, certification and watchkeeping for seafarers on an international level. The convention is accompanied by the STCW Code which gives a minimum standard for competence for personnel onboard a ship and has a mandatory part and a non-mandatory part. The IMO maintains a list of countries ("White List") which have given full effect to the STCW Convention (STCW 95). Countries on the "White List" can refuse to accept a seaman with a certificate of competence that is from a country not on the "White List".

The International Convention on Maritime Search and Rescue (SAR 1979): This convention established an international search and rescue plan so that help can reach vessels in distress as fast as possible and lives can be saved. The convention divides the world into thirteen areas of which members to the convention conduct their search and rescue actions.

With respect to the type 2 events, three unilateral legal instruments have been identified and are also included in the analysis. The first one is the *Oil Pollution Act (OPA 90)* which is the response of the United States of America to the *Exxon Valdez* disaster. In the European Union and in response to *Erika* and *Prestige*, unilateral action was given by *EC Regulation 417/2002* and *EC Regulation 1726/2003*. All measures introduce stricter requirements for oil tankers trading in US waters and EU waters which also have a global impact since both are important trading areas. As the amendments of MARPOL contain the development of the EC regulations, we only incorporate OPA90 into the models.

The final events of interest for the analysis are the type 3 and type 4 events dealing with the creation of the inspection regimes. Safety inspections can be divided into mandatory and industry inspections which may overlap (see Knapp and Franses [13] for a detailed analysis of inspections). For the purpose of this analysis, we concentrate on the development of the PSC regimes and industry vetting inspections as follows.

- 1982: in response to the *Amoco Cadiz (1978)* incident, the Paris Memorandum of Understanding (MoU) is created and covers Europe and the North Atlantic region
- 1992: the Viña del Mar Agreement was created and covers Latin America
- 1993: SIRE starts vetting inspections on oil tankers
- 1993: the Tokyo MoU is created and covers Asia and the Pacific region
- 1994: the USCG puts emphasis on foreign vessel inspection program
- 1994: CDI starts vetting inspections on chemical and oil tankers
- 1996: the Caribbean MoU is created
- 1997: the Mediterranean MoU is created
- 1998: the Indian Ocean MoU is created including parts of East Africa and Australia
- 2000: the Black Sea MoU is created

[7] IBC = Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk

- 2001: RightShip starts vetting inspections on dry bulk carriers

The Riyadh MoU, although signed in 2004 and which encompasses the Arab States of the Gulf, is not taken into consideration in this analysis as only very few inspections are carried out. The same applies for the Abjua MoU for the West and Central African region which was signed in 1999. For the econometric analysis, we use one an indicator covering the period of PSC inspections, namely the Paris MoU (1982 onwards) but we also incorporate detention data from six different PSC inspection regimes where data was available.

CDI inspections are performed by the Chemical Distribution Institute and SIRE inspections are performed by OCIMF (Oil Companies International Marine Forum). Both are based on a standardized questionnaire covering all areas of shipboard operations and are primarily for oil and chemical tankers. RightShip is a ranking system for dry bulk carriers which combine information obtained through vetting inspections, port state control, casualties, ship particular information and ship owner information. A RightShip Inspection covers all aspects of shipboard operations in addition to ship structure and cargo handling equipment including hatch covers which is important for dry bulk carriers.

3. Methods to measure effectiveness of conventions

3.1. Details of the variables and model type combinations

The dataset described in section 2 was used to create monthly figures for the time period January 1977 to December 2007. A full list of variables is given in Appendix 2 which groups the variables into variable groups and provides the variable types (e.g. monthly average, sums, dummy variable (0/1) etc.) for easier identification.

Each variable group represents a set of variables used in the models and which are either the variables of interest to measure effectiveness of conventions, the effect of ratification of the convention and a set of variables which are used as correction factors. The latter variables represent actions that influence safety besides the conventions and deal with enforcement (PSC and industry inspections) or ship economic cycles. In this way, the effect of interest should be filtered out. The variables are grouped as follows:

Variables of interest

- Indicators for entry into force of legal instruments and amendments (0 before, 1 from the time of entry onwards)
- Indicators for interim periods between adoption and entry into force (0 before, 0 after, and 1 in between)
- Number of IMO member states which have ratified a legal instrument or protocol (count)

Correction factors

- Ship particulars (age and gross tonnage)
- Indicators for starting periods of safety inspections (PSC and industry inspections) (0 before, 1 from the start onwards)
- Average earnings per months which represent the ship economic cycles
- Seasonal dummy variables for the month January to December (1 in season, 0 in other seasons)

Table 2 provides a list of the different types of combinations of the models which lists the conventions and the different dependent variables (*DV)* of the model combinations. We distinguish between four model types – type A for SOLAS, type B for MARPOL and type C for all other conventions. Type D models are combination models or models with specific interest such as the effect of conventions on fire & explosions, hull related failures or machinery related failures. In these models, we also combine SOLAS and MARPOL.

Table 2: Combinations of models and dependent variables

model	convention	ship types	Description of dependent variable (DV) – values per month
A1:	SOLAS	all ship types	sum of very serious casualties/total ships
A2:	SOLAS	all ship types	sum of serious casualties/total ships
A3:	SOLAS	all ship types	sum of less serious casualties/total ships
A4:	SOLAS	dry bulk	sum of casualties - dry bulk/total ships
A5:	SOLAS	general cargo	sum all casualties - general cargo/total ships
A6	SOLAS	tanker	Sum of casualties – tanker/total ships
A7:	SOLAS	container	sum of casualties – container/total ships
A8:	SOLAS	passenger	sum of casualties - passenger ships/total ships
B1:	MARPOL	all ship types	sum of casualties with pollution/total ships
B2:	MARPOL	tankers	sum of very serious casualties of tankers/total ships
B3:	MARPOL	tankers	tonnes of chemical pollution (LRF)
B4:	MARPOL	tankers	tonnes of oil pollution (ENSAD, LRF and ITOPF)
C1:	SAR	all ship types	sum of total loss of life
C2:	COLREG	all ship types	sum of collisions and contacts/total ships
C3:	LOADLINE	all ship types	sum of hull related failures*)/total ships
C4:	TONNAGE	dry bulk	sum of hull related failures*) for dry bulk carriers/total ships
C5:	TONNAGE	tanker	sum of hull related failures*) for tankers/total ships
C6:	TONNAGE	general cargo	sum of hull related failures*) for general cargo vessels/total ships
C7:	STCW	all ship types	sum of very serious casualty types/total ships
C8:	STCW	all ship types	sum of serious casualty types/total ships
C9:	STCW	all ship types	sum of less serious casualty types/total ships
C10:	ILO	all ship types	sum of very serious casualty types/total ships
C11:	ILO	all ship types	sum of serious casualty types/total ships
C12:	ILO	all ship types	sum of less serious casualty types/total ships
D1:	Fire/Explosion	all ship types	sum of fire & explosions/total ships
D2:	Fire/Explosion	tankers	sum of fire & explosions for tankers/total ships
D3:	Hull related*)	tankers	sum of hull related failures*) for tankers/total ships
D4:	Hull related*)	dry bulk	sum of hull related failures*) for dry bulk/total ships
D5:	Machinery failure^	all ship types	sum of engine machinery related failures/total ships

**) hull related failures: flooding, foundering, hull related failures, wrecked and stranded*
^ machinery related failure: contains all casualties in relation to engine failures and electrical failures

For the SOLAS type A models, we also include separate models per ship type for SOLAS and MARPOL. The dependent variables vary according to the legislative measures and can be defined by casualty type, casualty seriousness[8], and loss of life or pollution.

The models for SOLAS, STCW and ILO contain all types of casualties excluding pollution with are dealt with in MARPOL. This is due to the fact that all three cover all areas of ship operation and it is assumed that adequate education (STCW) and working and living conditions (ILO) lead to less casualties for all casualty types. Separate models per seriousness type (very serious, serious and less serious) are created to see where legislation shows the strongest effect. For SOLAS, we also present separate models for the major ship types where the dependent variable is the sum of all casualty types per ship type.

[8] Casualty seriousness is defined as per IMO definitions into very serious, serious and less serious casualties.

Furthermore, for the type C models, we use loss of life for SAR (search and rescue) and collisions and contacts for COLREG. With these models, we do not distinguish between ship types. For LOADLINE and TONNAGE which are conventions dealing with hardware related items such as hull integrity and the measurement of dimensions which affects the design of ships and therefore has an indirect effect on safety, casualties dealing with the hull integrity and related casualties are taken into consideration. For TONNAGE, we further provide a model for the three main ship types – dry bulk carriers, tankers and general cargo ships.

For the type B models dealing with pollution, several types of dependent variables are used. First we use the number of casualties with pollution for all ship types, and then we take a closer look at tankers and present a model on very serious casualties. Finally we also look at tonnes of pollution for chemicals and oil. The construction of the dependent variable for MARPOL requires some explanation. It is very difficult to obtain quality data for tons of pollution as the commercial data providers do not classify pollution categories in detail nor are there units recorded uniformly. At first hand, data from LRF and LMIU was obtained on a ship level where only data from LRF covered the whole time period. The data was then manually classified and converted into tons which lead to a total monthly figure for tons of oil and chemicals for the period on hand.

The oil pollution figures where then compared to ITOPF figures and figures from ENSAD – the Energy Related Severe Accident Database. ENSAD was developed and maintained by the Scherrer Institute (PSI) in the mid 1990s and contains the most comprehensive database on energy related accidents. ENSAD contains data on spills of 700 tonnes and more while the ITOPF data contains spills of 7 tonnes and above and the raw data from LFF/LMIU is irrespective of the spill. In order to use the best possible combination of data, we combine the data from all sources and use average figures for oil pollution. For chemicals, only data from LRF was available and used accordingly.

Finally, the models for type D are specific models where we combine SOLAS and MARPOL related measured for fire and explosion on all ships and tankers and for hull related failures with respect to tankers. We also show machinery related failures for all ship types. These models should provide an overview on these three types of casualties versus the findings related to the seriousness of casualties.

3.2. The econometric models

For the general model used in this article, we use a standard regression model with a small adaptation for time series data. In time series, it is common to find serial correlation which is correlation of the error terms of the model. Serial correlation can lead to an underestimate of the standard errors of the parameters of interest (the coefficients) and can lead to an exaggeration of the significance thereof.

To correct for serial correlation and for short run dynamics within the time series, we include lagged variables for two periods (DV_{t-1} and DV_{t-2}) of the dependent variable (DV). We use ordinary least squares (OLS) to estimate the parameters but in addition to the inclusion of the lagged variables, we also estimate the standard errors of the parameters by using Newey-West HAC[9] standard errors and covariance which is a standard option in Eviews, the

[9] HAC means heteroskedastistic and autocorrelation (serial correlation) consistent.

software used to estimate the models. The basic model given in Equation 1 can be written in the form of

$$y = \beta + \beta_1 x + \beta_2 y_{(-1)} + \beta_3 y_{(-2)} + \varepsilon \qquad (1)$$

where y is the dependent variable, β is the intercept, x are the explanatory variables with β_1 as the main coefficient of interest, $y_{(-1)}$ and $y_{(-2)}$ are the lagged variables of y with β_2 and β_3 their respective coefficients and finally ε are the residuals. We use the Breusch-Godfrey test (refer to Heij et al., chapter 5 for a detailed description [14]) to see how many lags should be included and find that two lags are usually sufficient. The final basic model is given in Equation 2 including the denotation of the explanatory variables.

We use the logarithm for the dependent variable, the lags and for scale variables such as grt, earnings and the number of countries which have ratified a convention. The model is changed according to the type of model given in Table 2 with different dependent variable (*DV*) and explanatory variables. We use the same type of model across all conventions to facilitate interpretation of the parameters. Denotation of the variable groups is given below the equation where k is an index from 1 to n_ℓ and ℓ represents the variable groups with total number of variables being n_ℓ within each group of ℓ. The total number of n_ℓ depends on the model type and is indicated below with the relevant notation group.

$$\begin{aligned}\log(1+DV)_t = {} & \beta_0 + \beta_2 \,\mathrm{AGE}_t + \beta_3 \log(\mathrm{GRT})_t + \sum_{k=1}^{n_4} \beta_{4,k}\, \mathrm{IN}_{k,t} + \sum_{k=1}^{n_5} \beta_{5,k} \log(1+\mathrm{CR}_k)_t \\ & + \sum_{k=1}^{n_6-1} \beta_{6,k} \mathrm{SEAS}_{k,t} + \beta_7 \log(1+DV)_{t-1} + \beta_8 \log(1+DV)_{t-2} + \beta_9 \,\mathrm{PSC}_t + \beta_{10} \log(1+\mathrm{det})_t \\ & + \beta_{11} \,\mathrm{SIRE}_t + \beta_{12} \,\mathrm{RS}_t + \beta_{13} \,\mathrm{CDI}_t + \beta_{14} \log(\mathrm{EARN})_t + \sum_{k=1}^{n_{15}} \beta_{15,k} \,\mathrm{AD}_{k,t} + \varepsilon_t \end{aligned} \qquad (2)$$

where

DV = dependent variables as listed in table 2 (monthly data). We sometimes add 1 in case the DV takes the value 0)
AGE, GRT = mean age (grt) of all ships or respective ship type (on average for vessels with incidents), for GRT, we use logs
IN = dummy variable indicating when legal instrument entered into force (0 before and 1 after) where $n_\ell = 31$
CR = number of countries which have ratified a certain convention (amount per month) where $n_\ell = 13$
SEAS = seasonal dummies for months (we include February until December and set January as the benchmark) where $n_\ell = 12$
$Log(1+DV)_{t-1}$ and $Log(1+DV)_{t-2}$ = lags 1 and 2 of the dependent variable to account for short-run dynamics
PSC, SIRE, RS, CDI = indicators that mark the start of port state control and industry inspections depending on the model (0 before, 1 from the start onwards)
Det = number of detentions (per month) for all ships or respective ship type
EARN = earnings per month for all ship types or respective ship type
AD = dummy indicating time between adoption and enforcement for certain measures where $n_\ell = 14$

For the interpretation of the models, we concentrate on the parameters of interest which are in our case, the parameters *IN* (indicators for entry into force of legal instruments), *AD* (indicators for the timing between adoption and entry into force), *CR* (the number of

countries which have ratified a convention). We also comment on the results with reference t the seasonal variables (SEAS).

By itself, β_1 of Equation 1 is called the short-run or immediate effect of x which is the main parameter of interest for interpretation. The total or cumulative effect is given by a combination of the parameter of β_1 and the parameters of the lagged variables (β_2 and β_3) in the form of $\beta_1/(1-(\beta_2+\beta_3))$ only to be computed like this when the parameter of the lagged variable is unequal and smaller than (1). The total effect is a scale-free value, so its absolute value is not interesting, only its relative value to other total effects.

For the model diagnostics, we use the Breusch-Godfrey Serial Correlation LM Test to test for serial correlation (refer to Heij et al. [14] for a detailed explanation of the test). The results are given in Table 3 for each model type. One can still observe some serial correlation for some of the SOLAS models, COLREG, Tonnage (dry bulk) and the less serious models for STCW and ILO. As said, we use Newey-West HAC standard errors and covariance for the final models and believe that the serial correlation is not strong enough to influence the parameters. We prefer to keep the models the same across all conventions in order to facilitate interpretation.

Table 3: Results of Breusch-Godfrey Serial Correlation LM Test (12 lags)

model	Convention	LM-test p value	model	Convention	LM-test p value
A1:	SOLAS, very serious	0.001	C4:	Tonnage, dry bulk	0.003
A2:	SOLAS, serious	0.001	C5:	Tonnage, tanker	0.025
A3:	SOLAS, less serious	0.027	C6:	Tonnage, general cargo	0.209
A4:	SOLAS, dry bulk	0.010	C7:	STCW, very serious	0.004
A5:	SOLAS, general cargo	0.012	C8:	STCW, serious	0.519
A6	SOLAS, tanker	0.017	C9:	STCW, less serious	0.007
A7:	SOLAS, container	0.063	C10:	ILO, very serious	0.019
A8:	SOLAS, passenger	0.298	C11:	ILO, serious	0.030
B1:	MARPOL, pollution	0.157	C12:	ILO, less serious	0.009
B2:	MARPOL, very serious	0.375	D1:	Fire/Explosion, all ships	0.129
B3:	MARPOL, chemicals	0.421	D2:	Fire/Explosion, tankers	0.637
B4:	MARPOL, oil	0.028	D3:	Hull related, tankers	0.055
C1:	SAR, loss of life	0.141	D4:	Hull related, dry bulk	0.055
C2:	COLREG, collision & contact	0.006	D5:	Machinery related, all ships	0.078
C3:	LOADLINE, hull related	0.011			

3.3. Presentation and discussion of results

This section presents the regression results of the models which are presented by model type in the tables that follow. We present the coefficients with standard errors and indicate the level of significance (1%, 5% or 10%). Table 4 presents the results for SOLAS for the three level of seriousness of casualties while Table 5 presents the results per ship type.

The results with respect to the seriousness of casualties are mixed where some entry into force of conventions show a decreasing effect on the number of casualties, some show a positive effect and some are not significant. Not surprisingly, the strongest effect is related to very serious casualties for the entry into force of the SOLAS 74 Convention.

The introduction of the Global Maritime Distress and Safety System (GMDSS) via the SOLAS 88 Amendment show a decrease in the number of very serious and serious casualties but no effect on less serious casualties which is understandable. The SOLAS 93 Amendment

with is dealing with the adoption of the ISM Code and introduced safety management to the shipping industry is negative for all three types of casualties and indicates that the adoption, entry into force and time between adoption and entry into force (given by the variable time to 93 Amend) has a negative effect on the number of casualties. On a ship type level, one can observe that the decrease applies primarily to dry bulk carriers and general cargo vessels but not to other ship types such as tanker, container vessels and passenger vessels.

Table 4: Type A Model Results – SOLAS, all ship types per seriousness

	A1: very serious			A2: serious			A3: less serious		
Variable	**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**	
Intercept	-0.308	1.263		-1.654	1.146		-2.357	1.542	
AGE	0.036	0.022	^	0.035	0.014	**	-0.011	0.015	
GRT	-0.554	0.127	*	-0.251	0.102	*	-0.027	0.112	
74 Convention	-3.387	2.018	^	-1.652	1.674		0.418	1.408	
78 Protocol (inert gas)	1.161	1.173		1.349	0.942		0.177	0.837	
81 Amendment (fire measures)	0.082	0.157		0.184	0.147		-0.082	0.142	
88 Protocol (HSSC)	1.591	0.763	**	-0.149	0.580		2.047	1.126	^
88 Amendment (GMDSS)	-0.405	0.134	*	-0.292	0.091	*	-0.092	0.086	
93 Amendment (ISM)	-0.239	0.106	**	-0.240	0.121	**	-0.358	0.156	**
94 Amendment (ESP)	-0.011	0.048		-0.024	0.053		0.021	0.066	
95 Amendment (damage stab.)	0.114	0.075		-0.095	0.072		-0.036	0.069	
96 Amendment (LSA, Fire test)	-0.044	0.054		0.085	0.072		0.095	0.077	
97 Amendment (add safety)	0.086	0.184		0.347	0.101	*	0.002	0.165	
02 Amendment (various)	0.044	0.114		-0.083	0.089		-0.037	0.201	
04 Amendment (add safety)	-0.125	0.068	^	0.137	0.062	**	-0.203	0.141	
Time to 81 Amend.	0.155	0.100		0.199	0.105	^	0.013	0.101	
Time to 97 Amend.	-0.210	0.088	**	-0.202	0.066	*	0.108	0.055	**
Time to 93 Amend.	-0.172	0.056	*	-0.205	0.066	*	-0.051	0.054	
Countries ratified 74 Conv.	0.917	0.526	^	0.433	0.440		-0.108	0.365	
Countries ratified 78 Prot.	-0.424	0.406		-0.447	0.335		-0.057	0.286	
Countries ratified 88 Prot.	-0.525	0.203	*	0.034	0.154		-0.426	0.291	
February	-0.221	0.070	*	-0.086	0.075		-0.143	0.071	**
March	-0.174	0.062	*	-0.060	0.066		-0.023	0.079	
April	-0.277	0.073	*	-0.205	0.068	*	-0.129	0.068	^
May	-0.305	0.066	*	-0.286	0.070	*	-0.140	0.082	^
June	-0.078	0.079		-0.194	0.072	*	-0.157	0.072	*
July	-0.093	0.078		-0.022	0.071		-0.006	0.076	
August	-0.274	0.088	*	-0.081	0.067		-0.141	0.088	
September	-0.176	0.074	**	-0.205	0.070	*	-0.090	0.089	
October	-0.133	0.082		-0.063	0.072		0.001	0.078	
November	-0.084	0.081		-0.029	0.083		-0.054	0.089	
December	0.029	0.077		0.018	0.059		0.080	0.077	
Log(1+DV)t-1	0.248	0.056	*	0.427	0.061	*	0.504	0.103	*
Log(1+DV)t-2	0.233	0.048	*	0.280	0.061	*	0.013	0.101	
Earnings	0.151	0.064	**	0.180	0.058	*	-0.049	0.080	
PSC	-0.016	0.108		0.078	0.100		-0.045	0.083	
Detentions	-0.048	0.026	^	-0.004	0.025		0.018	0.065	
R^2 of model	0.858			0.865			0.790		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%*

All other amendments are not significant with the exception of the SOLAS 04 Amendment which introduces improved bulk carrier safety and new requirements and makes the free fall lifeboat mandatory for bulk carriers. The latter shows a negative effect for very serious and serious casualties. The variables indicating the number of countries which had ratified a convention is positive for the SOLAS convention and negative for the 88 Protocol indicating that the number of countries who had ratified the convention and protocol show opposite effects to the entry into force variables.

For some of the amendments to SOLAS, it is more interesting to look at the separate ship models given in Table 5. For dry bulk carriers, one can observe that the SOLAS convention in general, GMDSS, the ISM Code, the 2002 Amendments (additional safety measures for bulk carriers and high level alarms for water ingress) all show a negative effect on the number of casualties on dry bulk carriers.

For general cargo vessels, the ISM code and the SOLAS 02 Amendments show negative effects. With respect to GMDSS, while the entry into force is not significant, the time between adoption and entry into force shows a negative effect on the number of casualties on general cargo ships. The number of countries having ratified the convention and protocols however do not appear to be significant.

Tankers on the other hand show positive effects for almost all legal instruments which are significant. The only variable with negative effect is the number of countries which have ratified the 88 Protocol. For this ship type, the negative effect of the industry inspections is worth noticing. For passenger vessels, the SOLAS 88 Protocol, the 02 Amendments (additional measures for fire protection and life saving appliances) show negative effects as well as the number of countries which had ratified the 78 Protocol.

In *summary*, the SOLAS model show mixed results where the effect of entry into force can be measured for the SOLAS convention for very serious casualties and separately for dry bulk carriers. The ISM code including the time from adoption to entry into force presents a decreasing effect on all types of seriousness of casualties, especially for dry bulk carriers and general cargo vessels. The number of countries which have ratified the convention or protocol is mostly not significant. Finally, for all SOLAS models, seasonality matters and more casualties are associated with January then with any of the other months.

Table 6 presents the results for the models for MARPOL. With respect to the number of casualties with pollution (model B1), entry into force of MARPOL Annex I and II and the number of countries which had ratified the convention is not significant. However, the amendments for the phase out of the single hull tankers and the Condition Assessment Scheme (CAS) show a decreasing effect. The seasonal variables indicate that more incidents happen in December compared to April, May or September.

Type B2 model looks at tankers with respect to very serious casualties which by definition include significant pollution, loss of life or loss of the vessel. While Annex I and the number of countries which had ratified the convention is not significant, the amendments for the phase out of the single hull tankers as well as the revised phase out and CAS all show a decreasing effect including the time from adoption to entry into force. Type B4 model then presents the effect with respect to tonnes of oil pollution. The result indicate that the time from adoption to entry into force related to the phase out of single hull tankers decreased the amount of tonnes of oil due to accidental release.

Finally, the type B3 model measures the effect of MARPOL Annex II with respect to tonnes of chemical pollution. The model shows that entry into force of this Annex presents a negative effect while the number of countries which have ratified the convention is positive. Seasonality for this type of casualty is not significant. It is also worth noting that the explained variance of this model (R^2) is rather low and that interpretation of this model is to be taken with caution. This could be due to the fact that there is very little data on chemical pollution available.

Table 5: Type A Model Results – SOLAS (dry bulk, general cargo, tanker, container and passenger ships)

Variable	A4: dry bulk			A5: general cargo			A6: tanker			A7: container			A8: passenger		
	Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE	
Intercept	-7.426	2.146		-3.966	1.205		-7.330	1.192		-6.301	1.624		-6.566	1.229	
AGE	0.018	0.011	^	-0.012	0.010		-0.006	0.006		0.004	0.009	**	0.003	0.005	
GRT	-0.054	0.111		0.158	0.081	^	0.063	0.068		0.069	0.054		0.011	0.041	
74 Convention	-3.930	2.172	^	-1.643	1.758		-0.919	1.570		-1.678	4.189		-1.741	3.063	
78 Protocol (inert gas)	3.762	1.392	*	1.339	1.009		1.142	0.935		1.088	2.658		2.928	1.747	^
81 Amendment (fire measures)	0.154	0.194		0.129	0.118		0.121	0.142		0.233	0.362		0.507	0.281	^
88 Protocol (HSSC)	3.025	2.128		-0.319	0.663		1.118	0.635	^	-1.491	1.169		-1.435	0.785	^
88 Amendment (GMDSS)	-0.236	0.137	^	-0.066	0.072		-0.114	0.112		-0.191	0.204		-0.090	0.157	
93 Amendment-1 (ISM)	-0.392	0.205	^	n/a	n/a		-0.146	0.123		n/a	n/a		0.158	0.233	
93 Amendment-2 (ISM)	n/a	n/a		-0.119	0.071	^	n/a	n/a		-0.158	0.166		n/a	n/a	
94 Amendment (ESP)	0.258	0.138	^	-0.017	0.068		-0.052	0.048		0.031	0.123		0.461	0.361	
95 Amendment (damage stability)	-0.002	0.169		-0.107	0.072		-0.100	0.068		-0.234	0.187		-0.612	0.401	
96 Amendment (LSA, Fire test.)	0.285	0.159	^	0.086	0.083		-0.068	0.058		0.236	0.204		0.200	0.176	
97 Amendment (add. safety, bulk)	0.044	0.216		0.213	0.062	*	0.139	0.086	^	0.501	0.104	*	0.350	0.107	*
02 Amendment (various)	-0.096	0.206		-0.138	0.074	^	0.024	0.107		-0.156	0.139		-0.270	0.134	**
04 Amendment (add safety, bulk)	-0.007	0.116		0.074	0.063		0.131	0.111		0.006	0.090		-0.081	0.110	
Time to 81 Amend.	0.200	0.149		0.200	0.084	**	0.169	0.086	**	0.170	0.269		0.325	0.201	^
Time to 88 Amend.	-0.084	0.089		-0.104	0.056	^	0.061	0.083		-0.157	0.151		0.074	0.095	
Time to 93 Amend.-1	-0.131	0.087		n/a	n/a		0.177	0.097	^	n/a	n/a		0.092	0.148	
Time to 93 Amend.-2	n/a	n/a		-0.085	0.043	**	n/a	n/a		-0.167	0.127		n/a	n/a	
Time to 95 Amend.	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		-0.474	0.337	
Time to 97 Amend.	0.137	0.131		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Time to 02 Amend.	-0.213	0.127	^	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Time to 04 Amend.	0.058	0.236		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified 74 Conv.	1.083	0.572	^	0.421	0.462		0.258	0.409		0.482	1.108		0.503	0.799	
Countries ratified 78 Prot.	-1.254	0.475	*	-0.454	0.353		-0.400	0.327		-0.474	0.945		-1.019	0.620	^
Countries ratified 88 Prot.	-0.745	0.566		0.060	0.177		-0.324	0.174	^	0.375	0.323		0.466	0.210	**
February	-0.134	0.085		-0.217	0.102	**	-0.146	0.052	*	0.013	0.115		0.040	0.155	
March	-0.051	0.089		-0.199	0.118	^	-0.040	0.040		0.088	0.116		0.051	0.134	
April	-0.172	0.090	^	-0.321	0.108	*	-0.184	0.044	*	-0.159	0.125		-0.097	0.142	
May	-0.183	0.094	**	-0.408	0.118	*	-0.232	0.057	*	-0.244	0.140	^	-0.104	0.127	
June	-0.185	0.104	^	-0.208	0.132		-0.234	0.050	*	-0.105	0.107		0.065	0.134	
July	-0.143	0.085	^	-0.148	0.147		-0.133	0.056	**	-0.082	0.132		0.208	0.131	
August	-0.266	0.116	**	-0.274	0.156	^	-0.264	0.055	*	-0.123	0.127		0.153	0.133	
September	-0.145	0.088	^	-0.211	0.123	^	-0.165	0.066	**	-0.126	0.131		-0.122	0.129	
October	-0.228	0.106	**	-0.045	0.132		-0.121	0.047	**	0.044	0.118		-0.007	0.136	
November	-0.104	0.112		-0.088	0.153		-0.157	0.048	*	-0.007	0.137		0.174	0.157	
December	0.009	0.090		-0.047	0.138		-0.032	0.049		0.092	0.134		0.125	0.124	
Log(1+DV)t-1	0.251	0.064	*	0.461	0.082	*	0.096	0.066		0.231	0.066	*	0.214	0.087	**
Log(1+DV)t-2	0.189	0.087	**	0.272	0.071	*	0.048	0.059		0.133	0.069	**	0.138	0.069	**
Earnings	0.391	0.155	**	0.116	0.056	**	0.093	0.042	**	-0.150	0.174		n/a	n/a	
PSC	0.295	0.136	**	0.127	0.091		0.040	0.087		0.339	0.288		0.290	0.169	^
Detentions	-0.002	0.089		0.001	0.021		0.008	0.053		0.002	0.087		0.092	0.065	
SIRE	n/a	n/a		n/a	n/a		-0.090	0.093		n/a	n/a		n/a	n/a	
RS	0.206	0.171		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
CDI	n/a	n/a		n/a	n/a		-0.349	0.076	*	n/a	n/a		n/a	n/a	
R^2 of model	0.553			0.760			0.903			0.461			0.599		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%*

Table 6: Type B Model Results – MARPOL

	B1: all ships casualties with pollution			B2: tankers very serious casualties			B3: tankers tonnes chemicals			B4: tankers tonnes oil		
Variable	Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE	
Intercept	-9.598	1.643		-11.377	1.555		-5.872	4.000		-2.172	2.242	
AGE	0.011	0.020		0.020	0.015		-0.003	0.043		0.033	0.029	
GRT	-0.052	0.133		0.049	0.094		0.188	0.384		0.293	0.150	^
Marpol Annex I (oil)	0.589	0.830		-0.844	1.148		n/a	n/a		0.016	1.435	
Marpol Annex II (NLS)	not incl	not incl		not incl	not incl		-0.625	0.354	^	n/a	n/a	
Marpol Annex III (packaged substances)	0.304	1.561		n/a	n/a		n/a	n/a		n/a	n/a	
92 Amend. (double hull)	0.075	0.182		-0.404	0.190	**	n/a	n/a		0.261	0.421	
99 Amend. (extension double hull)	0.569	0.156	**	-0.550	0.280	**	n/a	n/a		0.195	0.470	
01 Amend. (CAS, phase out)	-0.227	0.138	^	-0.348	0.151	**	n/a	n/a		0.260	0.342	
03 Amend. (revised phase out)	-0.368	0.137	*	-0.412	0.150	*	n/a	n/a		-0.300	0.198	
IBC code mandatory (chemicals)	-0.040	0.171		-0.354	0.243		not incl	not incl		n/a	n/a	
Opa 90 (US law)	0.095	0.137		-0.154	0.116		n/a	n/a		0.397	0.308	
Time to 92 Amend.	0.223	0.125	^	-0.095	0.109		n/a	n/a		0.078	0.308	
Time to 99 Amend.	0.459	0.109	*	-0.498	0.236	**	n/a	n/a		-0.097	0.234	
Time to 01 Amend.	-0.082	0.168		-0.462	0.235	**	n/a	n/a		0.028	0.351	
Time to 03 Amend.	-0.072	0.120		-0.003	0.103		n/a	n/a		-0.458	0.233	**
Countries ratified Annex I	-0.194	0.242		0.335	0.335		n/a	n/a		-0.160	0.385	
Countries ratified Annex II	not incl	not incl		not incl	not incl		0.122	0.068	^	n/a	n/a	
Countries ratified Annex III	-0.186	0.390		n/a	n/a		n/a	n/a		n/a	n/a	
February	-0.097	0.099		-0.305	0.124	**	-0.329	0.325		-0.429	0.319	
March	-0.095	0.112		-0.199	0.096	**	-0.232	0.356		-0.246	0.280	
April	-0.208	0.121	^	-0.317	0.104	*	0.119	0.338		-0.283	0.256	
May	-0.294	0.125	**	-0.191	0.110	^	0.130	0.413		-0.468	0.242	
June	-0.137	0.118		-0.179	0.116		0.089	0.392		-0.114	0.257	
July	-0.082	0.108		-0.028	0.100		0.092	0.384		0.056	0.283	
August	-0.066	0.107		-0.359	0.112	*	0.076	0.452		-0.321	0.277	
September	-0.170	0.120	^	-0.244	0.123	**	-0.218	0.351		-0.252	0.281	
October	-0.145	0.113		-0.117	0.101		0.284	0.437		-0.048	0.305	
November	-0.131	0.107		-0.128	0.087		-0.453	0.300		0.099	0.296	
December	-0.089	0.102		0.021	0.105		-0.316	0.302		0.039	0.348	
Log(1+DV)t-1	0.064	0.057		0.064	0.061		-0.026	0.059		0.305	0.045	*
Log(1+DV)t-2	0.074	0.057		-0.026	0.061		0.039	0.060		0.240	0.057	*
Earnings	0.209	0.068	*	0.167	0.069	**	0.448	0.214	**	0.333	0.161	**
PSC	0.238	0.130	^	0.388	0.120	**	0.497	0.281	^	0.438	0.478	
Detentions	-0.046	0.025	^	-0.084	0.077		0.014	0.092		-0.216	0.133	^
SIRE	0.171	0.132		0.178	0.092	^	-0.086	0.194		-0.258	0.244	
CDI	0.152	0.149		-0.062	0.166		0.311	0.220		-0.644	0.234	*
R^2 of model	0.239			0.623			0.059			0.564		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%*

In *summary*, the MARPOL models indicate that the various amendments in relation with the phase out of single hull tankers and CAS decreased the number of casualties with pollution and to a certain degree also the amount of pollution. The effect of MARPOL Annex III cannot be measures but the number of countries who had ratified the convention shows a decreasing effect. Furthermore, the IBC code decreased casualties with relation to fire and explosion on tankers.

Table 7 presents the results of the type C models. For the SAR convention, entry into force does not show a negative effect while ratification does show a negative effect on the number of lives lost. The more countries ratify the convention, the more likely lives can be saved. For COLREG, the effect of the convention and number of countries which had ratified it cannot be measured. This could be due to the fact that COLREG came into force in July 1977 and the time frame to measure its effect is therefore too short.

For the LOADLINE convention, the results confirm that ratification matters and its effect is negative on the number of casualties for hull related issues and subsequent casualties which includes flooding, foundering, capsizing, wrecked, stranded, grounded and hull related failures in general. The TONNAGE convention is split into separate models for the main ship types. We do not include an indicator for the entry into force since it lies outside the time frame used for this analysis. However, ratification clearly shows a negative effect for all ship types with respect to hull related issues (the same dependent variable as for LOADLINE).

Table 8 presents the type C models which are related to human factors such as the working and living conditions of the crew (ILO) and the training of the crew (STCW). The models for STCW indicate that the introduction of the STCW White List by IMO has a negative effect on the number of very serious casualties but not serious and less serious casualties. Furthermore, ratification of the STCW 78 convention shows a negative effect for very serious and serious casualties while the entry into force shows a positive effect. We cannot measure the effect of the STCW95 amendment to the Convention. The results for the ILO 76 convention and 96 Protocol cannot be measured for any type of casualties but the number of countries which have ratified the ILO 96 Protocol have a decreasing effect on very serious casualties.

In *summary*, for the type C models, the number of countries which had ratified the SAR convention decreases the number of lives that are lost. The LOADLINE and TONNAGE conventions both improved the number of casualties related to hull related issues, the latter for all major ship types. This is reflected by the number of countries who have ratified the conventions. The number of countries which have ratified the STCW 78 Convention decreases very serious and serious casualties while the introduction of the STCW While List decreases the number of very serious casualties.

Finally, we cannot measure the effect of COLREG with the time frame used in this analysis and we also cannot measure the effect of the ILO convention. For the type C models, seasonality matters for the conventions dealing with SAR and hull related casualties as well as for the STCW and ILO conventions for very serious casualties. More lives are lost in January or more hull related casualties are found in the winter months.

Table 7: Type C Model Results – SAR, Colreg, Loadline, Tonnage

	C1: SAR			C2: COLREG			C3: Loadline			C4: Tonnage dry bulk			C5: Tonnage tanker			C6: Tonnage general cargo		
Variable	**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**	
Intercept	9.144	4.402		-0.251	1.400		3.702	1.037		-4.385	1.601		-3.199	0.917		-8.768	1.301	
AGE	0.028	0.057		-0.053	0.013	*	0.023	0.013	^	0.027	0.010	**	-0.001	0.009		0.007	0.011	
GRT	-0.883	0.433	**	-0.317	0.110	*	-0.205	0.086	**	-0.123	0.143		0.125	0.053	**	0.230	0.094	**
Colreg 72 Convention	n/a	n/a		1.019	1.135		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Loadline 88 Protocol	n/a	n/a		n/a	n/a		-0.066	0.272		n/a	n/a		n/a	n/a		n/a	n/a	
SAR 79 Convention	2.682	1.497	^				n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified Colreg 72C	n/a	n/a		-0.204	0.246		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified Loadline 66C	n/a	n/a		n/a	n/a		-1.227	0.268	*	n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified Loadline 88P	n/a	n/a		n/a	n/a		0.049	0.068		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified SAR 79C	-0.763	0.431	^	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified Tonnage 69C	n/a	n/a		n/a	n/a		n/a	n/a		-0.667	0.171	*	-0.455	0.178	**	-0.745	0.146	*
February	0.135	0.259		-0.126	0.069	^	-0.217	0.045	*	-0.338	0.103	*	-0.243	0.085	*	-0.258	0.088	*
March	-0.488	0.253	^	0.014	0.072		-0.203	0.048	*	-0.132	0.103		-0.277	0.103	*	-0.246	0.076	*
April	-0.554	0.283	^	-0.164	0.069	**	-0.319	0.053	*	-0.256	0.101	**	-0.482	0.098	*	-0.242	0.076	*
May	-1.333	0.237	*	-0.152	0.079	^	-0.454	0.065	*	-0.413	0.128	*	-0.591	0.107	*	-0.488	0.083	*
June	-0.415	0.229	^	-0.153	0.068	**	-0.222	0.077	*	-0.183	0.116		-0.214	0.136		-0.403	0.091	*
July	-0.758	0.253	*	-0.053	0.073		-0.141	0.063	**	-0.361	0.112	*	-0.067	0.125		-0.271	0.100	*
August	-1.105	0.240	*	-0.214	0.082	**	-0.233	0.062	*	-0.330	0.121	*	-0.287	0.127	**	-0.328	0.083	*
September	-0.715	0.306	**	-0.260	0.074	*	-0.160	0.069	**	-0.176	0.102	^	-0.147	0.122		-0.162	0.093	^
October	-0.561	0.257	**	-0.126	0.075	^	-0.030	0.062		-0.225	0.099	**	0.047	0.121		-0.132	0.088	
November	-0.591	0.244	**	-0.105	0.109		-0.042	0.076		-0.172	0.124		0.088	0.109	*	-0.217	0.087	**
December	-0.285	0.333		-0.088	0.079		0.109	0.051	**	-0.003	0.113		0.047	0.115		0.041	0.085	
Log(1+DV)t-1	-0.024	0.059		0.397	0.046	*	0.269	0.067	*	0.273	0.053	*	0.290	0.076	*	0.172	0.048	*
Log(1+DV)t-2	-0.006	0.051		0.139	0.049	*	0.281	0.056	*	0.203	0.044	*	0.427	0.060	*	0.132	0.053	**
Earnings	0.377	0.192	^	0.079	0.044	**	0.065	0.036	^	0.103	0.063	^	0.007	0.038		0.090	0.039	**
PSC	0.158	0.287		0.024	0.089		0.072	0.061		2.774	0.729	*	1.861	0.704	*	3.074	0.643	*
Detentions	-0.003	0.042		0.020	0.014		-0.003	0.016		0.042	0.025	^	0.026	0.013	^	-0.100	0.027	*
R^2 of model	0.158			0.578			0.756			0.359			0.710			0.721		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%, Grt, age, inspection information is specific for each ship type*

Table 8 Type C Model Results - STCW, ILO

	C7: STCW very serious			C8: STCW serious			C9: STCW less serious			C10: ILO very serious			C11: ILO serious			C12: ILO less serious		
Variable	**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**		**Coeff**	**SE**	
Intercept	1.015	0.991		-1.138	1.054		-1.060	1.179		1.217	1.069		1.308	0.759		-1.090	0.855	
AGE	0.025	0.019		0.026	0.013	^	-0.013	0.016		-0.008	0.015		-0.009	0.009		-0.032	0.010	*
GRT	-0.480	0.116	*	-0.174	0.091	^	-0.034	0.088		-0.450	0.121	*	-0.208	0.086	*	-0.022	0.087	
STCW 78 Convention	1.180	0.457	**	1.348	0.387	*	0.348	0.308		n/a	n/a		n/a	n/a		n/a	n/a	
STCW 95 Amendment	0.032	0.057		-0.026	0.060		-0.038	0.063		n/a	n/a		n/a	n/a		n/a	n/a	
STCW White List	-0.252	0.106	**	0.098	0.119		0.227	0.288		n/a	n/a		n/a	n/a		n/a	n/a	
ILO 76 Convention	n/a	n/a		n/a	n/a		n/a	n/a		0.056	0.083		0.001	0.095		-0.018	0.075	
ILO 96 Protocol	n/a	n/a		n/a	n/a		n/a	n/a		0.013	0.122		0.029	0.105		-0.172	0.152	
Time to STWC 95 Amendment	-0.064	0.058		-0.053	0.059		-0.040	0.059		n/a	n/a		n/a	n/a		n/a	n/a	
Time to ILO 96 Protocol										-0.078	0.067		-0.044	0.052		-0.035	0.064	
Countries ratified STCW 78C	-0.283	0.112	**	-0.361	0.100	*	-0.103	0.082		n/a	n/a		n/a	n/a		n/a	n/a	
Countries ratified ILO 47C	n/a	n/a		n/a	n/a		n/a	n/a		0.061	0.087		-0.015	0.058		0.022	0.034	
Countries ratified ILO 96P	n/a	n/a		n/a	n/a		n/a	n/a		-0.178	0.061	*	0.005	0.057		-0.061	0.118	
February	-0.235	0.071	*	-0.099	0.079		-0.136	0.081	^	-0.258	0.073	*	-0.126	0.080		-0.171	0.073	**
March	-0.181	0.067	*	-0.084	0.068		0.003	0.091		-0.214	0.070	*	-0.115	0.073		-0.033	0.081	
April	-0.272	0.078	*	-0.214	0.069	*	-0.094	0.082		-0.288	0.078	*	-0.229	0.070	*	-0.111	0.073	
May	-0.297	0.074	*	-0.305	0.071	*	-0.099	0.094		-0.324	0.070	*	-0.326	0.070	*	-0.130	0.088	
June	-0.050	0.085		-0.196	0.071	*	-0.107	0.085		-0.079	0.070		-0.209	0.071	*	-0.137	0.072	^
July	-0.063	0.082		-0.011	0.072		0.037	0.085		-0.081	0.078		-0.004	0.071		0.006	0.073	
August	-0.256	0.091	*	-0.066	0.068		-0.112	0.096		-0.283	0.096	*	-0.074	0.069		-0.139	0.090	
September	-0.150	0.082	**	-0.192	0.070	*	-0.064	0.097		-0.170	0.079	**	-0.200	0.069	*	-0.094	0.087	
October	-0.101	0.086		-0.043	0.075		0.031	0.088		-0.123	0.084	^	-0.049	0.074		0.001	0.077	
November	-0.056	0.088		-0.007	0.083		-0.034	0.094		-0.056	0.085		0.006	0.084		-0.050	0.087	
December	0.033	0.083		0.021	0.061		0.094	0.080		0.010	0.084		0.004	0.061		0.063	0.075	
Log(1+DV)t-1	0.320	0.049	*	0.475	0.059	*	0.608	0.095	*	0.321	0.048	*	0.509	0.055	*	0.614	0.084	*
Log(1+DV)t-2	0.296	0.048	*	0.308	0.061	*	0.092	0.110		0.278	0.041	*	0.367	0.057	*	0.103	0.114	
Earnings	0.063	0.045		0.116	0.040	*	-0.046	0.049		0.031	0.045		0.014	0.037		-0.016	0.050	
PSC	0.040	0.066		0.093	0.064		-0.085	0.069		-0.090	0.051	^	-0.064	0.082		-0.139	0.040	*
Detentions	-0.070	0.018	*	0.027	0.022		-0.042	0.065		-0.043	0.017	**	0.015	0.019		0.048	0.043	
R^2 of model	0.848			0.856			0.767			0.845			0.849			0.770		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%*

Table 9 presents the type D combination models where we measure the effect of legislation and ratification on casualty types. Since we already took collisions and contacts into account with the COLREG convention and loss of life with SAR, we concentrate on fire and explosions and machinery related failures. Notwithstanding the models for the TONNAGE and LOADLINE convention were we also use hull related failures, we reuse this type of dependent variable and also present individual results for tankers and dry bulk carriers. We further combine relevant SOLAS and MARPOL measures when appropriate, especially for fire and explosions and for hull related issues with tankers.

The results for fire and explosion clearly indicate that the entry into force of SOLAS 74 had a decreasing effect on this type of casualty as well as the IBC code. Similar as with the type A models, the number of countries which had ratified SOLAS 74 presents a positive effect. For the SOLAS 88 Protocol and for MARPOL Annex III, this is not the case where ratification matters rather than the actual entry into force. Most relevant amendments for SOLAS show a positive immediate effect including the SOLAS 81 Amendment which introduced a revised chapter on fire safety requirements on cargo ship and the SOLAS 96 Amendments which modified Chapter II of SOLAS and made the *International Code for Application of Fire Test Procedures* mandatory. For tankers, the picture slightly changes and only the ISM code including the time to entry into force shows a decreasing effect besides the IBC Code. The SOLAS 78 Protocol which introduced inert gas or other SOLAS amendments is not significant.

Seasonality is not very strong for fire and explosions and machinery related failures but is much stronger for the hull related failures for tankers and dry bulk carriers where January is the worst month. For hull related failures on tankers, only the SOLAS 94 and 95 amendment shows a negative effect which are not directly related to hull related issues while Annex I gives a positive effect while the number of countries who had ratified the convention present is negative. The same applies for the time to entry into force of the SOLAS 97 amendment which is dealing with safety related issued. Finally, time to entry into force of the phase out of the singly hull tankers clearly decreased the number of hull related failures with tankers.

For dry bulk carriers, none of the measures for additional safety for bulk carriers come out to be significant; however the entry into force of the ISM code including time to entry into force does show a decreasing effect on hull related failures. The same applies for ratification of the SOLAS 78 Protocol. With respect to machinery related failures on all ships, again the ISM code and the SOLAS 02 Amendments gives a decreasing effect, the latter included new measures for machinery and electrical installations as well as fire protection and life saving appliances.

In *summary*, the type D models indicate that overall, some decreasing effects of the legislative framework can be found with respect to fire and explosions, hull related and machinery related casualties where sometimes the effect is associated with the timing of entry into force and sometimes, it is associated with ratification. Seasonality is strongest with hull related failures and not very significant for fire and explosions and machinery failures.

Table 9 Type D Model Results – Fire & Explosion, Hull and Machinery related failures

	D1: Fire & Explosion all ships			D2: Fire & Explosion tanker			D3: Hull related failures tanker			D4: Hull related failures, dry bulk			D5: Machinery related failures all ships		
Variable	Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE	
Intercept	-8.461	1.784		-12.406	1.858		-11.275	1.376		-8.808	1.865		-4.430	1.153	
AGE	0.020	0.023		-0.005	0.016		0.016	0.011		0.025	0.011	**	-0.006	0.013	
GRT	-0.438	0.148	*	0.008	0.114		0.193	0.099	^	-0.090	0.148		-0.146	0.088	^
SOL-74 Convention	-7.101	3.867	^	-3.449	5.395		-2.516	3.356		-5.344	3.424		-2.134	1.825	
SOL-78 Protocol (inert gas)	1.981	2.250		1.827	3.117		-1.811	2.105		6.088	2.010	*	1.687	1.013	^
SOL-81 Amendment (fire measures)	0.093	0.220		-0.270	0.315		-0.046	0.256		0.467	0.270	^	0.101	0.145	
SOL-88 Protocol (HSSC)	4.234	2.349	^	4.107	3.648		1.421	2.176		1.985	1.221		-0.403	0.568	
SOL-88 Amendment (GMDSS)	n/a	n/a		n/a	n/a		-0.215	0.183		-0.073	0.131		-0.084	0.077	
SOL-93 Amendment (ISM)	0.179	0.183		-0.938	0.247	*	0.079	0.146		-0.360	0.173	**	-0.244	0.103	**
SOL-94 Amendment (ESP)	n/a	n/a		n/a	n/a		0.078	0.079		0.237	0.150		-0.102	0.090	
SOL-95 Amendment (damage stability)	n/a	n/a		n/a	n/a		-0.332	0.136	**	0.141	0.097		0.114	0.059	^
SOL-96 Amendment (LSA, Fire testing)	0.394	0.131	*	0.128	0.166		-0.221	0.119	^	0.350	0.144	**	-0.020	0.081	
SOL-97 Amendment (add safety, bulk)	n/a	n/a		n/a	n/a		-0.160	0.127		0.006	0.137		0.070	0.087	
SOL-02 Amendment (safety, machinery, fire, LSA)	-0.138	0.182		-0.129	0.247		-0.026	0.203		0.037	0.199		-0.280	0.102	*
SOL-04 Amendment (add. safety, bulk)	n/a	n/a		n/a	n/a		0.143	0.132		0.010	0.130		0.054	0.076	
MAR-Annex I (oil)	0.069	1.198		-2.149	2.076		2.188	1.313	^	n/a	n/a		n/a	n/a	
MAR-Annex III (packaged substances)	5.444	1.734	*	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
IBC Code mandatory (chemicals)	-0.597	0.141	*	-0.612	0.221	*	-0.041	0.143		n/a	n/a		n/a	n/a	
MAR-01 Amendment (CAS, phase out)	0.484	0.244	**	0.217	0.331		0.195	0.238		n/a	n/a		n/a	n/a	
MAR-03 Amendment (revised phase out)	0.379	0.239		0.546	0.216	**	-0.069	0.239		n/a	n/a		n/a	n/a	
Time to 81 SOL Amend.	0.364	0.177	**	-0.005	0.266		0.198	0.192		0.274	0.238		0.095	0.097	
Time to 97 SOL Amend.	n/a	n/a		n/a	n/a		0.245	0.116	**	0.059	0.090		-0.008	0.058	
Time to 93 SOL Amend.	0.112	0.123		-0.570	0.187	*	0.048	0.116		-0.138	0.101		-0.240	0.092	*
Time to 01 MAR Amend.	0.549	0.197	*	0.214	0.427		0.038	0.167		n/a	n/a		n/a	n/a	
Time to 03 MAR Amend.	0.045	0.161		0.486	0.384		-0.388	0.156	**	n/a	n/a		n/a	n/a	
Countries ratified 74 Conv.	1.898	1.016	^	0.890	1.427		0.688	0.885		1.463	0.903		0.568	0.478	
Countries ratified 78 Prot.	-0.691	0.778		-0.509	1.082		0.455	0.741		-2.077	0.705	*	-0.549	0.358	
Countries ratified 88 Prot.	-1.055	0.628	^	-1.143	0.975		-0.368	0.572		-0.483	0.309		0.160	0.147	
Countries ratified Annex I	-0.137	0.414		0.596	0.708		-0.723	0.427	^	n/a	n/a		n/a	n/a	
Countries ratified Annex III	-1.408	0.430	*	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	

Table 9 continued	Fire & Explosion all ships			Fire & Explosion tanker			Hull related failures tanker			Hull related failures dry bulk			Machinery related failures all ships		
February	0.089	0.069		0.072	0.111		-0.201	0.082	**	-0.310	0.102	*	-0.080	0.071	
March	0.026	0.070		0.088	0.102		-0.242	0.074	*	-0.136	0.101		-0.043	0.072	
April	-0.104	0.083		-0.101	0.120		-0.285	0.076	*	-0.279	0.099	*	-0.135	0.079	^
May	-0.161	0.105		-0.013	0.139		-0.528	0.075	*	-0.433	0.128	*	-0.176	0.071	**
June	-0.190	0.093	**	-0.032	0.139		-0.508	0.089	*	-0.226	0.117	^	-0.151	0.073	**
July	-0.027	0.075		0.115	0.122		-0.387	0.095	*	-0.416	0.111	*	-0.031	0.069	
August	-0.056	0.078		-0.064	0.119		-0.419	0.074	*	-0.393	0.122	*	-0.138	0.073	^
September	-0.239	0.087	**	-0.025	0.134		-0.249	0.096	*	-0.251	0.098	**	-0.123	0.085	
October	-0.091	0.075		-0.050	0.138		-0.198	0.075	*	-0.282	0.100	*	-0.080	0.071	
November	-0.167	0.083	**	0.106	0.129		-0.270	0.080	*	-0.220	0.126		-0.056	0.084	
December	-0.014	0.079		0.006	0.122		0.021	0.082		-0.038	0.113		0.017	0.073	
Log(1+DV)t-1	-0.004	0.048		0.038	0.066		-0.027	0.056		0.174	0.060	*	0.326	0.055	*
Log(1+DV)t-2	0.039	0.049		-0.088	0.053	^	-0.035	0.051		0.116	0.052	**	0.091	0.077	
Earnings	0.488	0.116	*	0.266	0.093	*	0.072	0.060		0.382	0.133	*	0.177	0.060	*
PSC	-0.128	0.184		-0.048	0.248		-0.417	0.163	**	0.632	0.279	**	0.090	0.071	
Detentions	-0.045	0.034		-0.047	0.110		-0.006	0.085		-0.018	0.056		-0.021	0.026	
R^2 of model	0.535			0.424			0.771			0.417			0.641		

*Note: * = significant at 1%, ** = significant at 5%, ^ = significant at 10%, grt, age, inspection information is specific for each ship type*

4. Conclusions and recommendations on policy implications

In this article, we made a first attempt and presented econometric models to measure the effectiveness of international conventions and relevant amendments. We based our analysis on 45 milestones of the legislative framework and corrected for other factors which can influence safety such as ship economic cycles, safety inspections and other unilateral legislation. We also measured the effect of ratification of a convention by taking the number of parties into account. Finally, we accounted for the time of adoption to the time of entry into force of relevant measures. This final section presents a global summary of the main findings of the models and tries to identify areas of weaknesses in the legislative framework. Finally, we also present our recommendations to the policy makers.

4.1. Summary of main findings per convention

For the *SOLAS* models, the effect of entry into force shows a negative relationship for very serious and serious casualties, especially for dry bulk carriers. The implementation of the ISM code including the time from adoption to entry into force decreased all types of casualties, especially for dry bulk carriers and general cargo vessels. Other amendments which show a negative effect are GMDSS and the SOLAS 02 and 04 Amendments (enhanced bulk carrier safety, freefall lifeboats, additional measures for fire protection and life saving appliances). However, the number of countries which had ratified the convention is mainly not significant which could be explained by the fact that SOLAS is the main convention of IMO and many countries have ratified the convention. In addition, some of the amendments of SOLAS such as the 78 and 88 Protocol, ESP and LSA are not significant or show a positive effect.

The *MARPOL* models indicate that the various amendments in relation with the phase out of single hull tankers and CAS decreased the number of casualties with pollution and to a certain degree also the amount of pollution. The effect of MARPOL Annex III cannot be measures but the number of countries who had ratified the convention shows a decreasing effect. Furthermore, the IBC code decreased casualties with relation to fire and explosion on tankers.

For the LOADLINE, TONNAGE, the SAR and STCW convention, the number of countries which ratified the convention indicates improvement rather than the entry into force of the convention itself. For STCW, the introduction of the STCW White List further decreased the number of very serious casualties. We cannot measure the effect of COLREG which might be due to the fact that the convention came into force very early in our time frame for the analysis. Some disappointing results can be associated with the ILO convention where we cannot measure the effect of entry into force nor the number of countries which had ratified it. However, the effect of the ILO 96 Protocol presents a decreasing effect for very serious casualties.

Our results also show that seasonality matters and that January is the worth month, be it with the various types of seriousness of casualties or the loss of life. We can observe less seasonality with respect to MARPOL and fire and explosions. This is not surprisingly since casualties of a technical nature (hull integrity, flooding, foundering, wrecked, etc.) are more prone to the effects of weather while pollution related casualties and fire and explosion are more influenced by operational issues which are less dependent on the weather.

4.2. Overall evaluation and recommendations on policy implications

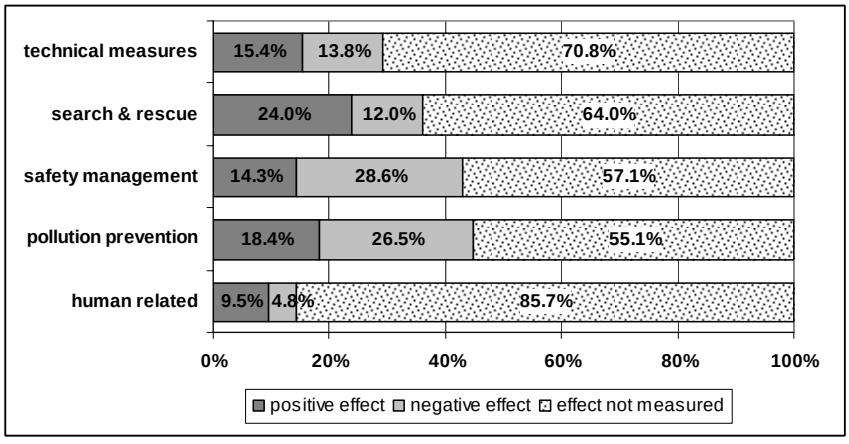
In order to provide a higher level evaluation of the legislative framework, we look at two aspects in aggregated format as follows: 1) the number of countries that had ratified a convention and 2) the legislative measures identified in the milestones and grouped into areas such as technical areas, pollution, search & rescue, safety management and human related areas such as living and working conditions and certification. For both areas, we count the effects of all 29 models and distinguish between three possible outcomes: 1) positive effects, 2) negative effects (which mean less accidents and pollution) and 3) effects which could not be measured.

For the number of countries which had ratified a convention, we have 65 possible outcomes of which 21 are significant (32%). Of the significant variables, 16 show negative effects and 5 a positive effect. We conclude that overall, the number or countries that have ratified a convention is associated with a negative effect on accidents and pollution but that overall, the results also indicate that there is a certain degree of enforcement. At the moment, the only means of measuring the lack of enforcement at IMO level is in aggregated format and not by identifying flags which do have a problem in enforcing legislation.

Given the negative effect which was associated with the "STCW White list", a policy implication for this finding could be that it might be beneficial for IMO to create similar lists for other conventions and indicate the level of enforcement of its member states. This could be measured by using for instance casualty data or port state control data from all regional regimes and by creating performance indicators for flag states which could be published yearly following the same idea as the STCW White list.

For the second area dealing with the entry into force of certain measures, aggregation of the results is a bit more complex but the same approach is taken. Out of the total 29 models, we have 260 possible outcomes which are grouped into effects that are positive, negative and effects which cannot be measured. Out of the 260 outcomes, we have 87 that are significant (33%) and 45 which show a negative effect. The variables are then grouped into the areas mentioned in the beginning of this section and the result is presented in Figure 1 below for all model types and in Figure 2 based on the models using the seriousness of a casualty as dependent variable.

Figure 1: Effect of legislation per area based on all model types

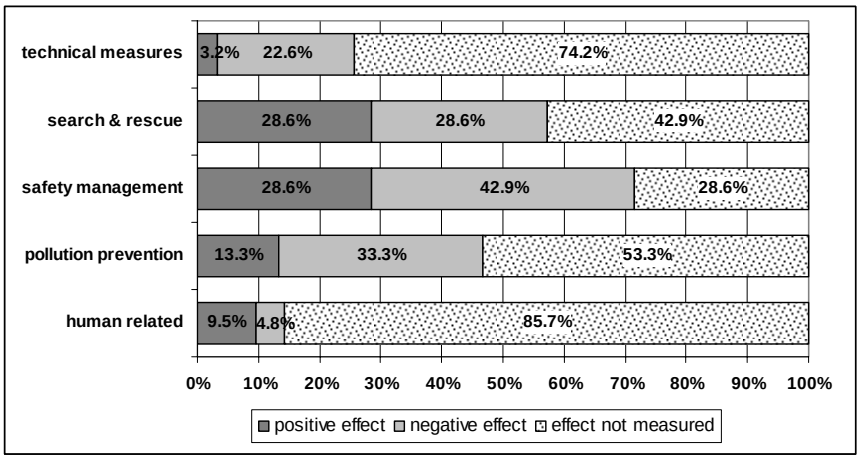


As indicated previously, the classification of seriousness of casualty can be considered as the most reliable classification and we therefore also present the results based on the models

where seriousness of casualty was used as dependent variable compared to all types of casualties (e.g. casualty first events such as hull related or machinery related casualties or casualties per ship type irrespective of seriousness). This means, we exclude all other models with the exception of the SAR model (lives lost).

The results in Figure 1 indicate that most of the negative effect on incidents can be measured in areas related to safety management and pollution prevention while human related areas which are associated with working and living conditions and certification only present a small amount of negative effects. The results in Figure 2 now show stronger effects which can be measured in all areas but still presents the strongest effect associated with safety management and pollution prevention. Human related measures are still weak in impact.

Figure 2: Effect of legislation per area based on seriousness



We obtain surprising results with respect to the technical areas where one would expect to find a stronger decreasing effect and especially as the shipping industry has always put more emphasis on the technical side of ships. This attitude is slowly changing as the implementation of the ISM code, which increased the awareness of safety management and its effect, is reflected by the negative effect of the legislation in this area shown in Figure 1 and 2.

The ISM code however does not necessarily contribute towards enhancing the living and working conditions of the crew. The various ILO conventions recently benefited from a major overhaul of the legislative framework ending in the adoption of the 2006 Maritime Labor Convention. Tentative entry into force date is set for 2010 or 2011. Our immediate policy implication is to support the new convention and to place more emphasis on the well being of the crew.

Another policy implication and recommendation for the findings with respect to the seasonality aspects where more casualties can be found in the winter month is to improve crew training in general and also to improve the situation of fatigue associated with bad weather conditions. Perhaps minimum safety manning standards could be changed for the winter months so that the crew can get more resting periods. This recommendation also goes in line with the general findings of the ILO convention.

As policy implication for the results of some of the positive effects associated with the technical areas primarily given by the SOLAS models, one could conclude that the positive effects indicate the fact that legislation follows after a major disaster and that by the time it

come into force, the effect cannot be measured immediately since the number of casualties is still high. It is therefore important for IMO to shifts its emphasis to preventive measures such as the Formal Safety Assessment framework so that risk can be identified before hand and action be taken accordingly. In order to use FSA for legislative measures, a common database should be developed with common classifications of casualty first events and the combination of data sources from commercial data providers and IMO. Another aspect would be to improve the population of data with respect to pollution such as oil or chemicals.

4.3. Future research

Finally, we would like to suggest areas for further research. This article used time series of monthly totals or averages for the time period 1977 to 2007. The models therefore do not measure the effect of legislation at an individual ship level which would be a further area for investigation if more data becomes available and if the classification of casualties is improved throughout the industry. If measured at a ship level, the individual effects of the flags could also be included so as to identify weak areas of enforcement irrespective from ratification. We also believe that a similar analysis could be performed for SOLAS, MARPOL and ILO (once the new convention has entered into force) every five years in order to continue measuring the effect of new amendments.

References

[1] Goulielmos AM and Giziakis K, 1998, Treatment of uncompensated cost of marine accidents in a model of welfare economics, Disaster Prevention and Management, Volume 7, Number 3, pp 183-187

[2] Assembly Resolution A.989(25), Strategic Plan for the Organization (for the six-year period 2008-2013), adopted 20th November 2007, IMO, London

[3] Assembly Resolution A.990(25), High Level Action Plan of the Organization and Priorities for the 2008-2009 biennium, adopted 29th November 2007, IMO, London

[4] Oran R. Young, The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms, Cambridge, MA: MIT Press, 1999

[5] E. Eliopoulou and A. Papanikolaou, Casualty analysis of large tankers, J Mar Sci Technol (2007), 12:240-250

[6] S. Delautre, E. Eliopoulou and N. Mikelis, The Influence of Regulations on the Safety Record of the Aframax Tankers, Working Paper of the POPC project

[7] Bijwaard G and Knapp S, Analysis of Ship Life Cycles – The Impact of Economic Cycles and Ship Inspections, Marine Policy 2009, volume 33, pp. 350-369

[8] Ronald B. Michel, Regime Design Matters: Intentional Oil Pollution and Treaty Compliance, International Organization, Volume 48, Issue 3 (Summer, 1994), 425-458

[9] MSC/Circ. 953, MEPC/Circ. 372, Reports on Marine Casualties and Incidents, Revised harmonized reporting procedures, adopted 14th December 2000, IMO, London

[10] MSC Resolution MSC.255(84), Casualty Investigation Code, adopted 16 May 2008, IMO, London

[11] Status of Multilateral Conventions and Instruments in respect of which the International Maritime Organization or its Secretary General performs depositary or other functions, December 2007, IMO, London, www.imo.org

[12] IMO, MSC 82/INF.11, Implementation of Instruments and related matters, Note by the secretariat, 6 October 2006

[13] Knapp S, Franses PH, Comprehensive Review of the Maritime Safety Regimes - Present Status and Recommendations on improvement, Econometric Institute Report 2007-Nr. 19: http://repub.eur.nl/publications/index/888058212/

[14] Heij C., De Boer P., Franses, PH, Kloek T. and van Dijk, HK, Econometric Methods with Applications in Business and Economics, Oxford University Press, New York, 2004

Appendix 1: Development of the legislative framework in shipping

ST	Main Events influencing safety	Damage/ in response to	Event year	Adoption date	Entry into force date	Time	MS	Detail of event or legal instrument
pax	**Titanic**	1517 lost	**1912**	n/a	n/a	n/a	A	**famous passenger liner accident, North Atlantic**
all	ILO C7 (Min Age)		1920	09/07/1920	27/09/1921	1.2	N	Minimum Age Sea Convention
all	ILO C8 (Unemployment)		1920	09/07/1920	16/03/1923	2.7	N	Unemployment Indemnity (Shipwreck)
all	ILO C9 (Placing of Seam)		1920	10/07/1920	23/11/1921	1.4	N	Placing of Seaman Convention
all	Conv. establishing IMO		1948	06/03/1948	17/03/1958	10.0	N	Conventions establishing IMO
all	LOAD LINES 66		1966	05/04/1966	21/07/1968	2.3	Y	regulated load line, strength of hull, freeboard allowance
tank	**Torrey Canyon**	119,000 tons	**1968**	n/a	n/a	n/a	A	**large tanker accident, coast of England**
	IACS starts operation		1968	11/09/1968	n/a	n/a	Y	IACS starts with 7 members
all	Tonnage Convention		1969	23/06/1969	18/07/1982	13.5	N	Intern. Convention on Tonnage Measurement of ships
all	CLC Convention	Torrey Canyon	1969	n/a	n/a	n/a	N	Convention related to civil liability for oil pollution damage
all	COLREG 72		1972	20/10/1972	15/07/1977	4.7	Y	regulates collision regulations
tank	**Metula**	47,000 tons	**1974**	n/a	n/a	n/a	A	**large tanker accident, Magellan Street, Chile**
all	SOLAS 74	Titanic	1974	01/11/1974	25/05/1980	5.6	Y	regulates technical aspects of safety
all	ILO147 MinSt 1976		1976	29/10/1976	28/11/1981	5.1	Y	improve working and living conditions
tank	**Argo Merchant**	28,000 tons	**1976**	n/a	n/a	n/a	A	**large tanker accident, Nantucket Sound, USA**
all	MARPOL 73/78 ANNEX I	Torrey Canyon	1978	17/02/1978	02/10/1983	5.6	Y	oil pollution, SBT, COW
all	MARPOL 73/78 ANNEX II	Torrey Canyon	1978	17/02/1978	06/04/1987	9.1	Y	harmful substances in liquid form (NLS)
all	MARPOL 73/78 ANNEX III		1978	17/02/1978	01/07/1992	n/a	Y	harmful substances in packaged form
all	MARPOL 73/78 ANNEX IV		1978	17/02/1978	27/09/2003	n/a	Y	sewage
all	MARPOL 73/78 ANNEX V		1978	17/02/1978	31/12/1988	n/a	Y	garbage
all	SOLASProt78		1978	17/02/1978	01/05/1981	3.2	Y	inert gas, two radars, remote steering gear, power units
tank	**Amoco Cadiz**	223,000 tons	**1978**	n/a	n/a	n/a	A	**large tanker accident, coast of France**
all	STCW 78		1978	07/07/1978	28/04/1984	5.8	Y	to improve quality of seafarers (training, certification & watchkeeping)
all	SARConvention		1979	27/04/1979	22/06/1985	6.2	Y	help reducing number of victims (search and rescue)
tank	**Atlantic Empress**	287,000 tons	**1979**	n/a	n/a	n/a	A	**large tanker accident, coast of Trinidad & Tobago**
bulk	**Derbyshire**	42 lost	**1980**	n/a	n/a	n/a	A	**large dry bulk carrier sunk, Japan**
all	SOLAS81-11Amend.	Amoco Cadiz	1981	20/11/1981	01/09/1984	2.8	Y	fire safety, machinery and electrical installations
all	Paris MoU starts	Amoco Cadiz	1982	26/01/1982	01/07/1982	0.4	Y	PSC inspections mainly Europe
tank	SOLAS83Amend.		1983	17/06/1983	01/07/1986	3.0	N	IBC Code and IGC Code mandatory
tank	**Castillo de Bellver**	252,000 tons	**1983**	n/a	n/a	n/a	A	**large tanker accident, South Africa**
pax	**Herald of Free Enterprise**	193 lost	**1987**	n/a	n/a	n/a	A	**major ferry accident, coast of Belgium**
pax	**Dona Pax**	4000 lost	**1987**	n/a	n/a	n/a	A	**major ferry accident, Philippines**
pax	SOLAS88-04Amend	Herald of FE	1988	21/04/1988	22/10/1989	1.5	N	improved doors, emergency steering gear and lighting
all	SOLAS88-10Amend	Herald of FE	1988	28/10/1988	29/04/1990	1.5	N	compulsory lightweight surveys for pax vessels, stability of damage conditions
all	SOLAS88-11Amend		1988	11/11/1988	01/02/1992	3.2	Y	GMDSS, date into force varied per ship type
all	SOLAS88-Prot		1988	11/11/1988	03/02/2000	11.2	Y	introduced new harmonized system of surveys and certification (HSSC)

ST	Main Events influencing safety	Damage/ in response to	Event year	Adoption date	Entry into force date	Time	MS	Detail of event or legal instrument
all	LOAD LINES 88Prot		1988	11/11/1988	03/02/2000	11.2	Y	introduced new harmonized system of surveys and certification (HSSC)
tank	**Exxon Valdez**	37,000 tons	**1989**	n/a	n/a	n/a	A	**large tanker accident, Alaska, USA**
pax	**Scandinavian Star**	158 lost	**1990**	n/a	n/a	n/a	A	**ferry accident, fire, Baltic Sea**
bulk	SOLAS90-Amend		1990	01/05/1990	01/02/1992	1.8	N	damage stability on cargo ships
tank	OPA90	Exxon Valdez	1990	01/08/1990	01/08/1990	0.0	Y	US law - mandatory for all tankers calling the US
bulk	SOLAS91-05Amend		1991	24/05/1991	01/01/1994	2.6	N	Grain Code mandatory, fire safety
tank	MARPOL 92Amend	Exxon Valdez	1992	06/03/1992	06/07/1993	1.3	Y	phase out of single hull tankers
all	Vina del Mar starts		1992	05/11/1992	05/11/1992	0.0	Y	PSC inspections in the South American region
tank	SIRE starts inspections	Exxon Valdez	1993	01/01/1993	n/a	n/a	Y	industry inspections performed on tankers
tank	**Braer**	84,700 tons	**1993**	n/a	n/a	n/a	A	**large tanker accidents, Shetland Islands, UK**
all	SOLAS93-11Amend1	Herald of FE	1994	01/11/1993	01/07/1998	4.7	Y	ISM code for pax, tanker, bulk carriers
all	SOLAS93-11Amend2	Herald of FE	1994	01/11/1993	01/07/2002	8.7	Y	ISM code for all other ships
all	Tokyo MoU starts		1993	01/12/1993	01/01/1994	0.1	Y	PSC inspections mainly Asia
all	USCG emphasis on PSC		1994	01/01/1994	n/a	n/a	Y	PSC inspections in the US
tank	CDI starts inspections		1994	10/01/1994	n/a	n/a	Y	CDI starts inspection program, chemical tankers
bulk, tank	SOLAS94-05Amend		1994	01/05/1994	01/01/1996	1.7	Y	Enhanced Survey Program (A.744(18)), ISM Code Mandatory
pax	**Estonia**	852 lost	**1994**	n/a	n/a	n/a	A	**Ferry accident, Baltic Sea**
bulk	SOLAS94-12Amend		1994	09/12/1994	01/07/1996	1.6	N	Code of Safe Practice for Cargo Stowage & Securing mandatory
all	SOLAS95-05Amend		1995	16/05/1995	01/01/1997	1.6	N	Ships routing mandatory for all ships
pax	STCW_95Amend	Estonia	1995	07/07/1995	01/02/1997	1.6	Y	Improved crowd and crisis management
pax	SOLAS95-11Amend	Estonia	1995	29/11/1995	01/07/1997	1.6	Y	stability of passenger ships, lifesaving, VTS
all	Caribbean MoU starts		1996	09/02/1996	09/08/1996	0.5	Y	PSC inspections in the Caribbean
tank	**Sea Empress**	72,000 tons	**1996**	n/a	n/a	n/a	A	**larger tanker accident, Milford Haven, UK**
tank	CAP (ABS, DNV,LR)		1996	01/06/1996	01/06/1996	n/a	N	Condition Assessment Program - industry driven
all	SOLAS96-06Amend		1996	04/06/1996	01/07/1998	2.1	N	dedicated BWT to have corrosion prevention, oil tankers, LSA Code
all	ILO147Prot1996		1996	22/10/1996	10/01/2003	6.2	Y	minimum rest hours
all	SOLAS96-12Amend		1996	06/12/1996	01/07/1998	1.6	N	Emergency towing arrangements, Code for of Fire Test Procedures mandatory
all	SOLAS97-06Amend		1997	04/06/1997	01/07/1999	2.1	N	introduction of VTS, safety for Ro-Ro passenger ships
all	Mediterranean MoU starts		1997	11/07/1997	23/02/1998	0.6	Y	PSC inspections in the Mediterranean
all	MARPOL 73/78 ANNEX VI		1997	01/09/1997	19/05/2005	7.7	N	air pollution
bulk	SOLAS97-11Amend	Derbyshire	1997	27/11/1997	01/07/1999	1.6	Y	additional safety measures for bulk carriers, BLU Code (Assembly Res. A.862(20))
all	Indian Ocean MoU starts		1998	05/06/1998	22/01/1999	0.6	Y	PSC inspections in the Indian Ocean Area
tank	MARPOL 99Amend		1999	01/07/1999	01/01/2001	1.5	N	increase of application of double hull
tank	**Erika**	20,000 tons	**1999**	n/a	n/a	n/a	A	**oil tanker disaster, Brittany, France**
tank	Greenaward starts (1994)		2000	01/01/2000	n/a	n/a	N	Greenaward starts certification program
all	STCW_WhiteList		2000	06/02/2000	n/a	n/a	Y	Publication of the white list (countries with endorsements), valid for 5 years
all	Black Sea MoU starts		2000	07/04/2000	07/10/2000	0.5	Y	PSC inspections in the Black Sea

ST	Main Events influencing safety	Damage/ in response to	Event year	Adoption date	Entry into force date	Time	MS	Detail of event or legal instrument
all	SOLAS00Amend		2000	06/12/2000	01/07/2002	1.6	N	AIS, FSS Code, FTP Code
tank	MARPOL 01Amend	Erika	2001	27/04/2001	01/09/2002	1.3	Y	Condition Assessment Scheme, oil tankers
bulk	Rightship starts vetting		2001	01/10/2001	n/a	n/a	Y	RightShip starts vetting inspection system, dry bulk
bulk	**Christoper**	27 lost	**2001**	n/a	n/a	n/a	A	**bulk carrier accident - forward flooding, similar to Derbyshire**
tank	EC Regulation 417/2002	Erika	2002	18/02/2002	01/09/2002	0.5	Y	phasing out of single hull, category 1, 2 and 3 tankers
con	SOLAS02-05Amend		2002	24/05/2002	01/01/2004	1.6	N	IMDG mandatory
pax	**Joola**	1863 lost	**2002**	n/a	n/a	n/a	A	**ferry disaster, West Africa**
tank	**Prestige**	77,000 tons	**2002**	n/a	n/a	n/a	A	**oil tanker disaster, Spain**
bulk	SOLAS02-12Amend	Derbyshire	2002	12/12/2003	01/07/2004	1.6	Y	high level alarms, water ingress system (MSC Resolution 145(77))
tank	EC Regulation 1726/2003	Erika, Prestige	2003	22/07/2003	21/10/2003	0.2	Y	revised EU regulation 417/2002 - accelerated phase out
tank	**Tasman Spirit**	30,000 tons	**2003**	n/a	n/a	n/a	A	**oil tanker disaster, Pakistan**
tank	MARPOL 03Amend	Erika, Prestige	2003	04/12/2003	05/04/2005	1.3	Y	final phase out of SH, carriage of heavy grade oil
all	SOLAS04-05Amend		2004	01/05/2004	01/07/2006	2.2	N	reduce accidents with lifeboats
tank	MARPOL 04Amend		2004	01/10/2004	01/01/2007	2.3	N	new categories for harmful substances
bulk	SOLAS04-12Amend		2004	01/12/2004	01/07/2006	1.6	Y	new requirements related to double side skins, free fall lifeboat mandatory for bulk
all	Voluntary MS Audit		2005	01/12/2005	n/a	n/a	Y	Voluntary MS Audit Scheme adopted (Assembly Resolution A974(24))
pax	**Al Salam Boccachio 98**	1000 lost	**2006**	n/a	n/a	n/a	A	**ferry accident, Red Sea**
pax	**Star Princess**	1 lost	**2006**	n/a	n/a	n/a	A	**cruise ship accident - fire, coast of Jamaica**
pax	SOLAS06-12Amend		2006	01/12/2006	01/07/2008	1.6	N	amended fire protection requirements
all	Maritime Labor Conv. 2006		2006	07/02/2006	Not in force	n/a	Y	revised ILO Maritime Conventions, possible entry into force dates: 2010/11

Notes:
ST = ship types as follows: all, bulk (bulk carriers), pax (passenger vessels), tank (tankers)
Time = measures time between adoption and enforcement of legal instrument
MS = milestones: Y=yes, N=no, A=accident

Appendix 2: Summary of variables used in models

Ship particulars	**Description**	**Remark**
TOTALSHIPS	total ships used sometimes for the calculation of the dependent var.	sum/month
AGE_MEAN	mean age all ships	mean/month
AGE_DB	mean age dry bulk	mean/month
AGE_GC	mean age general cargo	mean/month
AGE_PA	mean age passenger ships	mean/month
AGE_TA	mean age tanker	mean/month
AGE_CON	mean age container vessels	mean/month
GRT_MEAN	mean GT all ships	mean/month
GRT_DB	mean GT dry bulk	mean/month
GRT_GC	mean GT general cargo	mean/month
GRT_CON	mean GT container vessels	mean/month
GRT_PA	mean GT passenger	mean/month
GRT_TA	mean GT tanker	mean/month
Ratification variables	**Description**	**Remark**
CR_COL72	number countries ratified COLREG	sum/month
CR_ILO47	number countries ratified ILO47 Convention	sum/month
CR_ILO96	number countries ratified ILO96 Protocol	sum/month
CR_LOA66	number countries ratified Load Line 66 Convention	sum/month
CR_LOA88	number countries ratified Load Line 88 Protocol	sum/month
CR_MARA1	number countries ratified MARPOL Annex I - oil	sum/month
CR_MARA2	number countries ratified MARPOL Annex II - NLS	sum/month
CR_MARA3	number countries ratified MARPOL Annex III - IMDG	sum/month
CR_SOL74	number countries ratified SOLAS 74 Convention	sum/month
CR_SOL78	number countries ratified SOLAS 78 Protocol	sum/month
CR_SOL88	number countries ratified SOLAS 88 Protocol	sum/month
CR_STW8	number countries ratified STCW Convention	sum/month
CR_TON69	number countries ratified Tonnage Convention	sum/month
Entry into force of legal instrum. and amendments	**Description**	**Remark**
IN_SOL74C	SOLAS 1974 convention	indicator 0/1
IN_SOL78P	Protocol of 1978 to SOLAS	indicator 0/1
IN_SOL88P	Protocol of 1988 to SOLAS	indicator 0/1
IN_SOL81A	SOLAS amendment 1981	indicator 0/1
IN_SOL88A	SOLAS amendment 1988	indicator 0/1
IN_SOL93A1	SOLAS amendment 1993-1 (tanker, dry bulk, passenger)	indicator 0/1
IN_SOL93A2	SOLAS amendment 1993-2 (container, general cargo, other ST)	indicator 0/1
IN_SOL94A	SOLAS amendment 1994	indicator 0/1
IN_SOL95A	SOLAS amendment 1995	indicator 0/1
IN_SOL96A	SOLAS amendment 1996 (FSA Code and Fire Testing)	Indicator 0/1
IN_SOL97A	SOLAS amendment 1997	indicator 0/1
IN_SOL02A	SOLAS amendment 2002	indicator 0/1
IN_SOL04A	SOLAS amendment 2004	indicator 0/1
IN_COL72C	COLREG convention 1972	indicator 0/1
IN_LL66C	Load Line convention 1966	indicator 0/1
IN_LL88P	Protocol of 1988 to Load line	indicator 0/1
IN_STW78C	STCW Convention 1978	indicator 0/1
IN_STW95A	STCW amendment 1995	indicator 0/1
IN_STWWL	STCW While List	indicator 0/1
IN_SAR79C	SAR convention 1979	indicator 0/1
IN_MARA1	MARPOL convention 73/78 Annex I	indicator 0/1
IN_MARA2	MARPOL convention 73/78 Annex II	indicator 0/1
IN_MARA3	MARPOL convention 73/78 Annex III	indicator 0/1
IN_MAR92A	MARPOL 92 amendment – double hull requirements for tankers	indicator 0/1

Entry into force cont.	Description	Remark
IN_MAR99A	MARPOL 99 amendment – increased double hull requirement	Indicator 0/1
IN_MAR01A	MARPOL 01 amendment - CAS for tankers	indicator 0/1
IN_MAR03A	MARPOL 03 amendment - final phase of single hull tankers	indicator 0/1
IN_ILO76C	International Labor Convention 147, 1976	indicator 0/1
IN_ILO96P	Protocol for ILO Convention 147	indicator 0/1
IN_IBC	IBC Code mandatory	Indicator 0/1
IN_OPA90	Oil Pollution Act 90 - mandatory aw for tankers calling the US	indicator 0/1
Time between adoption and entry into force	**Description**	**Remark**
AD_SOL81A	time between adoption and entry into force, all ships	dummy 0/1
AD_SOL88A	time between adoption and entry into force, all ships	dummy 0/1
AD_SOL93A1	time between adoption and entry into force, all ships	dummy 0/1
AD_SOL93A2	time between adoption and entry into force, all ships	dummy 0/1
AD_SOL95A	time between adoption and entry into force, passenger ships	dummy 0/1
AD_SOL97A	time between adoption and entry into force, bulk	dummy 0/1
AD_SOL02A	time between adoption and entry into force, bulk	dummy 0/1
AD_SOL04A	time between adoption and entry into force, bulk	dummy 0/1
AD_ILO96P	time between adoption and entry into force, all ships	dummy 0/1
AD_MAR92A	time between adoption and entry into force, tankers	dummy 0/1
AD_MAR99A	time between adoption and entry into force, tankers	dummy 0/1
AD_MAR01A	time between adoption and entry into force, tankers	dummy 0/1
AD_MAR03A	time between adoption and entry into force, tankers	dummy 0/1
AD_STW95A	time between adoption and entry into force, all ships	dummy 0/1
Inspection variables	**Description**	**Remark**
IND_PMOU	PSC inspections starts - covers all other regimes that follow	indicator 0/1
IND_CDI	industry inspections (tankers)	indicator 0/1
IND_RS	industry inspections (bulk carriers)	indicator 0/1
IND_SIRE	industry inspections (tankers)	indicator 0/1
DET_ALL	Detentions - all port state control inspections, all ships	sum/month
DET_DB	detentions – dry bulk carriers	sum/month
DET_TA	detentions - tankers	sum/month
DET_PA	detentions – passenger ships	sum/month
DET_GC	detentions – general cargo vessels	sum/month
DET_CON	detentions – container vessels	sum/month
Seasonal dummies	**Description**	**Remark**
SEAS01	season dummy January (used as reference)	dummy 0/1
SEAS02	season dummy February	dummy 0/1
SEAS03	season dummy March	dummy 0/1
SEAS04	season dummy April	dummy 0/1
SEAS05	season dummy May	dummy 0/1
SEAS06	season dummy June	dummy 0/1
SEAS07	season dummy July	dummy 0/1
SEAS08	season dummy August	dummy 0/1
SEAS09	season dummy September	dummy 0/1
SEAS10	season dummy October	dummy 0/1
SEAS11	season dummy November	dummy 0/1
SEAS12	season dummy December	dummy 0/1
Ship economic cycles	**Description**	**Remark**
EARN_CLARKINDEX	average earnings per months for all ships	mean/month
EARN_BULK	average earnings per months for bulk carriers	mean/month
EARN_CONT	Average earnings per months for container vessels	mean/month
EARN_TANK	average earnings per months for tanker	mean/month