The Overall View of the Effect of Inspections and Evaluation of the Target Factor to target substandard vessels

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Abstract

This report is the third part of a PhD project entitled *"The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea"* which is based on 183,000 port state control inspections[2] and 11,700 casualties from various data sources. Its overall objective is to provide recommendations to improve safety at sea. The second part looks into the differences across port state control regimes based on the probability of detention while the third part is measuring the effect of inspections on the probability of casualty which can be measured for very serious casualties but not for serious or less serious casualties. It further determines the magnitude of improvement areas for targeting substandard vessels and gives an evaluation of the target factor.

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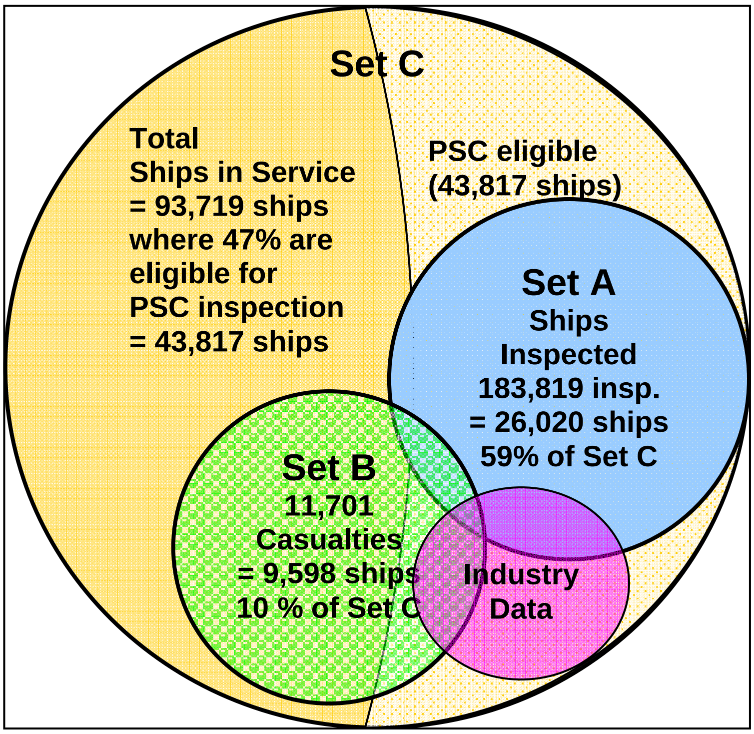
[2] The authors would like to thank the following secretariats for their kind co-operations: Paris MoU, Indian Ocean MoU, Viña del Mar Agreement on PSC, Caribbean MoU, Australian Maritime Safety Authority, the United States Coast Guard, Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit, the International Maritime Organization (IMO), Right Ship and the Greenaward Foundation.

1. Overview of Datasets and Variables Used

Chapter 1 of this report are extracts from Knapp (2006)[3] which are necessary in order to explain the datasets and variable preparation as a basis for the analysis explained in chapter 3. Three datasets have been used for the analysis and their relation can be seen in Figure 1. Set A consists of the inspection database of 183,819 inspections from various Memoranda of Understanding (MoU[4]) for the time period January 1999 to December 2004 where the time period is not fully covered by all regimes. This total dataset is a combination of six individual inspection datasets and when aggregated, it accounts for approx. 26,020 ships[5] where the average amount of inspections per vessel is by 7 per ship or 1.7 inspections per ship per year.[6]

Figure 1: Overview of Datasets Used



Set C represents an approximation of the total ships in existence[7]. Out of these vessels, ships below 400 gt[8] and ship types which are not eligible for port state control inspection such as fishing vessels, government ships, yachts and ferries (for the Paris MoU) have been eliminated from this dataset which leaves approx. 43,817 ships (46,75% of the total) for inspection. Since the amount of inspections from the Paris MoU is the dominating part of this dataset and ferries

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[3] Knapp, S. (2006), The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea, Doctoral Thesis (to be published), Econometric Institute, Erasmus University, Rotterdam

[4] A memorandum of understanding (MOU) is a legal document describing an agreement between parties but is less formal than a contract.

[5] 25,836 exact ships plus 184 estimated ships. Since there are 1,288 ships with missing IMO numbers out of the total port state control dataset and the average number of inspections per ship lies by 7, the unidentified ships can be aggregated to another 184 inspected ships.

[6] Based on an average of 4 inspection years which is the average of the total months per regime to bring the different years of data to the same level for all regimes. The total time period Jan. 1999 to Dec. 2004 therefore represents a total of full 4 inspection years instead of 6 years.

[7] As per data received from Lloyd's Register Fairplay.

[8] As per Marpol 73/78, Annex I, Regulation 4 which identifies the vessels subject to mandatory surveys (page 51)

are treated separately in the EU, ferries have been excluded from PSC eligible ships. The total estimated inspection coverage by the regimes in question of eligible ships is 59.4% between set A and the eligible ships of Set C for the time period in question (1999-2004).

Besides the port state control inspection dataset, a small industry inspection dataset has been collected and comprises of vetting inspection information[9] of vetting inspections performed on oil tankers and dry bulk carriers from Rightship. In addition, oil tankers which are certified by Greenaward have also been identified. The casualty and industry data is linked to the port state control data by the IMO number and within the same time frame.

This total dataset is a combination of six individual inspection datasets and when aggregated, it accounts for approx. 26,020 ships[10] where the average amount of inspections per vessel is 7 per ship or 1.7 inspections per year.[11] Set C represents an approximation of the total ships in existence[12]. Out of these vessels, ships below 400 gt[13] and ship types which are not eligible for port state control inspection such as fishing vessels, government ships, yachts and ferries have been eliminated from this dataset which leaves approx. 44,047 ships (47% of the total) for inspection. The total estimated inspection coverage by the regimes in question of eligible ships lies therefore by slightly above 59% between set A and the eligible ships of Set C.

Set B is the casualty dataset which consists of 11,701 records for time period 1993 to 2004 and is a combination of data received from Lloyd's Register Fairplay, LMIU[14] and the IMO (International Maritime Organization). The time period 2000 to 2004 is the most complete casualty dataset since it draws from all three datasets. Aggregated, this dataset accounts for approx. 9,598 ships or 10% of the total ships in existence from Set C where the average amount of casualties per ship is by 1.2. Port State relevant casualties without the fishing fleet aggregate to 6005 ships for the time period 1999 to 2004 or 13.7% of the total PSC eligible ships.

The sets are used in various ways depending on the kind of analysis which is conducted. In essence the combination of these datasets gives insight into the amount of ships that are inspected/not inspected, detained/not detained and have/do not have a casualty with their respective combinations. Figure 2 gives an overview of the variables used for all types of analysis for port state control and casualties where the link between the two datasets is given by the IMO number and the dates of inspection/casualty respectively.

This short introduction to the research questions, the methods and datasets used to conduct the analysis should provide enough evidence that the subject is covered from various angles and that great care was placed on the selection of the datasets and the data preparation.
Given the datasets used for the quantitative part, it can be assumed that with almost 60% of coverage of port state control data, a sensible interpretation can be made even with the lack of

[9] Rightship Rating Data (48,834 records of which 37,080 are used) and Greenaward Data on certified ships (244 records)

[10] 25,838 exact ships plus 184 estimated ships. Since there are 1,288 ships with missing IMO numbers out of the total port state control dataset and the average number of inspections per ship lies by 7, the unidentified ships can be aggregated to another 184 inspected ships.

[11] Based on an average of 4 inspection years which is the average of the total months per regime to bring the different years of data to the same level for all regimes. The total time period Jan. 1999 to Dec. 2004 therefore represents a total of full 4 inspection years instead of 6 years.

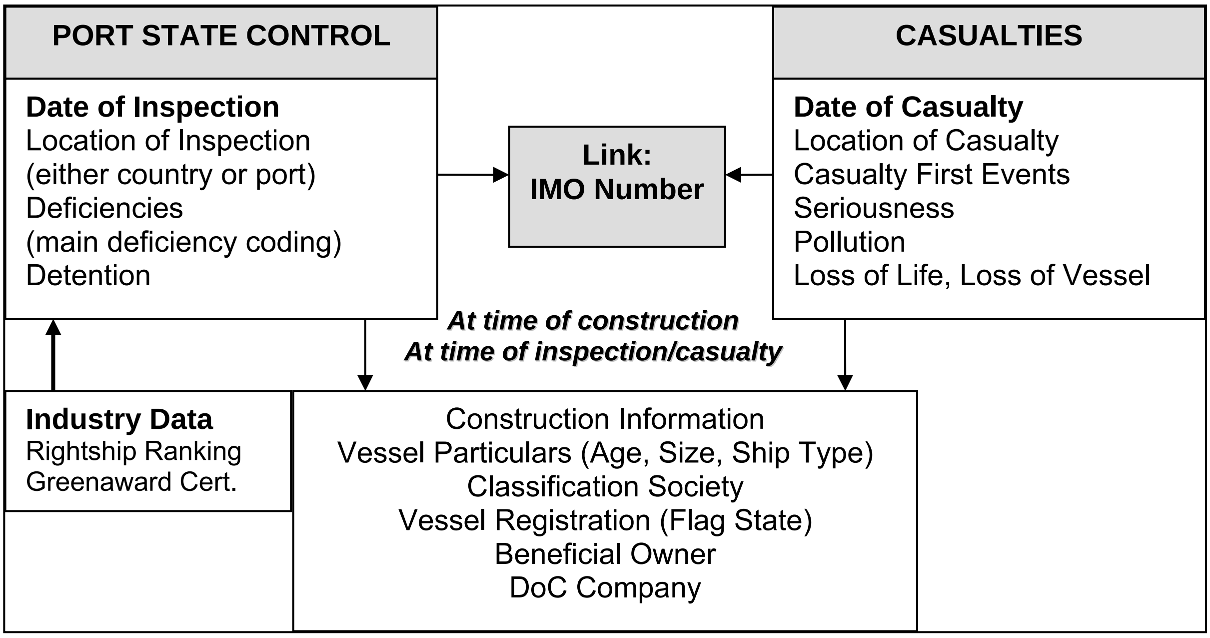
[12] As per data received from Lloyd's Register Fairplay.

[13] As per Marpol 73/78, Annex I, Regulation 4 which identifies the vessels subject to mandatory surveys (page 51)

[14] Lloyds Maritime Intelligence Unit

data from one of the major safety regimes – the Tokyo MoU where cooperation for this analysis unfortunately could not be obtained.

Figure 2: Overview of Variables Used



Note: DoC = Document of Compliance Company, an ISM requirement

Depending on the type and method of analysis, either dummy variables for each variable are used or the data is coded into groups (e.g. flag states can be used individually or grouped into black, grey or white listed flag states). The incorporation of the ownership of a vessel is not a straight forward task in shipping and requires some careful thinking. Two types of variable groups have therefore been used. The first one is information concerning the Document of Compliance Company (DoC) of a vessel based on information received from Lloyd's Register Fairplay and the second one and due to the lack of the completeness of information on the DoC Company is the addition on the ownership of a company which represents the "beneficial owner"[15]. Variable transformation and regrouping was performed for port state control data and casualty data. Transformation tables were used to re-code all of the following variables:

1) Flag States (Black, Grey, White, Undefined) – Paris MoU
2) Classification Societies – IACS and Not IACS recognized
3) Ownership of a vessel as per Alderton & Winchester or technical management as per LR Fairplay (DoC Company)
4) Ship Types

Variables were recoded using a transformation table for each MoU and the casualty datasets into standard codes for each variable group (flag, class, owner, ship type). The standard coding used for the total datasets were then transferred into dummy variables for the regressions or descriptive statistics.

Flag States

Flag States were coded individually or grouped into four major groups according to the Paris MoU Black, Grey and White List[16] where white listed flag states are performing well followed

[15] based on Lloyd's Register Fairplay data of the "World Shipping Encyclopedia CD" and Lloyd's "Maritime Database CD"

[16] Paris Memorandum of Understanding Annual Reports for 2000 – 2004.

by grey. Black listed flag states are performing worst. Flag states in the group "undefined" are flag states that do not have enough inspections for the Paris MoU or do not trade in the Paris MoU area.

Classification Societies (RO)
Classification Societies have been coded individually or grouped into two groups – either they are a member of the International Association of Classification Society or not which serves as a kind of quality indicator. There are currently ten members as follows:[17]

1) American Bureau of Shipping
2) Bureau Veritas
3) China Classification Society
4) Det Norske Veritas
5) Germanischer Lloyd
6) Korean Register of Shipping
7) Lloyd's Register
8) Nippon Kaiji Kyokai (ClassNK)
9) Registro Italiano Navale
10) Russian Maritime Register of Shipping

Ownership or Technical Management
Ownership is represented by two variables. It is either the "true owner" (not the registered one) who has the financial benefit or it is the technical manager on the ISM Document of Compliance[18] The datasets were merged with data from Lloyds Register Fairplay in order to identify the ownership of a certain vessel for both variables. For the true ownership, the country of location was then grouped according to Alderton and Winchester (1999)[19] to reflect the safety culture onboard. The grouping of the countries into six main groups is found in Appendix 1 for further reference but is as follows:

- traditional maritime nations
- emerging maritime nations
- new open registries
- old open registries
- international open registries
- "unknown" for unknown or missing entries.

The Selection of Ship Types
The selection of ship types for the analyses is important and therefore considerable amount of time was spent to find the best possible grouping. This provides a more accurate analysis of the probability of detention. The decision was based on five points as follows:

- *Point 1:* Legal Base including the major conventions and related codes distinguishing different applications based on ship types and the deriving differences in conducting a port state control inspection.
- *Point 2:* World Trade Flows to capture exposure of the regimes in connection with the % of ship types that were inspected/detained by each regime and the special commercial characteristics of each segment

[17] As per IACS, http://www.iacs.org.uk
[18] The Document of Compliance is a requirement by the ISM (International Safety Management Code) Code. The technical manager responsible for the safety management of the vessel needs to be identified on this document. Sometimes for smaller companies, this can be the owner; otherwise it is contracted out to manager who runs the vessel on behalf of the owner.
[19] Alderton T. and Winchester N (2002). "Flag States and Safety: 1997-1999". *Maritime Policy and Management*, Vol 29, No. 2, pp 151-162

- *Point 3:* Analysis of Casualties per ship type and their severity[20]
- *Point 4:* Analysis of Regression Results of port state control data for each ship type and in aggregated version
- *Point 5:* Correspondence Analysis based on port state control data in order to visualize the effects on aggregating the data and to provide an overall confirmation on the selection of the grouping of ship types.

Taking the decision points listed above into account where the detailed analyses involved deriving at the grouping is shown in detail in Knapp (2006), the following ship types have been aggregated out of the 19 original ship types:

1. **General Cargo & Multipurpose** (General Cargo, Ro-Ro Cargo, Reefer Cargo, Heavy Load)
2. **Dry Bulk**
3. **Container**
4. **Tanker** (Tanker, Oil Tanker, Chemical Tankers, Gas Carriers, OBO)
5. **Passenger Vessel** (Passenger Ships, Ro-Ro Passenger, HS Passenger)
6. **Other** (Offshore, Special Purpose, Factory Ship, Mobile Offshore, Other Ship Types)

2. Descriptive Statistics and Key Figures for Casualties

2.1. Selection of Port State Control Relevant Casualties

Considerate care was given on the selection of casualties for the analysis. From the casualty dataset within the time period 1999 to 2004 of 9,851 cases, the following cases were eliminated.

1. Cases due to extreme weather conditions such as hurricanes, typhoons, gales and very heavy storms
2. Ships attacked by pirates or ships lost due to war
3. Ships involved in a collision with no identified fault[21]
4. Any other miscellaneous items not relevant to PSC such as drugs found, virus outbreaks of passengers or accidents which happened in dry docks
5. Not PSC relevant ships types such as ferries, the fishing fleet, tugs or government vessels. The fishing fleet cases were kept separate and a separate analysis was performed based only on the fishing fleet above 400gt.

The remaining 6291 cases concern 6,005 ships when aggregated by IMO number and were then reviewed and re-grouped into the three groups of seriousness as per IMO MSC Circular 953 of December 2000:[22]

1. ***Very serious casualties:*** casualties to ships which involve total loss of the ship, loss of life or severe pollution
2. ***Serious casualties*** are casualties to ships which do not qualify as "very serious casualties" and which involve fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, hull cracking, or suspected hull defect, etc. resulting in: immobilization of main engines, extensive accommodation damage, severe structural damage, such as penetration of the hull under water, etc. rendering the ship unfit to

[20] Figures on casualties are preliminary at this stage of the project and will be shown in the next report covering the second part of the PhD.

[21] The identification of "no fault" in this case was not straight forward and some cases still included in the dataset might be ships with no fault and were not eliminated due to lack of exactness of data.

[22] as per IMO MSC Circular 953, 14th December 2000

proceed, or pollution (regardless of quantity); and/or a breakdown necessitation towage or shore assistance.

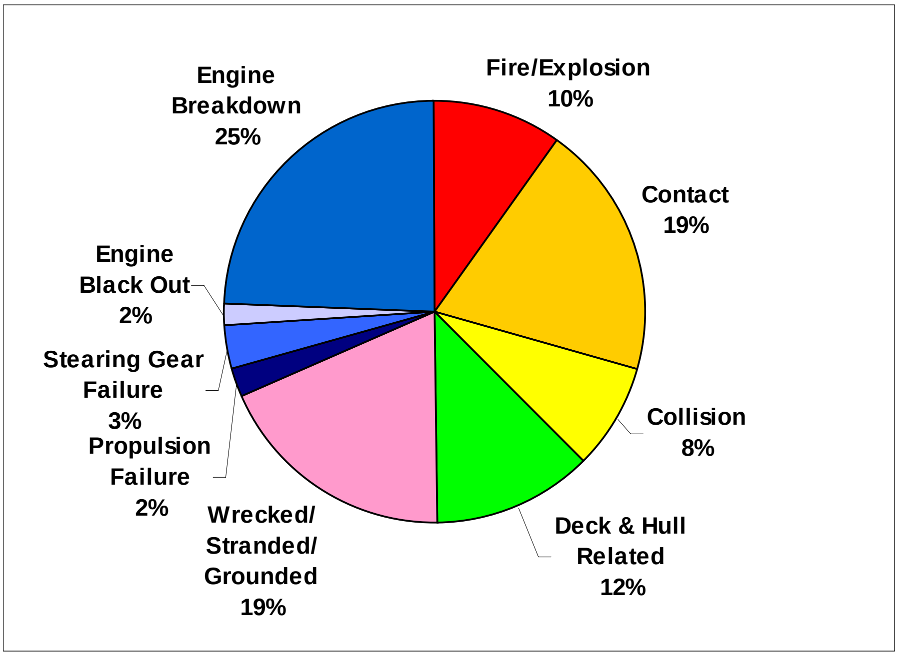
3. ***Less serious casualties*** are casualties to ships which do not qualify as "very serious casualties" or "serious casualties" and for the purpose of recording useful information also include "marine incidents" which themselves include "hazardous incidents" and "near misses".

In addition to the classification of seriousness of casualties, the cases were also examined and re-classified according to casualty first events and which are as follows:

- *Deck and Hull related casualties:* Deck and hull related items such as maintenance items (cracks, holes, fractures, hatch cover problems, cargo equipment failure, lifeboat gear failure, anchor and mooring ropes problems), stability related items such as capsizing, listing, cargo shifts and flooding
- *Fire/Explosion:* Fire and Explosion anywhere on the vessel (main areas are engine room)
- *Engine or machinery related casualties:* Engine related items including engine breakdown, black outs, steering gear failure and propulsion failure
- *Wrecked/Stranded/Grounded:* Wrecked, Stranded, Grounded where a large portion of the ships in this category are stranded or grounded. 112 ships in this category are ships that were lost and therefore could probably be classified as wrecked. Nevertheless, for the purpose of the analysis, this category is to be interpreted primarily for stranded and grounded vessels.
- *Collision and Contact:* Collision and Contact

Figure 3 then gives an overview of the split up of the casualty first events. The graph is not detailed but can be understood as a first attempt to break up the casualty types into relevant categories.

Figure 3: Casualty First Events per Ship Type (1999 to 2004)



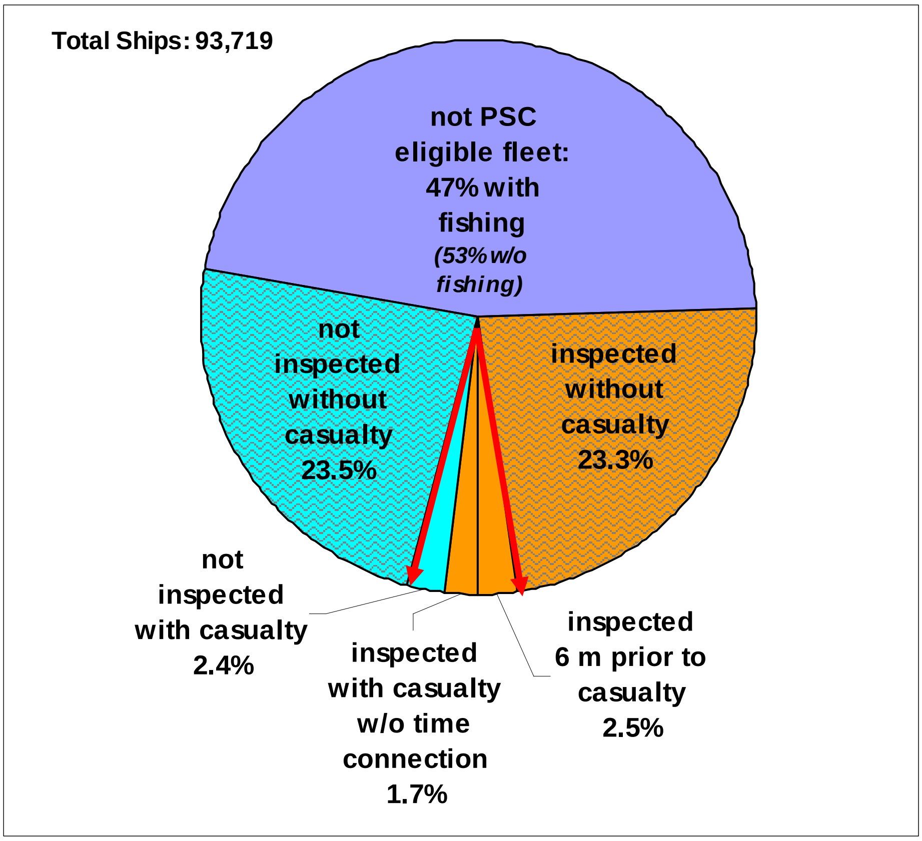
PSC Relevant Cases, compiled by author

The lack of information and fragmentation of the data does not permit a better split up. Interesting to see is the high amount of engine and machinery related events of about 32% (engine breakdown, engine black out, steering gear failure and propulsion failure).

2.2. Overview of Inspections and Casualties.

The next section in should give an overview of the PSC eligible fleet in relation to port state control inspections and casualties which is shown in Figure 4. The fishing vessels (>400gt) of which the casualties are also considered in the regressions are also incorporated into this figure. The graph gives an overview of the total fleet where the portion on top shows the portion not exposed to port state control minus a portion of the fishing fleet (above 400gt) which is also considered in this study. The right hand lower part of the graph represents inspected ships and the left hand side of the graph represents ships that have not been inspected by the respective regimes[23] or not inspected at all. The lower middle portion summarizes the vessels that had casualties.

Figure 4: The Overall View on Inspections and Casualties (1999 to 2004)



Note: Casualties are over a time frame (1999 to 2004) and only PSC relevant casualties are shown in this graph plus the fishing fleet (>400gt)

One can see that about an equal amount of ships that had not been inspected by the regimes in question (they might have been inspected by another regime only) did not have a casualty – about 46% (23.5% plus 23.3%) of the world fleet including fishing vessels above 400gt. Not inspected ships with casualties accounted for 2.4% of the world fleet versus 1.7% of the vessels which had a casualty and were inspected without any related time frame and 2.5% of the vessels were inspected six months prior to a casualty.

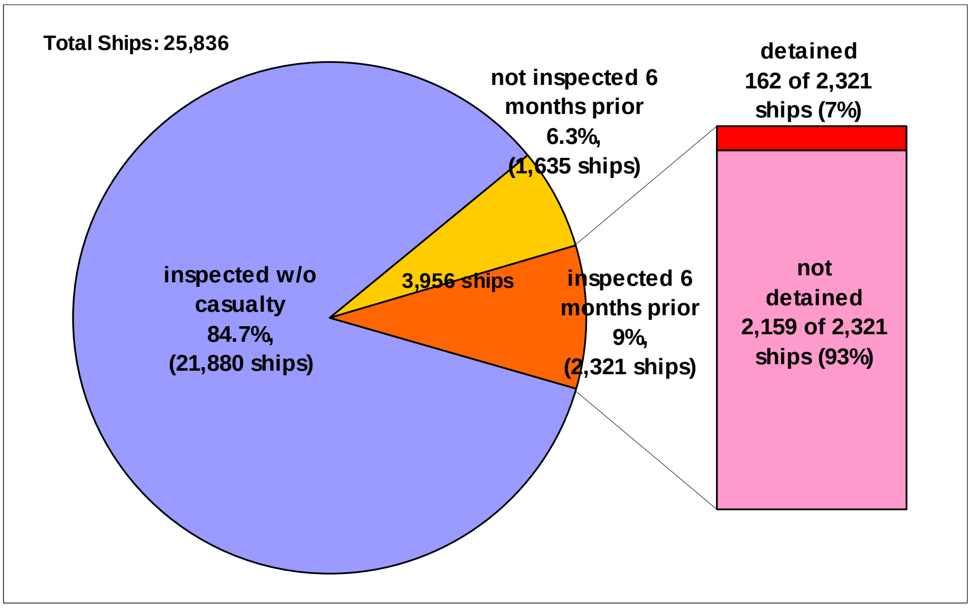
Interesting to notice but which is not shown in this graph is that, based on the individual port state control inspections, 54% of all inspections were inspections with zero deficiencies while

[23] As explained previously, some Port State Control regimes decided not to participate in this study such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU while others did not have any data available yet.

when aggregated by ship and taken as a summary of all inspections performed on vessels, this percentage reduces to 16% of all inspections for the time frame 1999 to 2004. On the other hand, if only looking at the last inspection six months prior to a casualty as shown in the figure with 2.5% of the total world fleet, 52.3% of these vessels were ships with zero deficiencies. The lower left side of Figure 4 then shows the portion of ships that have not been inspected but had a casualty which accounts for 2.4% of the vessels. In number of ships, this accounts for 2,213 vessels or approx. 369 ships per year. This could indicate a possible room for improvement of targeting vessels.

Zooming into inspected ships only, the result can be seen in Figure 5. From a total of 25,836 ships with inspections, 3,956 ships had a casualty and 2,321 ships were inspected within a time frame of six months prior to a casualty. Of these 2,321 ships, 162 were detained which accounts for 0.6% of total inspected vessels (25,836), 4% of vessels with casualty (3956 ships) or 7% of ships with casualty and inspection six months prior to casualty.

Figure 5: Ships Inspected in Relation to Ships with Casualties (1999-2004)

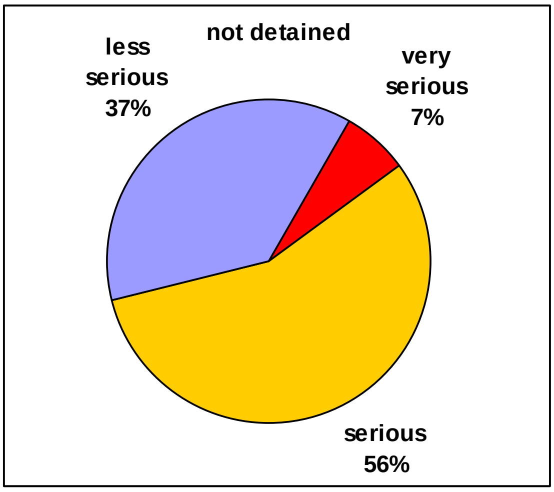


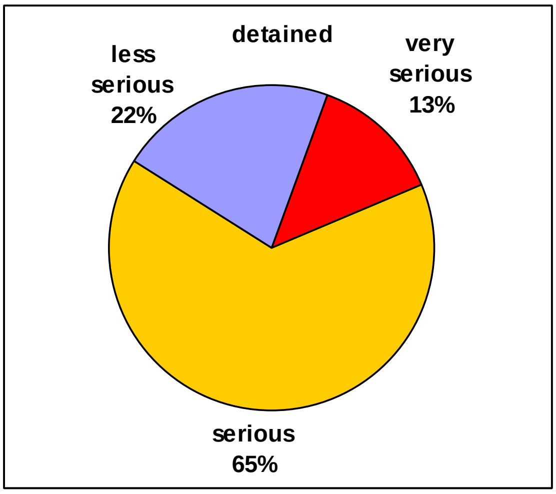
Note: compiled by author

Interesting to see is that the percentage of very serious and serious casualties is higher for vessels that have been inspected and detained six month prior to the casualty then for vessels that have not been detained. Figure 6 gives a further split up of the seriousness of the casualties and detention. Detained ships show a considerable higher amount of very serious and casualties then not detained ships.

Room for improvement to target vessels can be identified in the area of vessels that had a casualty but were not inspected and in the portion of vessels that were inspected but without any time related to the casualty. Another area of improvement for the inspections itself versus the targeting could be within the portion of ships that was inspected and/or detained six months prior to a casualty.

Figure 6: Ships Detention and Seriousness of Casualty (1999-2004)

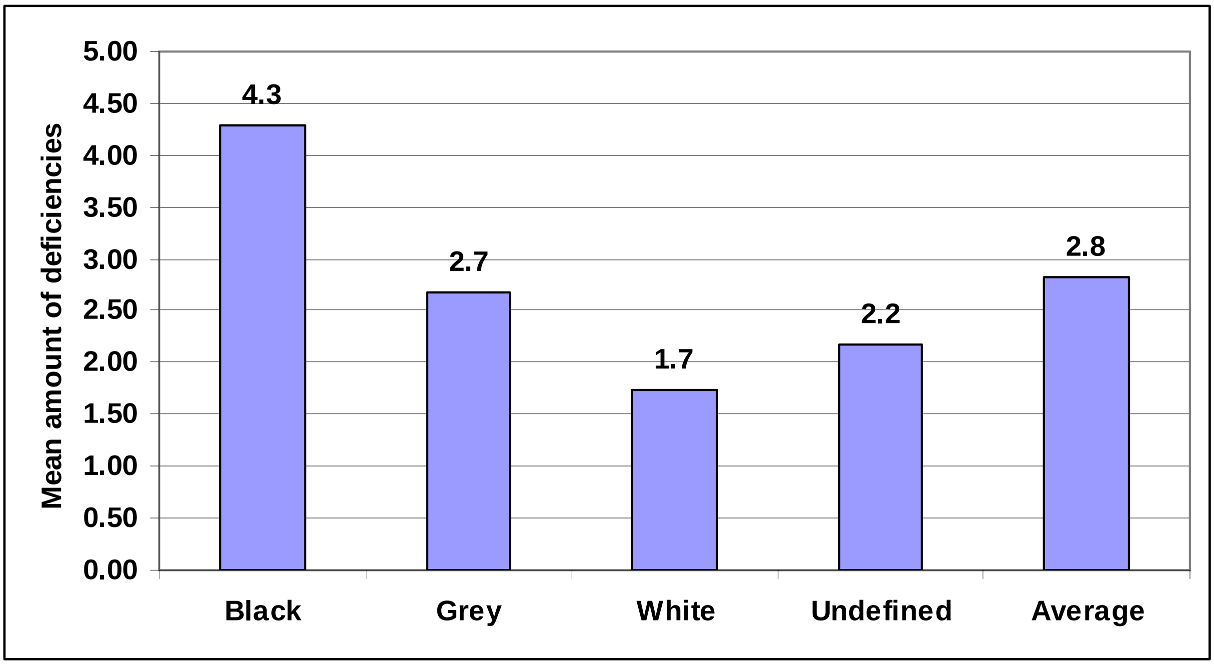




Note: based on ships that were inspected six month prior to casualty

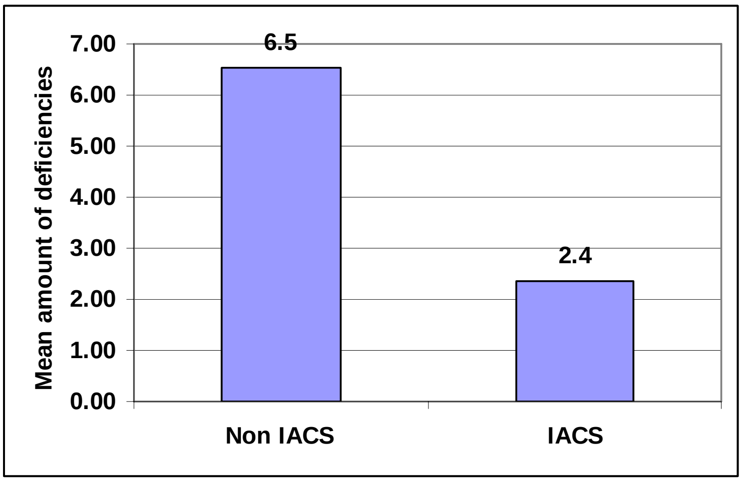
Figure 7 gives an overview of the mean amount of deficiencies found six month prior to a casualty per flag state group while Figure 8 shows the split up for IACS recognized classification societies and non IACS recognized classification societies. Black listed flag states have an average of 4.3 deficiencies versus 1.7 deficiencies for white listed flag states. Ships of Non-IACS classification societies have an average of 6.5 deficiencies versus 2.4 for ships with ICAS classification in an inspection at least six months prior to a casualty.

Figure 7: Mean Amount of Deficiencies per Flag State: 6 months prior to casualty



Note: based on ships that were inspected six month prior to casualty

Figure 8: Mean Amount of Deficiencies per Class: 6 months prior to casualty



Note: based on ships that were inspected six month prior to casualty

3. The Probability of Casualty – Overall View

This chapter tries to identify the difference of the probability of having a casualty (very serious, serious and less serious) between inspected ships and not inspected ships to see what the effect is of inspections on casualties.

3.1. Description of Model and Methodology

This model will provide the estimated probability (P) of a ship having a casualty based on each ship type defined previously for each safety regime. The dependent variable (y) in this case is "casualty" or "no casualty". In a binary regression, a latent variable y^* gets mapped onto a binominal variable y which can be 1 (casualty) or 0 (no casualty). When this latent variable exceeds a threshold, which is typically equal to 0, it gets mapped onto 1, other wise onto 0. The latent variable itself can be expressed as a standard linear regression model

$$y^*_i = x_i\beta + \varepsilon_i$$

where i denotes ship i. The x_i contains independent variables such as age, size, flag, classification society or owner, and β represents a column vector of unknown parameters (the coefficients). The binary regression model can be derived as follows:[24]

$$P(y_i = 1 \mid x_i) = P(y^*_i > 0 \mid x_i) = P(x_i\beta + \varepsilon_i > 0 \mid x_i) = P(\varepsilon_i > - x_i\beta \mid x_i) = \mathrm{P}(\varepsilon_i \leq x_i\beta \mid x_i)$$

The last term is equal to the cumulative distribution function of ε_i evaluated in $x_i\beta$, or in short:

$$P(y_i = 1 \mid x_i) = \mathrm{F}(x_i\beta)$$

This function F can take many forms and for this study two were considered, namely the cumulative distribution function of the normal distribution (probit model) and the cumulative distribution function of the logistic function (logit model). The general model can therefore be

[24] for further reference, refer to Franses, P.H. and Paap, R. (2001). *Quantitative Models in Marketing Research*. Cambridge University Press, Cambridge, Chapter 4

written in the form of Equation 1 where the term $x_i\beta$ changes according to the model in question.

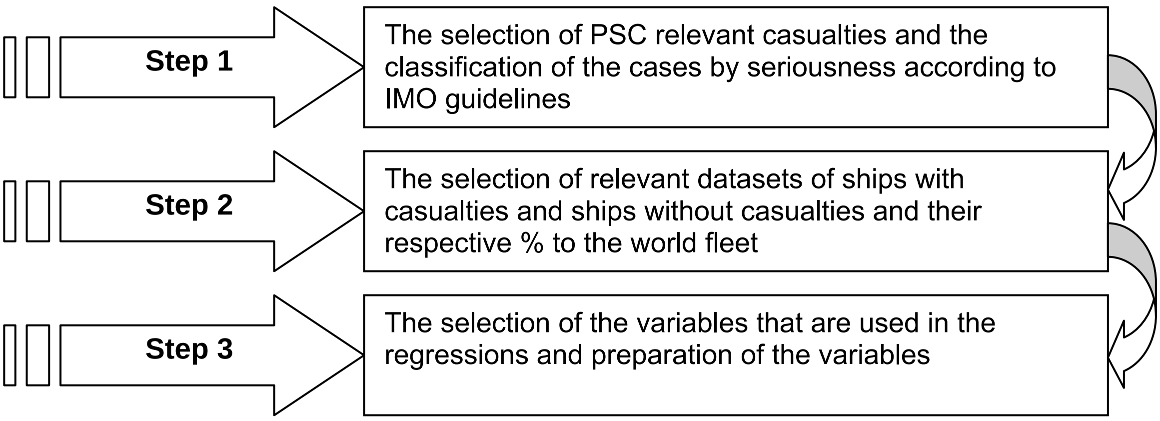
Equation 1: Probability of Casualty (per seriousness)

$$P_i = \frac{e^{(x_i\beta)}}{1 + e^{(x_i\beta)}}$$

To estimate the coefficients, quasi-maximum likelihood (QML)[25] is used as method of estimation in order to give some allowance for a possible misspecification of the assumed underlying distribution function. For the final models, logit and probit models are compared to see if there are any significant differences and logit models are used for the visualization part.

Figure 9 gives an overview of the steps that were performed to prepare the relevant datasets. The *first step* was the selection of casualties and their re-classification according to the IMO guidelines which was explained earlier. The *second step* was the selection of the relevant datasets and the *third step* the selection of variables used in the regressions.

Figure 9: Description of Methodology Used



3.2. The Selection of Relevant Datasets

The *second step* was the selection of the dataset and is based on the total casualty dataset (a combination of three sources), the inspection dataset (a combination of six regimes and data from the industry) and the general ship dataset including ship's particulars and ship history data. Table 1 lists the split up of the total dataset between ships that have been inspected and ships that have not been inspected for the time period in question. The fact that the ships have not been inspected does not necessarily mean that they have not been inspected by any of the other regimes where data could not be obtained such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU. The dataset therefore measures ships that have been inspected by the combined PSC dataset with ships that have not been inspected at all or inspected by another regime. This will be taken into consideration when interpreting the results. It is not possible to measure how the results would change when repeating the regressions with a full inspection dataset.

[25] for further details on QML, refer to Greene H.W. (2000), *Econometric Analysis*, Fourth Edition, page 823ff

Table 1: Split up of Ships with casualties versus non-casualties (1999 to 2004)

Summary	Ships not inspected	Ships inspected	Total Ships	% not inspected	% inspected
Casualties	2213	3956	6169	35.9%	64.1%
No Casualties	22061	21880	43941	50.2%	49.8%
Total	24274	25836	50110		

Note: the table includes the fishing fleet used in a separate regression (ships above 400gt)

The total dataset for casualties is based on 6169 ships with a casualty (6,005 without the fishing fleet) and 43,941 (37,812 without the fishing fleet) ships without casualties where the split up of the ships represent a sample similar to the world fleet for ships above 400gt as can be seen in Table 2 .

Table 2: Split up of Ship Types of Sample versus World Fleet (1999 to 2004)

				Casualties	Commercial > 400gt	
	No Casualty	Casualty		Sample	Sample	Total Ships
Ship Type	**Sum**	**Sum**	**Total**	**% to Total**	**% to Total**	**World Fleet**
General Cargo	12539	2665	15204	43.20%	34.7%	33.0%
Dry Bulk	5684	1017	6701	16.49%	15.3%	14.0%
Container	3571	492	4063	7.98%	9.3%	12.0%
Tanker	10184	1033	11217	16.75%	25.6%	25.0%
Passenger	1241	296	1537	4.80%	3.5%	3.0%
Other Ship Types	4593	502	5095	8.14%	11.6%	13.0%
Total w/o fishing	**37812**	**6005**	**43817**	**n/a**	**100.0%**	**100.0%**
Fishing (>400gt)	6129	164	6293	2.66%	n/a	n/a
Total w. fishing	**43941**	**6169**	**50110**	**100%**		

The fishing vessels are not split into seriousness but only one regression is performed on the total cases of fishing vessels above 400gt. The ideal situation would have been to include all fishing vessels of which the majority is under 400 gt but due to lack of data, this could not be done. In total four separate regressions are performed - one for each type of seriousness and a separate for all the cases of the fishing fleet. Multiple casualties were not taken into account. A ship with a casualty can therefore appear in each of the datasets if a ship had multiple combinations of casualties. If a ship had the same type of seriousness of casualty more than once (e.g. 2 serious casualties), the ship is only taken into consideration once. Table 3 gives an overview of the amount of observations in each model.

Table 3: Number of Observations in End Model

Nr. of Observations	Very Serious	Serious	Less Serious	Fishing Fleet
Total Observations	38076	41009	39929	6289
No Casualties	37354	37811	37811	6129
Casualties	722	3198	2118	160

Note: Figures are final figures used in the models and without outliers

One could argue that the number of ships with casualties (the 1's in the regressions) is over-represented in the dataset in comparison to the number of ships without casualties (the 0's) since the casualties are an accumulated figure over a time frame of six years where the ships with no casualties are of the same time period but are not counted six times. This raises the question if increasing the dataset accordingly adds more explanatory power to the regression and if the estimations would be different? This subject was investigated by Cramer, Franses and Slagter (1999)[26] for various sizes of a reduced dataset of zeros and no significant change was found. It is therefore assumed that the difference in the sample sizes does not have a serious effect on the coefficients and that by adding more data on the side of the zeros will not add much explanatory power to the models. The resulting probability represents the probability of having at least one casualty in a six year time period and will be converted to a yearly probability for the visualization part. The next section will explain the selection of variables that are used in the regressions as well as give an explanation of the model itself.

3.3. Explanation of Model and Variables Used

Equation 2 shows the model used to estimate the probability of casualty per seriousness and separately for the fishing fleet while Table 4 gives a list of the variables used in the model with their respective model types. The probabilities produced are for any individual ship (*i*) and the rest of the notation is defined as follows: ℓ represents the variable groups, n_ℓ is the total number of variables within each group of ℓ and k is an index from 1 to n_ℓ.

Equation 2: Probability of Casualty (Very Serious, Serious, Less Serious, Fishing)

$$x_i\beta = \beta_0 + \beta_1 \ln(\mathrm{AGE}_i) + \beta_2 \ln(\mathrm{SIZE}_i) + \sum_{k=1}^{n_3-1} \beta_{3,k}\,\mathrm{ST}_{k,i} + \beta_4\,\mathrm{STInd}_i$$
$$+ \sum_{k=1}^{n_5-1} \beta_{5,k}\,\mathrm{CL}_{k,i} + \beta_6\,\mathrm{CLInd}_i + \beta_7\,\mathrm{CLWdr}_i + \sum_{k=1}^{n_8-1} \beta_{8,k}\,\mathrm{FS}_{k,i}$$
$$+ \beta_9\,\mathrm{FSInd}_i + \sum_{k=1}^{n_{10}-1} \beta_{10,k}\mathrm{OWN}_{k,i} + \beta_{11}\,\mathrm{OWNInd}_i + \sum_{k=1}^{n_{12}-1} \beta_{12,k}\,\mathrm{SY}_{k,i}$$
$$+ \beta_{13}\,\mathrm{LIOWN}_i + \beta_{14}\,\mathrm{LIFS}_i + \beta_{15}\,\mathrm{DH}_i + \sum_{k=1}^{n_{16}-1} \beta_{16,k}\,\mathrm{RS}_{k,i} + \beta_{17}\,\mathrm{GR}_i$$
$$+ \sum_{k=1}^{n_{18}} \beta_{18,k}\,\mathrm{PSC}_{k,i}$$

Table 4: List of Variables Used in Casualty Normal Models

			Variable Type Total Number of Variables	Total n_ℓ
Variable	**ℓ**	**Casualty (Very Serious, Serious, Less Serious) plus a separate regression for the fishing fleet**	**0/1**	**1**
Ln(AGE)	1	Vessel Age at the time of casualty (or inspection)	C	1
Ln(SIZE)	2	Vessel Size in gross tonnage	C	1
ST	3	Ship Type (including fishing vessels)	D	7
STInd	4	Indicates if ship type changed since construction	D	1
CL	5	Classification Societies at time of casualty (or inspection)	D	42
CLInd	6	Indicates if classification society changed over time	D	1
CLWdr	7	Indicates if classification society withdrew	D	1
FS	8	Flag State at the time of casualty/inspection	D	130
FSInd	9	Indicator if flag changed over time	D	1
OWN	10	Ship Owner Countries	D	6
OWNInd	11	Indicates if ownership was changed over time	D	1

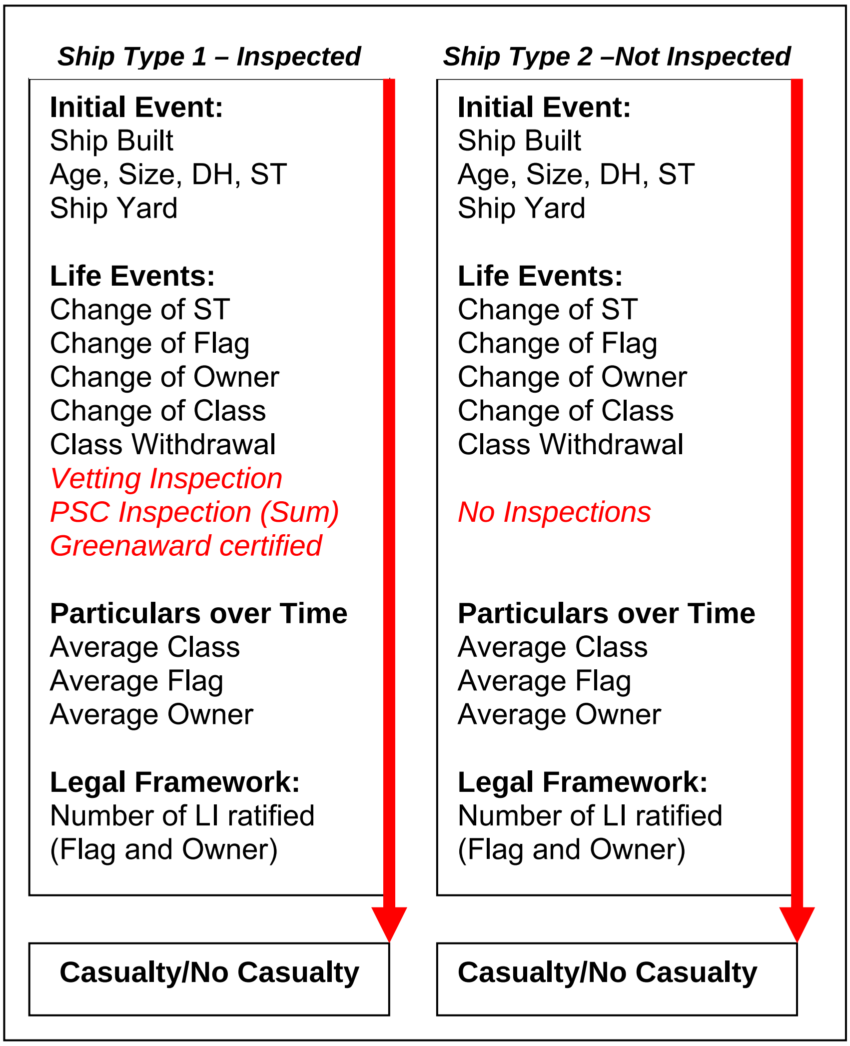
[26] Cramer, Franses and Slagter, (1999) Econometric Institute Research Report, 9939/A

SY	12	Country where ship was primarily built (>100 ships)	D	37
LIOWN	13	Number of legal instruments owner country rectified	C	1
LIFS	14	Number of legal instruments flag state has rectified	C	1
DH	15	Double Hull	D	1
RS	16	Ships inspected by Rightship (Vetting Inspection)	D	5
GR	17	Ship certified by Greenaward	D	1
PSC	18	Indicated total # of inspections per ship per regime (Sum)	C	6
		Total for the whole dataset (split into seriousness)		**244**

C = continuous, D = dummy of categorical variables

The variables which indicate change over time such as ship type, class, flag or ownership are based on information obtained by Lloyd's Register Fairplay and go back in time to either the time the vessel was constructed or at least the last five to six years of the ship being in operation. Three types of inspection variables are introduced. One which describes if a ship has been inspected by one of the industry vetting inspection systems (Rightship), one if a ship is certified by Greenaward and third, if a ship has been inspected by one of the respective regimes. Figure 10 shows the variable structure of the two types of ships that are used in this dataset. Ship type 1 reflects ships that have been inspected and ship type 2 are the ships that have not been inspected.

Figure 10: Visualization of Variable Structure: Normal Models



3.4. Model Evaluation and Final Results

The model for very serious casualty was tested for presence of heteroscedasticity using the LM test as described by Davidson and McKinnon (1993)[27]. The null hypothesis (h_o) assumes homoscedasticity and the alternative hypothesis assumes heteroscedasticity in the following form where γ is unknown and z are a number of variables which are assumed to be the cause of heteroscedasticity:

$$\text{Variance} = \exp(2z'\gamma)$$

The test was performed separately for two variables, namely tonnage and age and presence of heteroscedasticity was found with both variables.

Table 5: LM Test for Tonnage and Age

Variable	LM Statistic	p-value
Tonnage	23.06	0.00000 - *reject h_o*
Age	13.60	0.00022 - *reject h_o*

Note: 1% significant level used

In order to find out if the presence of heteroscedasticity has an effect on the estimators and the significance of the estimators in the model, a standard program which is part of Eviews and which was developed by Greene[28] and based on Harvey (1976) was used. This program allows estimation in the presence of the form of heteroscedasticity defined earlier. The corresponding probabilities are calculated based on Equation 3 where z depicts tonnage alone or tonnage and age and γ the coefficient for tonnage or age obtained by the Greene program.

Equation 3: Probability of Casualty allowing for heteroscedasticity

$$P_i = \frac{e^{\left(\frac{x_i\beta}{\exp(\gamma z)}\right)}}{1 + e^{\left(\frac{x_i\beta}{\exp(\gamma z)}\right)}}$$

First, the program was modified for two variables – tonnage and age. In this first trial, age comes out not to be significant. Therefore, the procedure was applied a second time without age and the results show that three variables come out not to be significant in comparison to the original model based on Equation 1. To see whether the probabilities differ from the original model and if heteroscedasticity, although present, has a serious effect on the estimation results, the corresponding probabilities are computed for Equation 3 versus Equation 1. The probabilities were then grouped according to tonnage groups, age groups, flag state groups, classification groups and ownership groups and the respective probabilities were calculated based on both models.

The results further show little difference between the two estimation processes. It is therefore concluded that although some presence of heteroscedasticity is present in the model, it does not have a serious effect on the estimation process with reference to the coefficients and the

[27] Davidson and McKinnon (1993), *Estimation and Inference in Econometrics*, New York: Oxford University Press, 1993, page 526ff

[28] Greene H.W. (2000), *Econometric Analysis, Fourth Edition*, Econometric Analysis, Prentice Hall, New Jersey; page 518ff; Furthermore, recognition is to be given to *Richard Paap* from the Econometric Institute for pointing this program out to me and for making it available to me.

resulting probabilities and the standard model is used and applied to all models in this section. Table 6 lists the key statistics of the final types of models reduced to 1% significance level for logit and probit estimation.

In comparing logit with probit, not much difference can be seen in the results other than that the HL-statistic suggests a better fit for the logit model versus the probit model. The results are acceptable for the amount of data in each of the models. The hit rate lies above 74% for all logit models except for the models of the fishing vessels. Outliers were identified and eliminated to improve the fit of the models. For visualization of the results in the next chapter, the logit model is used.

Table 6: Key Statistics of Final Models: Probability of Casualty

	Very Serious		**Serious**		**Less Serious**		**Fishing Fleet**	
# observations in final model	0 =	37354	0 =	37811	0 =	37811	0 =	6129
	1 =	722	1 =	3198	1 =	2118	1 =	160
	Total =	38076	Total =	41009	Total =	39929	Total =	6289
# of outliers	122		97		35		4	
Cut Off	0.0189		0.0780		0.0530		0.0250	
	LOG	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**
Mc Fadden R2	0.634	0.632	0.281	0.278	0.250	0.224	0.400	0.393
% Hit Rate y=0	93.53	92.60	79.87	78.05	76.09	81.93	89.98	85.51
% Hit Rate y=1	88.64	90.39	74.39	76.92	74.41	68.41	71.25	76.25
% Hit Rate Tot	93.43	92.56	79.44	77.97	76.00	81.21	89.51	85.28
HL-Stat. (df=8)	14.65	48.79	16.92	43.08	17.28	25.93	15.20	19.74
p-value	0.0663	0.0000	0.0309	0.0000	0.0273	0.0011	0.0552	0.0114

3.5. Visualization of Results: Effect of Inspections

In order to make the interpretation of the results easier, the probabilities are converted from a six year time frame to a yearly probability for the reason explained earlier. The conversion factor is derived as follows.

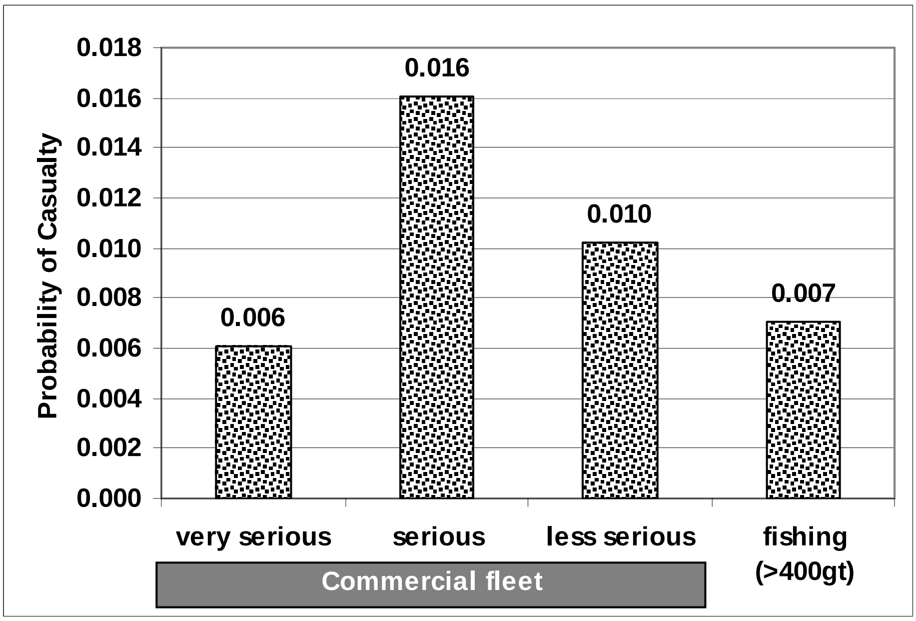
If p is denoted as a 1 year probability, then the probability of having no casualty in six years equals 1-p for 1 year and $(1\text{-}p)^6$ for 6 years. The probability of having at least one casualty in 6 years denoted by q is then $1\text{-}(1\text{-}p)^6$. While q is the result from the models, solving for p leads for the following factor which is then applied to all calculated probabilities in this section to convert the six year probability into a yearly probability:

$$p = 1-(1-q)^{1/6}$$

For the purpose of this study, it is assumed that the probability of having at least one casualty in a year is constant across the years which might not completely accurate as this change in probability can be affected by changes the industry such as commercial surroundings. For the purpose of visualization of the effect of inspection on casualties, it is assumed to be accurate enough as the change in probability is not the research question in this study but primarily the effect of inspections on the probability of casualty. The probability of detention is an average probability based on a ship with no deficiencies to reflect the basic ship profile of a vessel in order to bring the two into relation. In order to combine both probabilities, each estimated probability of the total dataset was combined using the IMO number of a respective vessel. For the probability of detention, averages per vessel were taken. The result is a comparison of both probabilities for about 50,110 ships, depending on the size of the actual dataset (e.g. very serious, serious, less serious casualties).

Figure 11 shows the average estimated probability of having a casualty based on the total dataset for the commercial fleet (split into seriousness) and the fishing fleet above 400gt. There is no particular reason based on existing legislation for the choice of size with reference to the fishing fleet[29]. The analysis is based on the fishing fleet above 400gt to bring them in line with larger fishing vessels or the so called factory ships. Technically, the factory ships are not fishing vessels and are therefore sometimes inspected by port state control (about 0.3% of the PSC dataset) but they belong to the same industry and are the only ships that can be compared to the larger vessels of the regular fishing vessels. In order to keep the size similar to the commercial fleet, 400 gt were used as cut off point.

Figure 11: Average Probability of Casualty



Note: Based on average estimated probabilities of approx. 50,000 vessels

The basic probability of a very serious casualty lies by 0.6% versus 1.6% for serious and 1% for less serious casualty. The fishing fleet lies slightly above the very serious casualty. In reality, this probability is expected to be much higher for fishing vessels below 400gt but for this analysis, only ships above 400gt are included as explained previously. The next set of graphs shows the difference between the fishing fleet of 400gt and above which is very little inspected by port state control and the commercial fleet. It further shows the main difference between vessels that are inspected by any of the regimes in question versus not inspected by any of the regimes. Not inspected does not necessarily mean that the vessel was not inspected by port state control at all.

Due to the lack of cooperation of some of the port state control regimes, a portion of vessels that are only inspected in these region is missing from the dataset and given the fact that the descriptive statistic section showed that the South and North China Sea are high risk areas with respect to loss of life and collision and contact, there are a portion of ships that fall into

[29] The Torremolinos International Convention for the Safety of Fishing Vessels, 1977 was adopted in 1977 but is not yet in force and only has a provision based on meters and not gross tonnage, http://www.imo.org/home.asp

the category of non-inspected vessels in this dataset but might have been inspected for instance by the Tokyo MoU. The same applies to a certain extend to the Black Sea MoU and the Mediterranean MoU although the amount of vessels that are inspected by those regimes are also partly covered by the Paris MoU. The results would have been refined by incorporating this data but will be left as a recommendation for future research.

Table 7 gives a short summary of some of the results of the variables of interest with their respective coefficients and significance across the casualty types. The coefficients are not to be interpreted as direct effects like in linear regression. It is merely the partial effect of a particular variable given all other variables remain the same. The interesting part is not necessarily the coefficient but its significance and sign which determines the tendency of the effect towards the probability of casualty.

Table 7: Summary of Main Variables: Casualty Normal Models

Significance at 1%		**very serious**	**serious**	**less serious**
Variable of Interest		**Coefficient**	**Coefficient**	**Coefficient**
Ship Types				
	General Cargo	1.2507	0.6684	0.8451
	Dry Bulk	n/s	0.4078	0.8240
	Container	n/s	n/s	0.7236
	Tanker	n/s	n/s	n/s
	Passenger	n/s	0.5917	0.8217
	Other Ship Types	n/s	n/s	n/s
Ship Particulars				
	Age	0.4059	n/s	n/s
	Tonnage	-0.3717	n/s	n/s
	Class changed	-0.6965	-2.1564	-2.0292
	Class withdrawn	0.5802	0.6703	0.4396
	Flag changed	n/s	n/s	n/s
	Owner changed	5.3686	2.4263	2.1583
	Legal Instr. ratified: Flag	-0.0543	-0.1244	-0.1804
	Legal Instr. ratified: Owner	n/s	-0.0360	n/s
	Double Hull	n/s	n/s	n/s
	Rightship Inspected	-0.9454	n/s	n/s
	Greenaward Certified	n/s	n/s	n/s
Port State Control Inspected				
	Paris MoU	-0.5443	0.0459	0.0535
	Caribbean MoU*)	not in model	n/s	n/s
	Viña del Mar MoU	-0.4934	n/s	n/s
	Indian Ocean MoU	-2.1760	n/s	n/s
	USCG	-1.4685	0.0295	0.0467
	AMSA	-1.5010	-0.1724	-0.1594
Other Variables (indicates number of variables left in model)				
	Classification Societies	1	8	17
	Flag States	4	49	58
	Ownership Groups	4	4	4
	Ship Yard Countries	3	25	26

*Note: n/s = not significant at a 1% level, *) Caribbean MoU is not included in the very serious model due to lack of sufficient amount of data*

The table summarizes the main findings as follows:

- General cargo vessels seem to show the highest risk although not necessarily the largest costs with respect to the aftermath of for instance pollution deriving from an oil tanker. Second in line are passenger vessels but primarily for serious and less serious casualties.

- Age is only significant for very serious casualties and its effect is positive. A separate graph is shown below to visualize this effect.
- Tonnage is also only significant for very serious casualties but is negative indicating that a smaller vessel seems to be at higher risk than larger vessels which goes in line with the general cargo vessels being more high risk prone.
- The coefficient of the variable indicating if the ship changed its class during its course of life is significant and negative for all types of casualties. This could mean that in general, if a class is changed, an inspection is performed which might have a positive influence on the quality of the vessel. On the other hand, the coefficient of the variable indicating if class was withdrawn certainly shows a positive effect.
- Change of flag does not seem to be significant while change of ownership is significant for all types of casualties but in particular for very serious casualties. It is further positive meaning that a change in ownership could indicate the move of a vessel to the second hand ownership market and maybe is related to less money being spent on maintenance and therefore an overall decrease in the safety level of a particular vessel.
- The variable double hull is not significant for any type of casualty.
- As for vetting inspections as part of the industry data, the coefficient of this variable clearly indicates that the inspections have a strong negative effect on the probability of a very serious casualty while it is not significant for the other two.
- The last group of coefficients of the variables showing the partial effects of the inspections of a particular regime shows that the effect is negative for all regimes for very serious casualties and varies for serious and less serious casualties. For very serious casualties, the Caribbean MoU had to be excluded due to lack of data.
- Certain classification societies, flag state, ownership variables and ship yards remain to be significant in the models.

The coefficients of the variables indicating where the ship was inspected were tested using the Wald Test for testing restrictions[30] in order to see if the mean varies across the regimes. The null hypothesis (h_o) for testing the restrictions states that the means do not vary across the regimes. The results can be seen in Table 8 below for various combinations of variables. For all three types of casualties, two groupings can be found. For very serious casualties, the group containing AMSA, the Indian Ocean MoU and the USCG are similar versus a group containing the Paris MoU and the Viña del Mar MoU. For serious and less serious casualties, the Paris MoU and the USCG are similar but different to AMSA.

Table 8: Testing of Restrictions - Inspection Variables

Very Serious Restrictions/p-value	**Serious Restrictions/p-value**	**Less Serious Restrictions/p-value**
AMSA=IMOU=USCG=PMOU (0.000)- *reject* h_o	AMSA=PMOU=USCG (0.000)- *reject* h_o	AMSA=PMOU=USCG (0.000)- *reject* h_o
AMSA-IMOU-USCG (0.2318)- *do not reject* h_o	PMOU=USCG (0.1526)- *do not reject* h_o	PMOU=USCG (0.6063)- *do not reject* h_o
PMOU=VMOU (0.6845)- *do not reject* h_o	n/a	n/a

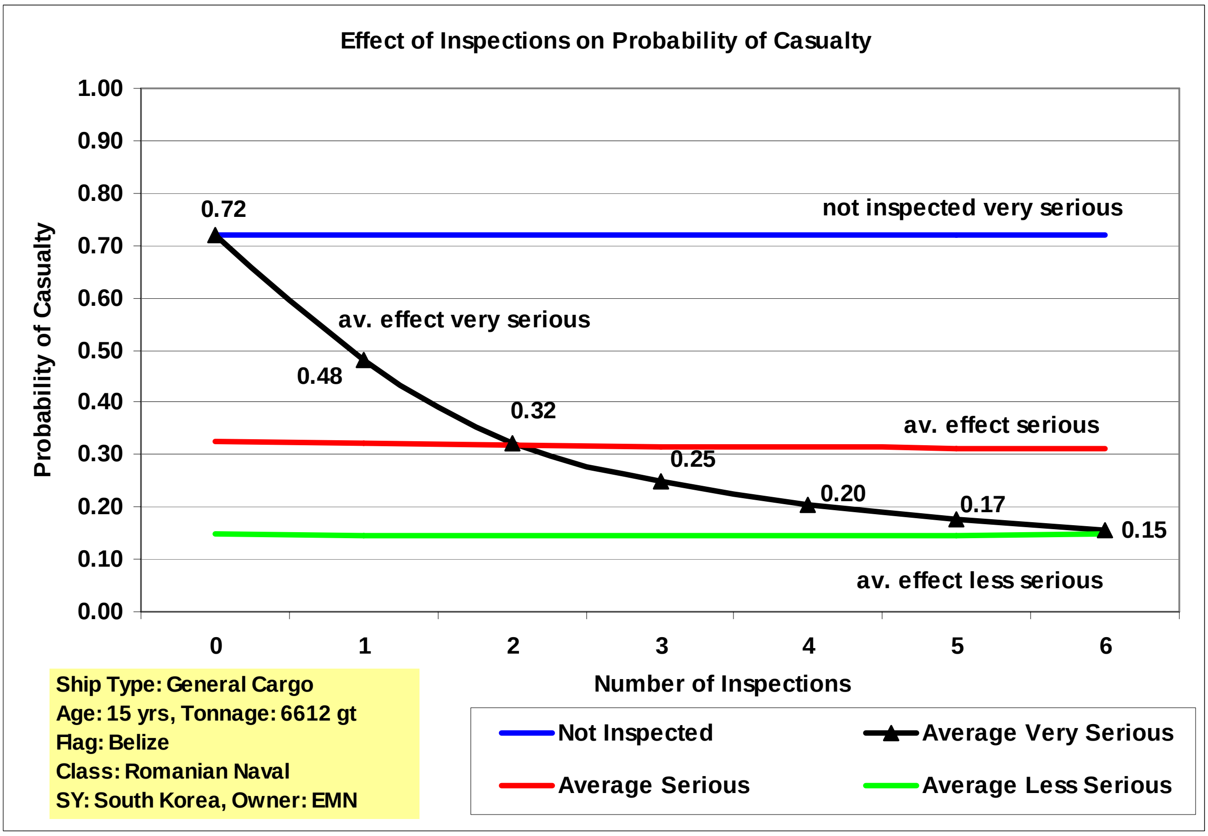
Note: Figure in brackets is the p-value of the test, 1% significance level

Figure 12 shows how the probability of casualty changes with the number of inspections of a certain vessel on average. The effect is clearly strongest for very serious casualties and very weak to non-existing or positive for serious and less serious casualties.

[30] based on Wald Test for Testing Coefficient Restrictions, a standard procedure in Eviews

For a vessel having been inspected in one of the regimes, the probability of having a very serious casualty decreases gradually as the number of inspections increases to a maximum of six inspections within six years. This probability is not based on a yearly probability but is left as a probability of having a casualty within a six year period in order to better visualize the change in the probability. It further shows that the magnitude of the effect decreases as the number of inspections increases. On average though, and depending on the overall risk profile of the vessel, an inspection can potentially decrease the probability of a very serious casualty by approx. 5% per inspection.

Figure 12: Average Effect of Inspection across Regimes on Very Serious Casualties



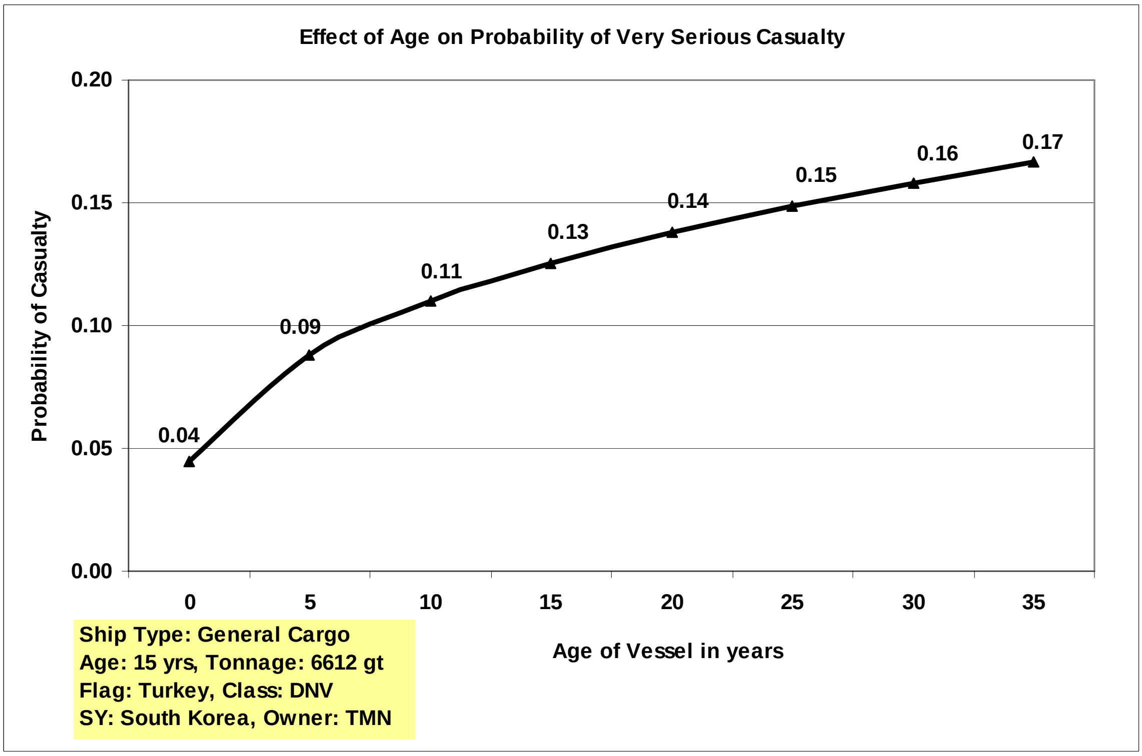
Note: the average effect represents the average effect of all regimes

Since the partial effects are in comparison to the benchmark of not inspected vessels, the positive signs for serious and less serious casualties could be explained with the fact that there is no significant difference between the ships that are not inspected or inspected in another regime (such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU) and that there is room for improvement.

Figure 13 gives an overview of the effect of age and is based on one particular ship profile where age is measured in years of age of the vessel. One can clearly see that as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about 0.35% per year. The age factor cannot be measured for serious and less serious casualties.

The next area will try to evaluate if the correct ships are targeted for inspection and will partly built on the previous section. It compares inspected vessels with non inspected vessels.

Figure 13: Effect of Age on the Probability of Casualty



3.6. Evaluation of the Target Factor: Can targeting be improved?

Figure 14 gives on overview of the magnitude of improvement possibilities for targeting vessels. In total, about 16% of all inspected vessels had zero deficiencies over the time period in question and these ships might have been ships which should not have been targeted (4,221 ships). On the other hand, looking at ships which have been inspected six months prior to a casualty (2,321 ships) where 52.3% of these vessels had zero deficiencies (1,215 ships) and the rest had deficiencies. This changes the 4,221 ships which should not have been targeted into 3,006 vessels or approx. 501 ships per year.

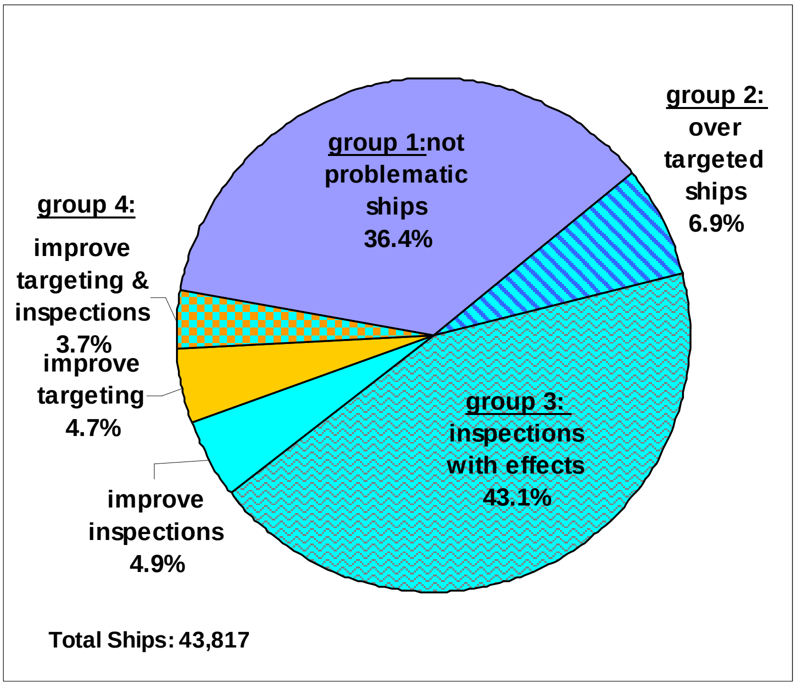
It is further worth noticing that out of the 1,106 vessels (2,321 – 1,215) with deficiencies, 14.6% were detained (162 vessels) and had a casualty. This portion could be understood as ships that have been targeted correctly and identified as sub-standard vessels but for some reason, detention was not sufficient to increase the safety standard of the vessel to prevent a casualty. The remaining portion of the vessels which have been inspected and were deficiencies were found are the vessels where the effect of inspections decreased the probability of a casualty which is the partial effect of the regressions. In number of vessels, this amounts to approx. 18,874[31] vessels or 3,146 ships per year.

The figure is only based on ships that are relevant for port state control (excluding the fishing fleet > 400gt) and is a summary of the total time frame. The graph shows several groups out of which *group 1* of about 36% of the vessels eligible for inspections are identified not to have been problematic over the time period and have also not been targeted by the regimes in question. About 7% of the vessels eligible for port state control have been targeted over the time frame

[31] 21,880 total inspected ships with no casualty minus 3,006 ships with no deficiencies

but did not have a casualty and also no deficiencies and therefore represent a group of over-inspected vessels *(group 2)*.

Figure 14: Improvement Areas for PSC eligible ships (1999-2004)



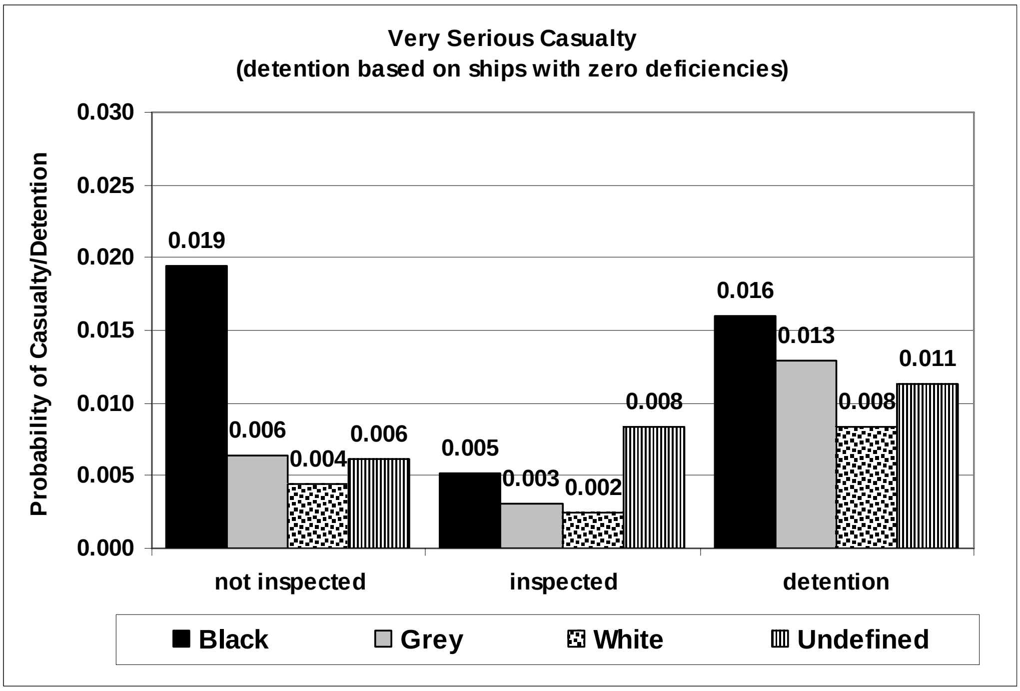
Note: Based on only PSC relevant ships and based on total time frame (1999-2004)

Group 3 of 43% of the vessels can be identified to belong to a group where inspections are effective in decreasing the probability of casualty where this effect can be measured for very serious casualties and estimated (depending on the basic ship risk profile) to be a 5% decrease per inspection. This category can also represent further room for improvement but shows that port state control is effective.

Group 4 is split into three portions. The first portion is 5.3% of PSC eligible vessels which are the amount of ships that have been targeted correctly but since they had a casualty within six month after the inspection, the enforcement could be improved. The second portion shows 4.7% of ships which had a casualty but were not inspected and where targeting could be improved. Finally, the last category shows a grey area. In this group, ships had a casualty but regardless of the time frame. Therefore, inspections and possibly targeting could be improved. Most improvement to decrease the probability of a casualty can be achieved by concentrating on the categories in group 4 by shifting the emphasis from group 2 to group 4.

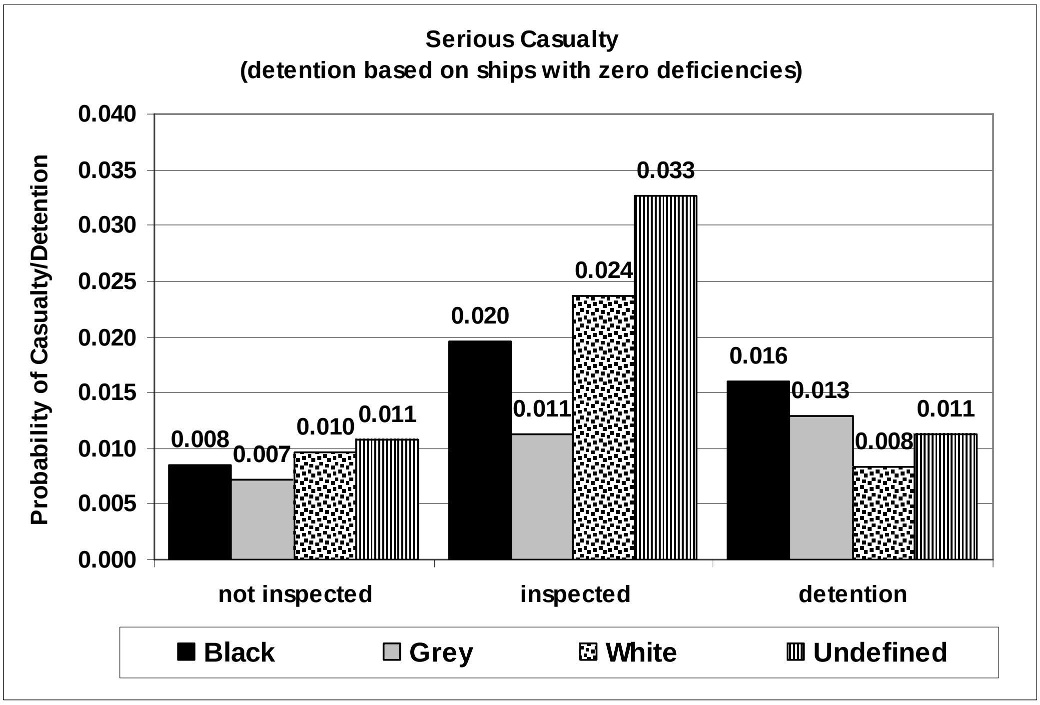
Figure 15 and Figure 16 both show the average probability of a very serious or serious casualty of flag state groups such as black, grey, white and undefined for flags that are not on the Paris MoU list. The Paris MoU classification is used since about half of the data derives from the Paris MoU dataset. Black listed flag states have a higher probability of having a very serious casualty followed by grey and white listed flag states and follows more or less in line with the probability of detention. For serious casualties, the picture changes and indicates that these vessels show a higher probability of having a serious casualty. It seems to indicate that these vessels are targeted for inspection but that there is less effect as can be seen for the very serious casualties.

Figure 15: Probability of Very Serious Casualty per Flag State Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

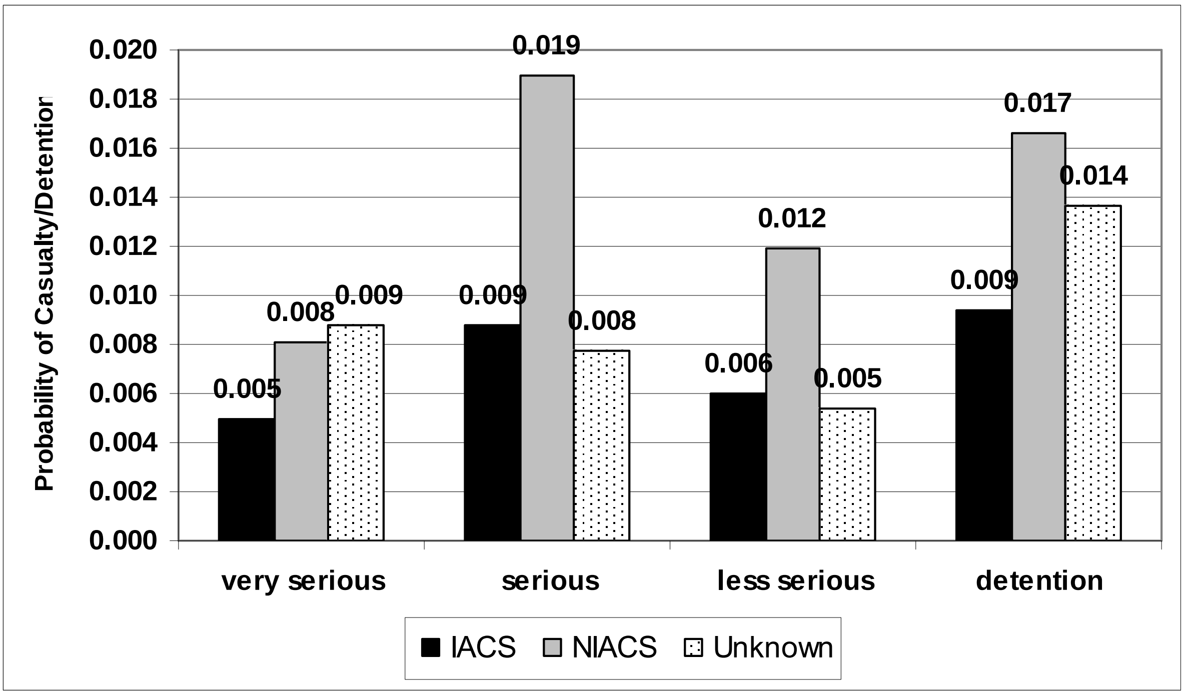
Figure 16: Probability of Serious Casualty per Flag State Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

The overall picture for classification societies is given in Figure 17 which is not split into inspected versus non inspected groups. For the graphs of the classification societies, the interpretation has to be careful due to the lack of some data. From the total casualty dataset, about 25% of the classification societies were missing and is indicated with unknown in the graph. Most of these observations are assumed to be Non-IACS class versus IACS class since one of the data providers does not indicate Non-IACS class. In general, ships classified with IACS class show a lower probability of casualty for all three categories and detention versus Non-IACS class.

Figure 17: Probability of Casualty and Class Groups



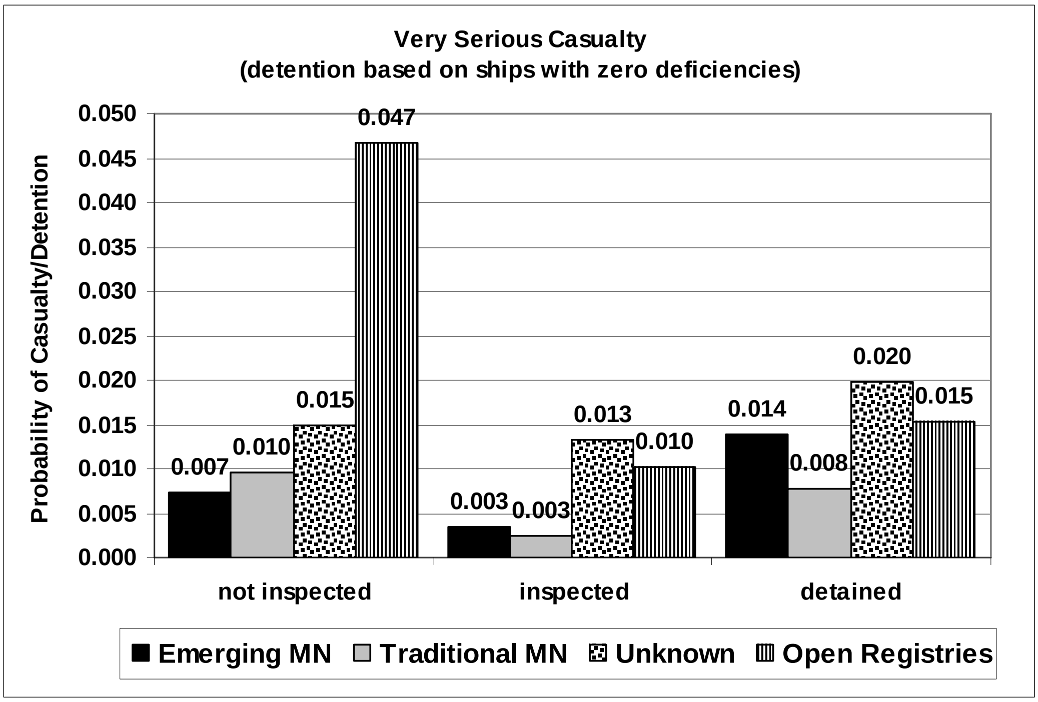
Note: Based on average estimated probabilities of approx. 50,000 vessels

In addition, the casualty and inspection data did not indicate the various types of classification societies a vessel can have which could be up to 4. The analysis is only based on the main class at the time of inspection or casualty which is primarily the classification society the vessel is classed in and does not necessarily has to be the classification society of ISM or ISPS[32]. An analysis which reflects the different types of classification societies per vessel are left as a recommendation for further research.

Figure 18 and Figure 19 look at the ownership of a vessel and it is interesting to notice that the highest probability of a very serious casualty lies with owners from open registries followed by unknown ownership, traditional maritime nations and emerging maritime nations. The difference between inspected and non-inspected vessels is also clear while traditional maritime nations shows the lowest probability for inspected vessels which is in line with the probability of detention. For serious casualties, the order changes as well as the difference between the groups. Not all regimes have this variable incorporated into the target factor to target vessels for inspection. More detailed research in this area is recommended. At this stage, company data was available but not used for the purpose of this study and the country of residence was used instead.

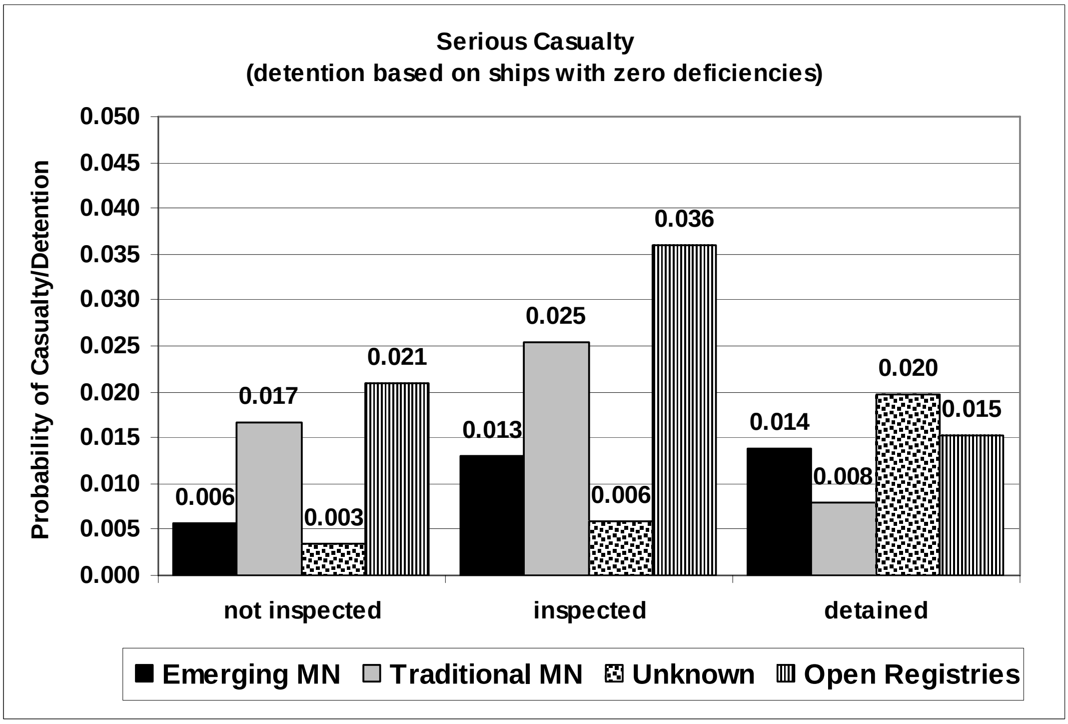
[32] ISPS for the purpose of this analysis is indifferent since security is not included.

Figure 18: Probability of Very Serious Casualty per Ownership Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 19: Probability of Serious Casualty per Ownership Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 20 shows the probability of casualty for ships that have not been inspected versus ships that have been inspected and detained (or not detained). It is based on an average probability and not split into seriousness. In general, ships not inspected by port state control show a lower probability of casualty while ships that have been inspected and detained show a higher probability. Detained vessels show the highest probability of a casualty. The graph confirms that on average, detained vessels seems to be more risk prone towards the probability of casualty but it also shows that detention by itself does not seem to have a negative effect on the probability of casualty. A possible room for improvement is therefore the follow up on detentions and deficiencies such as maybe the correct implementation of the safety management onboard.

Figure 20: Probability of Casualty of Detained versus not Detained Vessels

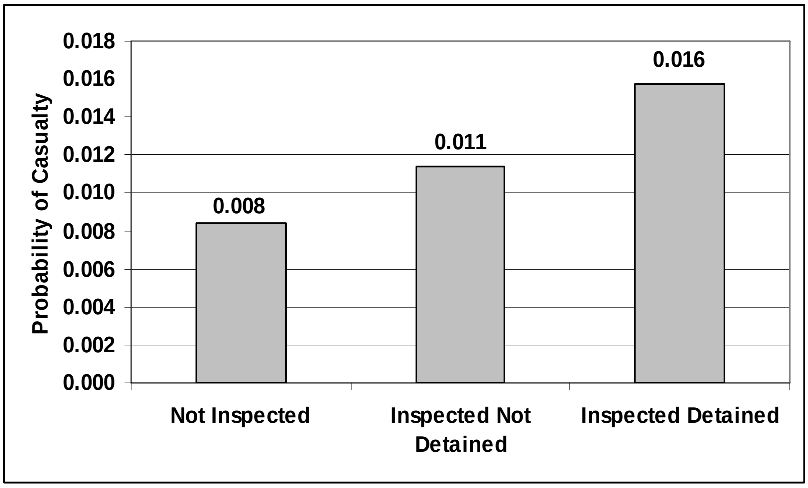
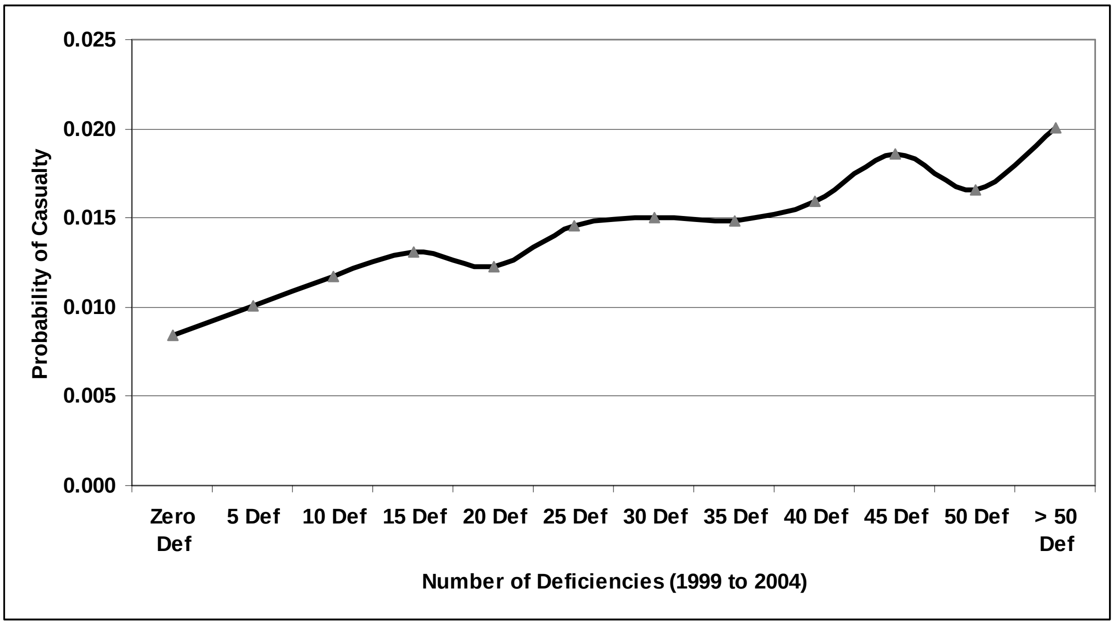


Figure 21 brings the probability of a casualty in relation to the number of deficiencies a vessel can have during a six year time period.

Figure 21: Probability of Casualty and Number of Deficiencies



Note: Based on average estimated probabilities of approx. 50,000 vessels

One can see that overall, the probability of having a casualty increases as the number of deficiencies increases with the exception of the group of 20 deficiencies and 50 deficiencies. This graph is based on the total time frame (1999 to 2004) and regardless of when the inspection was performed. It shows that port state control does find deficiencies on high risk vessels and that a vessel with more deficiencies also has a higher probability of casualty. It does not differentiate what type of deficiency but the matching models in the next section will look into this further and also split the probability into seriousness.

4. Conclusions on Casualties

About 32% of all port state control relevant casualties between 1999 to 2004 show signs of a casualty first event in engine related areas.

Improvement for port state control has been identified in the area of targeting and possibly the inspections itself. About 36% of the vessels eligible for inspections are identified not to have been problematic over the time period in question and have also not been targeted by the regimes in question. About 7% of the vessels eligible for port state control have been targeted over the time frame but did not have a casualty and also no deficiencies and therefore represent a group of over-inspected vessels.

About 43% of the vessels can be identified to belong to a group where inspections are effective in decreasing the probability of casualty where this effect is strongest for very serious casualties and estimated (depending on the basic ship risk profile) to be a 5% decrease per inspection. This category can also represent further room for improvement but shows that port state control is effective. Finally, about 5.3% of PSC eligible vessels have been targeted correctly but since they had a casualty within six month after the inspection, the enforcement could be improved. Another portion of 4.7% of ships had a casualty but was not inspected. This is an area where targeting could be improved.

The mean amount of deficiencies found at least six month prior to a casualty lies by 4.3 for black listed flag states versus 2.7 for grey and 1.7 for white listed flag states. Per seriousness of casualty, detained vessels show significantly higher amount of deficiencies (17 deficiencies for very serious) versus not detained vessels (3 deficiencies).

Regression analysis based on inspected and not inspected vessels reveals that the average probabilities of a casualty are by *0.06% (very serious), 1.6% (serious) and 1% (less serious) compared to 0.07% for the fishing fleet* above 400gt. Comparing an industry that is hardly or not inspected (the fishing fleet) with commercial fishing, one can see that performance of flag states changes accordingly. Flag states that are normally exposed to inspections under the port state control regime seem to perform better than if they are only exposed to their own flag state inspections which can be seen with the white listed flag states showing the highest probability of casualty under the fishing fleet.

With respect to the target factor, one can confirm that age is significant for very serious casualties and its effect is positive. One can clearly see that as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about *0.35% per year*. The average probability based on all ships changes according to ship type and general cargo ships and passenger vessels seem to show much of the variation with respect to age. Tonnage is also only significant for very serious casualties but is negative indicating that a smaller vessel seems to be at higher risk than larger vessels which goes in line with the general cargo vessels being more high risk prone.

The probability of casualty changes per ship type and confirms that general cargo vessels are ships with the highest probability of a casualty which is confirmed by the probability of detention. Black listed flag states or non inspected ships show a higher probability of a very serious casualty compared to grey and white listed flag states while the same does not hold for serious and less serious casualties. It might indicate that the target factors are targeting high risk vessels but are less effective in decreasing the probability of a serious and less serious casualty. This is confirmed with the partial effects which are only negative for very serious casualties.

With respect to classification societies, the probability of a casualty for Non-IACS class is higher than for IACS class and is also confirmed by the probability of detention. For ownership groups and in comparison of inspected to non –inspected vessels, highest probability of casualty lies within owners from open registry countries followed by unknown owners, owners from traditional maritime nations and emerging maritime nations. This does not follow the probability of detention where owners from traditional maritime nations show the lowest probability of detention.

Detained vessels show the highest probability of casualty compared to vessels that have been inspected but not detained and vessel that have not been inspected. The average probability of a very serious casualty of ships that are Greenaward certified or have been inspected by Rightship is lower than for non-certified or non-inspected vessels. A variable indicating both can be easily incorporated into target factors of port state control. In addition and based on average probabilities, the probability of casualty increases from about 0.1% to 0.2% as the number of deficiencies increases. This is irregardless of the time frame of the inspection and is based on the total inspection time frame of about six years.

The variable indicating if the ship type changed its class during its course of life is significant and negative for all types of casualties. This could mean that in general, if a class is changed, an inspection is performed which might have a positive influence on the quality of the vessel. On the other hand, the next variable indicating if class was withdrawn shows a positive effect which means that these types of vessel have a higher probability of having a casualty.

Change of flag does not seem to be significant while change of ownership is significant for all types of casualties but in particular for very serious casualties and positive. This could indicate a change of the vessel into second hand ownership or into a segment of the market where less money is spent on safety. The variable double hull is not significant for any type of casualty.

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Appendix

Appendix 1: Grouping of Countries of Ownership

The grouping of ownership of a vessel was made according to Alderton and Winchester (1999) and is as follows:

1. *Old Open Registries:* Antigua and Barbuda, Bahamas, Bermuda, Cyprus, Honduras, Liberia, Malta, Marshall Islands, Panama, St. Vincent & the Grenadines

2. *New Open Registries:* Barbados, Belize, Bolivia, Cambodia, Canary Islands, Cayman Islands, Cook Islands, Equatorial Guinea, Gibraltar, Lebanon, Luxembourg, Mauritius, Myanmar, Sri Lanka, Tuvalu and Vanuatu

3. *International Registries:* Anguila, British Virgin Islands, Channel Islands, DIS, Falklands, Faeroes, Hong Kong, Isle of Man, Kerguelen Islands, Macao, Madeira, NIS, Philippines, Sao Tome and Principe, Singapore, Turks and Caicos, Ukraine, Wallis and Fortuna, Netherlands Antilles

4. *Traditional Maritime Nations:* Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Russia, South Africa, Spain, Sweden, Switzerland, UK, Uruguay, USA, Venezuela.

5. *Emerging Maritime Nations:* Albania, Algeria, Angola, Azerbaijan, Bahrain, Bangladesh, Benin, Brunei, Bulgaria, Cameroon, Cape Verde, China, Colombia, Comoro, Congo, Costa Rica, Croatia, Cuba, Djibouti, Dominica, Dominican Republic, Egypt, El Salvador, Ecuador, Eritrea, Estonia, Ethiopia, Fiji, Gabon, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guyana, Haiti, Hungary, India, Indonesia, Iran, Iraq, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, North Korea, South Korea, Kuwait, Laos, Latvia, Libya, Lithuania, Madagascar, Malaysia, Maldives, Mauritania, Micronesia, Morocco, Mozambique, Namibia, Nicaragua, Nigeria, Oman, Pakistan, Papua New Guinea, Paraguay, Peru, Poland, Qatar, Romania, St. Helena, St. Kitts & Nevis, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Slovakia, Slovenia, Solomon Islands, Somalia Republic, Sudan, Surinam, Syria, Taiwan, Tanzania, Thailand, Togo, Trinidad, Tunisia, Turkey, Turkmenistan, UAE, Vietnam, Yemen

6. *Other/Unknown:* Undefined by dataset, Unknown (Fairplay), Azores, Cameroon, Greenland, Monaco, Puerto Rico, Serbia & Montenegro, St. Pierre & Miquel