The Global View on Port State Control

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Abstract

This report is the second 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 probability of detention across several port state control regimes while the third part looks at the effect of inspections on casualties as well as the evaluation of target factors. Using binary logistic regression, a method can be established that visualizes the differences of port state control inspections across several regimes. The results indicate that the differences towards the probability of detention are merely reflected by the differences in port states and the treatment of deficiencies and not necessarily by age, size, flag, class or owner. The analysis further shows that there is room for further harmonization in the area of port state control.

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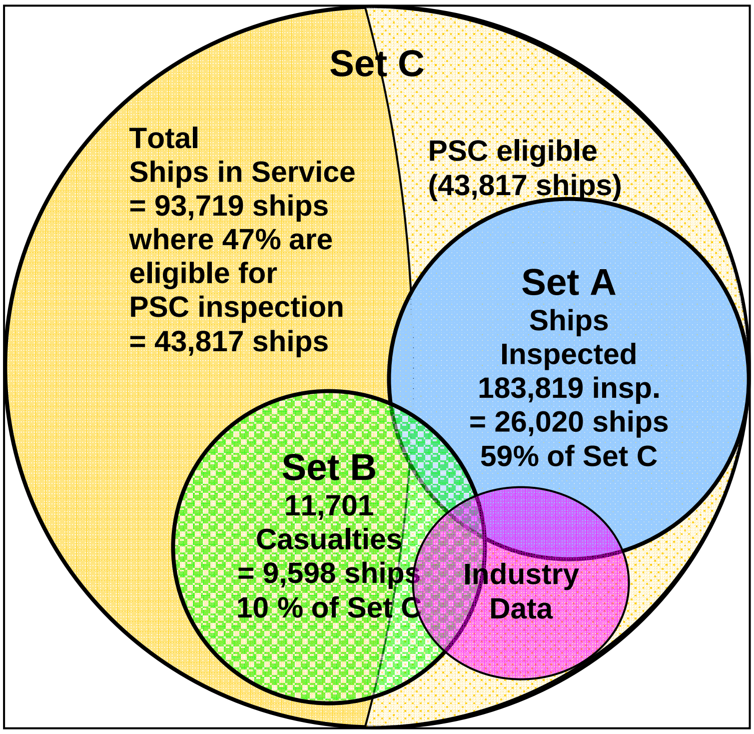
[2] The authors would like to thank the following secretariats for their kind co-operations: Paris MoU, Indian Ocean MoU, Viña del Mar Agreement on PSC, Caribbean MoU, Australian Maritime Safety Authority, the United States Coast Guard, Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit, the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

1. Overview of Datasets and Variables Used

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[3]) 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[4] where the average amount of inspections per vessel is by 7 per ship or 1.7 inspections per ship per year.[5]

Figure 1: Overview of Datasets Used



Set C represents an approximation of the total ships in existence[6]. Out of these vessels, ships below 400 gt[7] 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 are treated separately in the EU, ferries have been excluded from PSC eligible ships. The total estimated inspection coverage by the regimes in

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

[4] 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.

[5] 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.

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

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

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[8] 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[9] where the average amount of inspections per vessel is 7 per ship or 1.7 inspections per year.[10] Set C represents an approximation of the total ships in existence[11]. Out of these vessels, ships below 400 gt[12] 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[13] 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.

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

[9] 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.

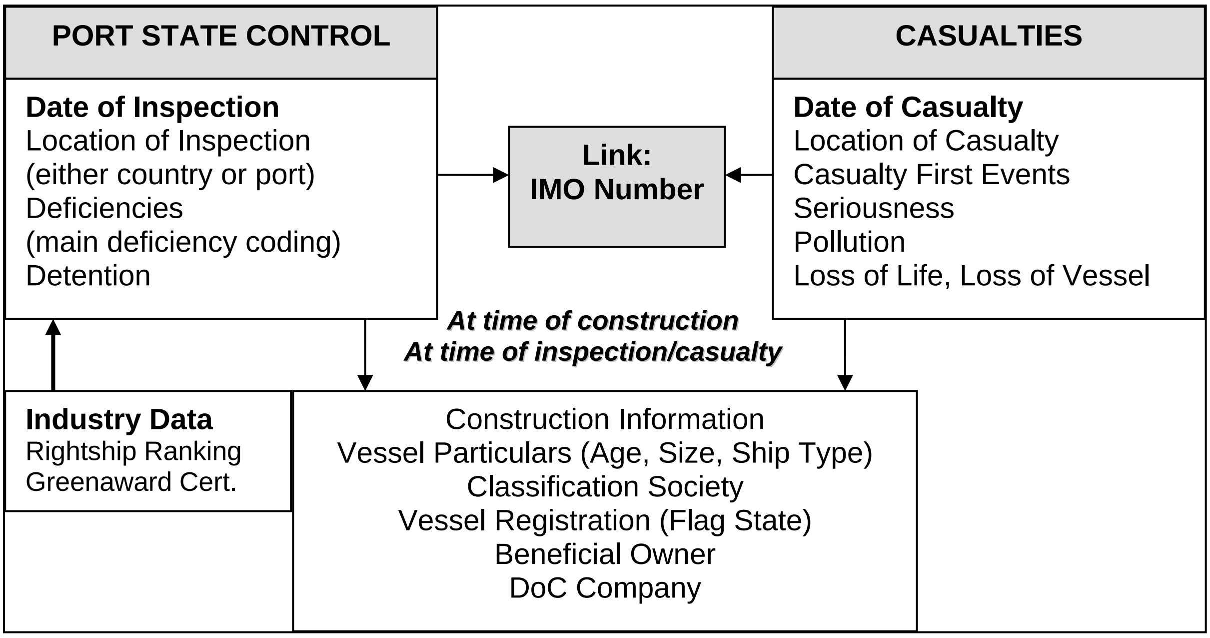
[10] Based on an average of 4 inspection years which is the average of the total months per regime to bring the different years of data to the same level for all regimes. The total time period Jan. 1999 to Dec. 2004 therefore represents a total of full 4 inspection years instead of 6 years.

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

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

[13] Lloyds Maritime Intelligence Unit

Figure 2: Overview of Variables Used



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

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

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"[14]. 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.

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

Flag States

Flag States were coded individually or grouped into four major groups according to the Paris MoU Black, Grey and White List[15] where white listed flag states are performing well followed 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:[16]

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[17] 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)[18] 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:

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

[16] As per IACS, http://www.iacs.org.uk

[17] 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.

[18] Alderton T. and Winchester N (2002). "Flag States and Safety: 1997-1999". *Maritime Policy and Management*, Vol 29, No. 2, pp 151-162

- *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
- *Point 3:* Analysis of Casualties per ship type and their severity
- *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 to derive at the grouping can be references in Knapp (2006)[19], 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

2.1. Key Figures on Port State Control

The actual split up of the commercial fleet which is eligible for inspection versus the total registered vessels can be seen in Figure 3. Oil tankers do have to comply with Marpol regulations if the vessels are above 150 gt. Most ships in service by number are general cargo ships (33%) followed by tankers (25%), dry bulk (14%) and containers (12%).

Table 1 provides a summary of each of the datasets from the various regimes and Figure 4 provides the visualization of the key figures of the total dataset. The data is based on all inspections which were conducted during the time frames including information on inspections with zero deficiencies.

Out of the total 183,819 inspections, 54% are without deficiencies and 5 % ended in a detention of the vessel. From the total amount of inspections of ships with deficiencies, 68% had 1 to 5 deficiencies while around 6% showed more than 16 deficiencies. One can see that the key figures presented in Table 1 vary accordingly such as the detention rate, the mean number of deficiencies per inspection and the amount of inspections with zero deficiencies.

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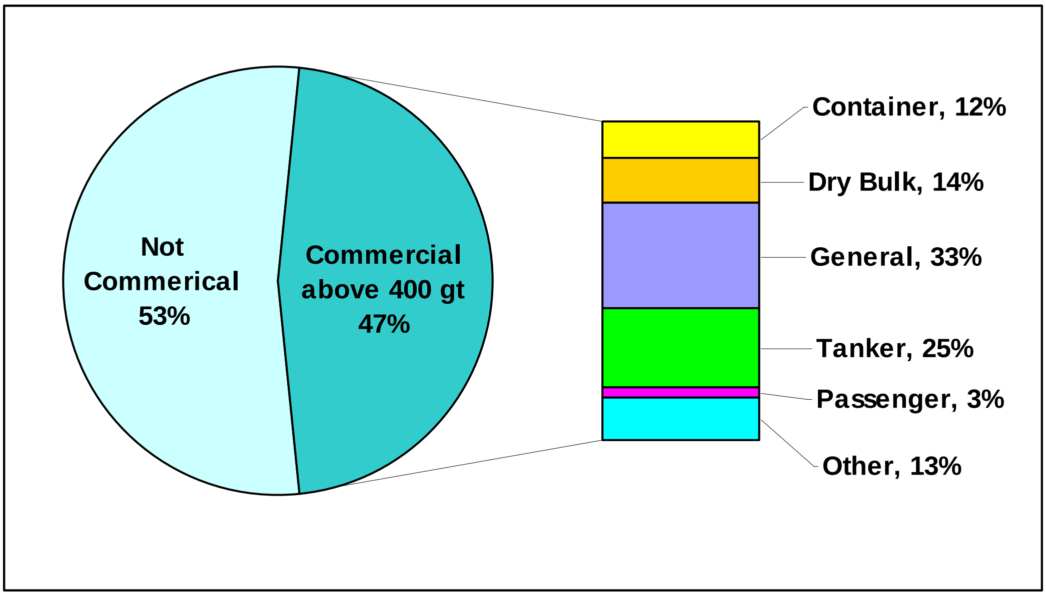
[19] Knapp, S. (2006), *"The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea"*, Doctoral Thesis (in print), Erasmus University, Rotterdam

Figure 3: Ships Eligible for Inspection



As per January 2005

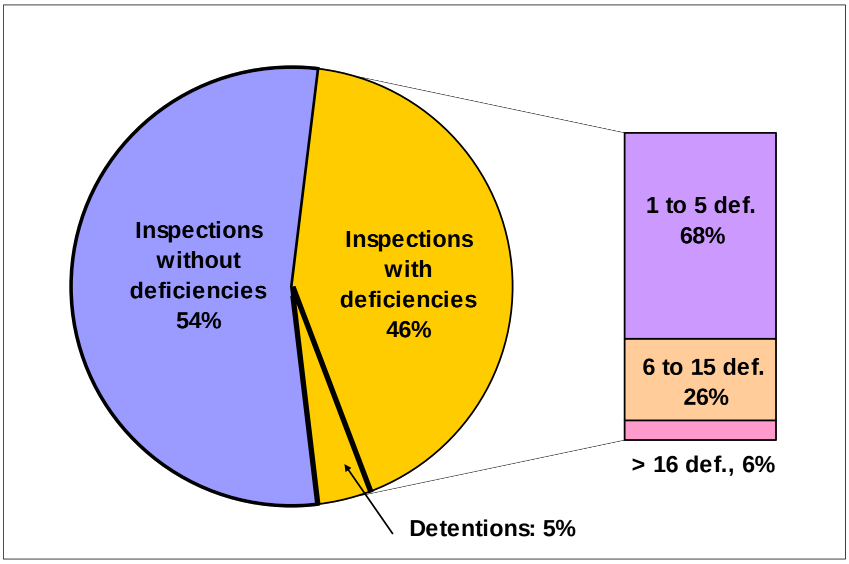
Table 1: Inspection Data Summary per MoU

Descriptive Statistics	Total Dataset	Paris MoU	Caribbean MoU	Viña del Mar Agreement	Indian Ocean MoU	US Coast Guard	AMSA
From To		05/00 12/04	01/03 07/05	01/00 12/04	01/02 12/04	01/01 12/04	01/99 12/04
Total Inspections	**183,819**	89,936	708	21,263	7,349	47,108	17,455
Detentions	**10,008**	7,005	36	644	732	660	931
Detention Rate	**5.44%**	7.79%	5.08%	3.03%	9.96%	1.40%	5.33%
Total Deficiencies	**471,764**	312,305	760	46,977	19,085	42,452	50,185
Mean # of Def.	**2.6**	3.5	1.1	2.2	2.6	0.9	2.9
Mean Age - yrs	**17**	17	18	15	18	13	11
Mean Size - gt	**22,079**	15,327	11,112	22,105	18,215	28,948	36,767
Insp. with zero def	**98,953**	39,333	597	13,359	3,943	34,560	7,161
% of insp. zero def	**53.8%**	43.7%	84.3%	62.8%	53.7%	73.4%	41.0%

Source: based on total inspection dataset

This does not necessarily mean that one regime performs worse than the other. Each of these datasets is the product of different legal bases and target factors and the trade flows which influences the ship types. The regression analysis will highlight the differences and look into areas of possible harmonization across the regimes.

Figure 4: Key Figures - Total PSC Dataset

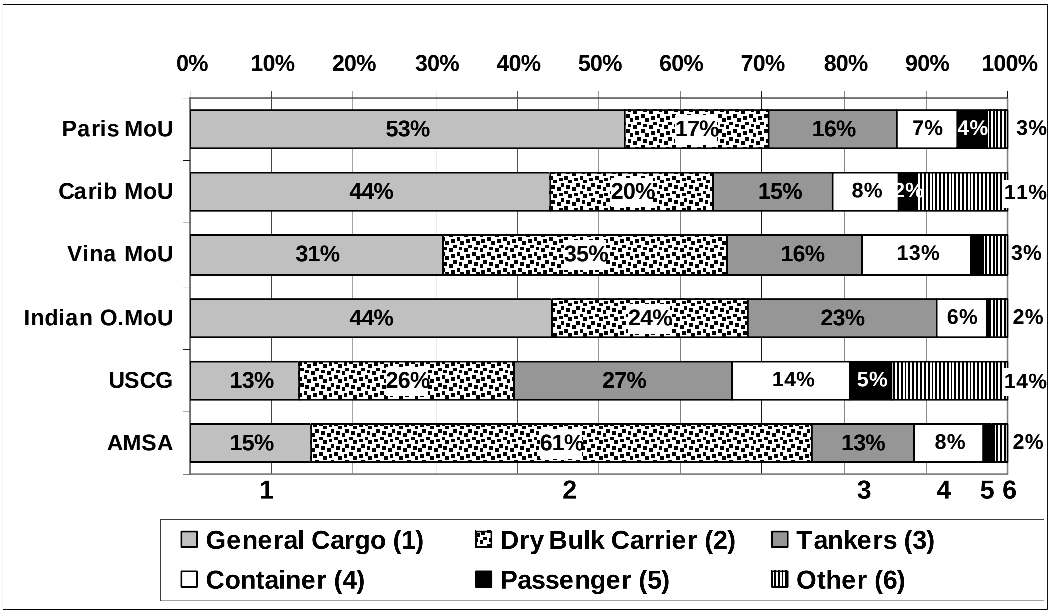


Source: based on total inspection dataset

2.2. Ship Types

Most cargo is shipped in bulk which can be liquid bulk (oil) and dry bulk (e.g. iron ore, coal, grains, bauxite, phosphate etc.). Figure 5 and Figure 6 show the ships inspected and ships detained per region to capture the exposure per regime.

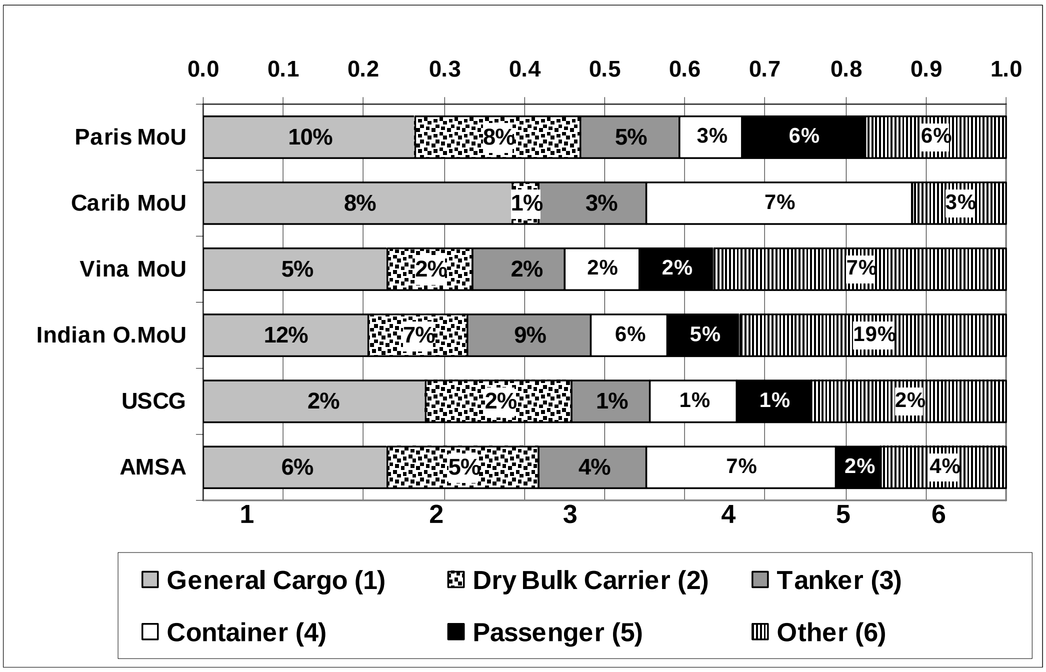
Figure 5: Ship Types Inspected per MoU



Source: based on total inspection dataset

This reflects the overall trade flows. Most ships inspected are general cargo & multipurpose ships and dry bulk carriers followed by tankers and container ships. The USCG and AMSA show a lower amount of general cargo ships but a higher amount of dry bulk carriers for AMSA and tankers for the USCG. Detention varies per ship type and regime.

Figure 6: Ship Types and Detention per MoU



Source: based on total inspection dataset

2.3. Classification Societies

The next section will look at the key figures for classification societies which have been classified into IACS and not IACS recognized classification societies and is shown in Table 2 and visualized in Figure 7.

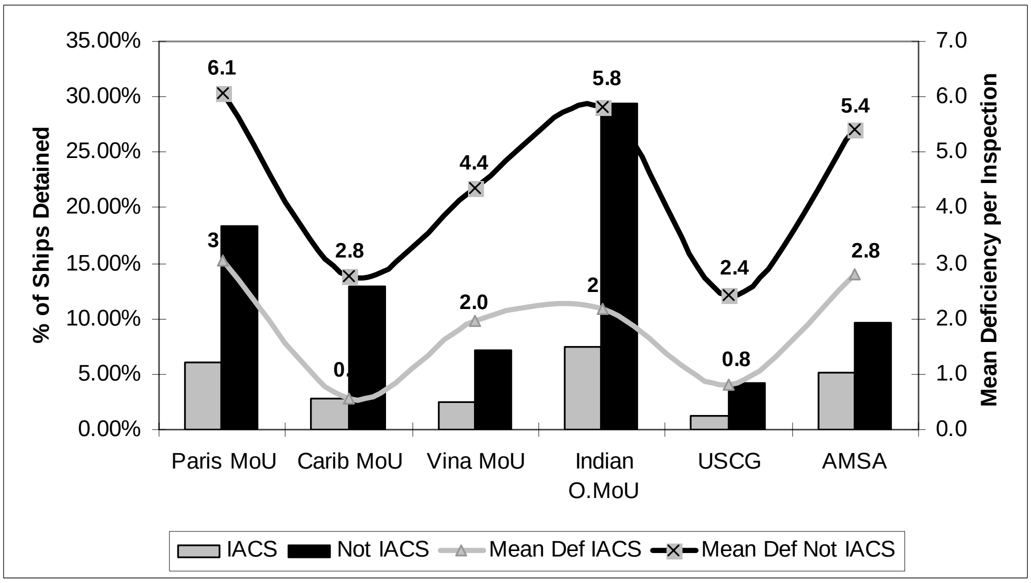
Table 2: Key Figures on Classification Societies – Total Dataset

	IACS					Not IACS				
	Total Inspections	Detentions	% Detained	% of Total MoU	Mean Deficiencies	Total Inspections	Detentions	% Detained	% of Total MoU	Mean Deficiencies
Paris MoU	77272	4688	6.07%	85.9%	3.0	12664	2317	18.30%	14.08%	6.1
Carib. MoU	545	15	2.75%	77.0%	0.6	163	21	12.88%	23.02%	2.8
Viña MoU	19029	484	2.54%	89.5%	2.0	2234	160	7.16%	10.51%	4.4
Ind.O. MoU	6530	491	7.52%	88.9%	2.2	819	241	29.43%	11.14%	5.8
USCG	44210	539	1.22%	93.8%	0.8	2898	121	4.18%	6.15%	2.4
AMSA	16954	883	5.21%	97.1%	2.8	501	48	9.58%	2.87%	5.4
Total	**164540**	**7100**				**19279**	**2908**			

Source: based on total inspection dataset

Most ships inspected are classified by IACS recognized class in each regime (some 77 to 97%) while detention rate is higher for non IACS recognized class across all regimes. The same applies to the amount of mean deficiencies per inspection where the amount of mean deficiencies for ships classified with non IACS class is more than double to IACS class which can easily be seen by the two lines in Figure 7.

Figure 7: Detention and Mean Deficiencies of Classification Societies



Source: based on total inspection dataset

2.4. Flag States

Table 3 gives and overview of the flag states which have been grouped into white, grey and black flag states according to the Paris MoU[20] "Black, Grey, White List" and undefined flag states as explained previously. The table shows the percentage of black, grey, white or undefined flag states which have been detained and their respective mean deficiencies per inspection. The table is visualized in Figure 8 for the percentage of detention. Most ships detained are black listed flag states while the USCG and AMSA also show a higher amount of detention with white listed flag states.

Table 3: Key Figures on Flag States – Total Dataset

	FS_Black	% Detained	Mean Deficiencies	FS_Grey	% Detained	Mean Deficiencies	FS_White	% Detained	Mean Deficiencies	FS_Undef	% Detained	Mean Deficiencies
Paris	36595	68.8%	5.1	9244	8.6%	3.0	43980	22.4%	2.2	117	0.2%	4.4
Carib.	378	80.6%	1.7	20	0.0%	0.3	229	16.7%	0.4	35	2.8%	0.4
Viña	9444	69.1%	3.0	1361	7.6%	2.6	9859	17.7%	1.3	599	5.6%	4.0
Indian	3257	58.7%	3.1	1600	13.7%	2.3	2186	13.3%	1.4	306	14.3%	7.3
USCG	18241	58.2%	1.2	3158	6.1%	1.0	24695	33.5%	0.7	1014	2.3%	1.4
AMSA	7230	45.5%	3.1	1993	14.8%	3.8	7998	36.7%	2.4	234	2.9%	5.8
Total	**75145**			**17376**			**88947**			**2305**		

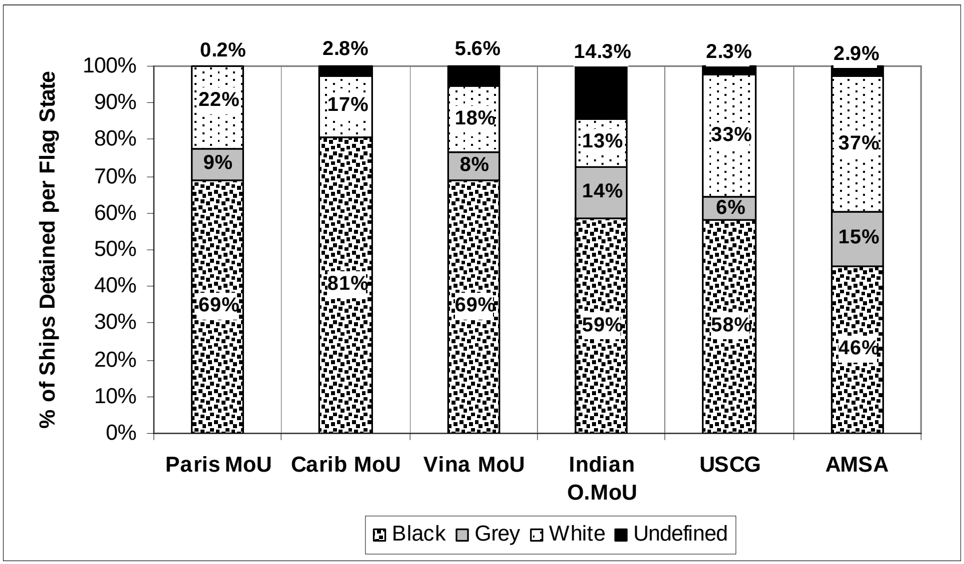
Source: based on total inspection dataset

The amount of mean deficiencies varies between each MoU and is highest for black listed flag states and undefined flag states with the exception of AMSA and the USCG. It is almost the double compared to the mean deficiencies of white listed flag states. For the Indian Ocean MoU, one can see a high percentage of undefined flag states that trade in

[20] Paris MoU Black, Grey and White List for the years 2000 to 2004

the Indian Ocean MoU area but not in the Paris MoU area and where the mean amount of deficiencies (7.3) and detention rate (14.3%) is significantly higher with the rest of the flag states.

Figure 8: Percentage of Detention per Flag State and MoU

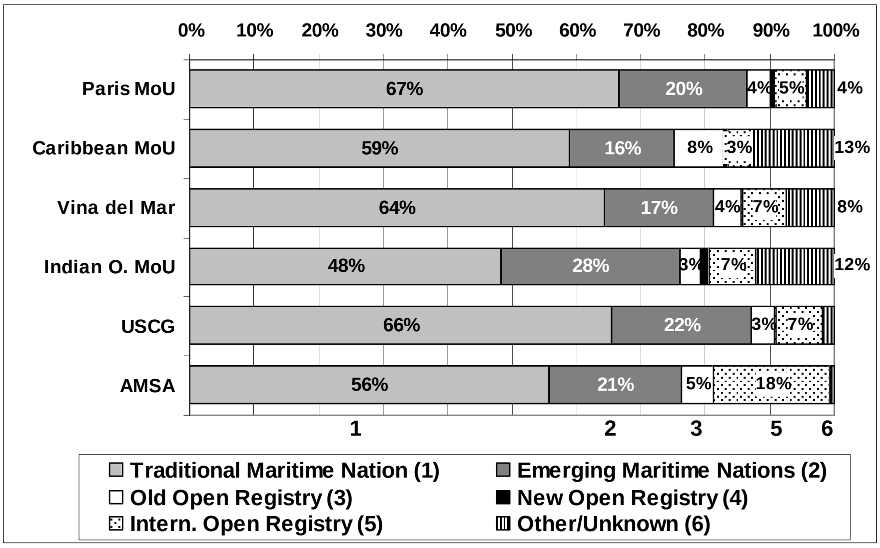


Source: based on total inspection dataset

2.5. Vessel Ownership

Looking at the dataset with reference to the ship owner, one can see from Figure 9 that more than half of the vessels inspected were owned by traditional maritime nations followed by emerging maritime nations and countries from open registries.

Figure 9: Ownership of Inspected Vessels



Source: based on total inspection dataset

This split up does vary across the regimes. The Indian Ocean MoU shows a higher percentage of owners from emerging maritime nations compared to the rest of the regimes which can be explained by the fact that the area has more regional trade.

3. The Probability of Detention across PSC regimes

3.1. Description of Model and Methodology

This model will provide the estimated probability (P) of a ship being detained based on each ship type defined previously for each safety regime. The dependent variable (y) in this case is “detained” or “not detained”. In a binary regression, a latent variable y^* gets mapped onto a binominal variable y which can be 1 (detained) or 0 (not detained). 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:[21]

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

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

Equation 1: Probability of Detention (either per regime or ship type)

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

All probabilities for the models to follow are probabilities for individual ships. To estimate the coefficients, quasi-maximum likelihood (QML)[22] 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. Since the datasets originate from different sources, a test is performed to see whether the coefficients obtained by the regressions differ significantly from each other across the regimes. The analysis is therefore spilt up into four main steps which are visualized in Figure 10 below for better understanding.

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

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

The amount of variables and observations used in the models change across the ship types and safety regimes. In total, there are six datasets generating from five PSC regimes and six ship types as shown in Table 4 which also shows the amount of total observations for each ship dataset and the number of observations entered into the combined ship models excluding the Caribbean MoU (708 observations). The Caribbean MoU had to be excluded from the combined models due to the lack of sufficient data.

Figure 10: Visualization of Methodology for data preparation

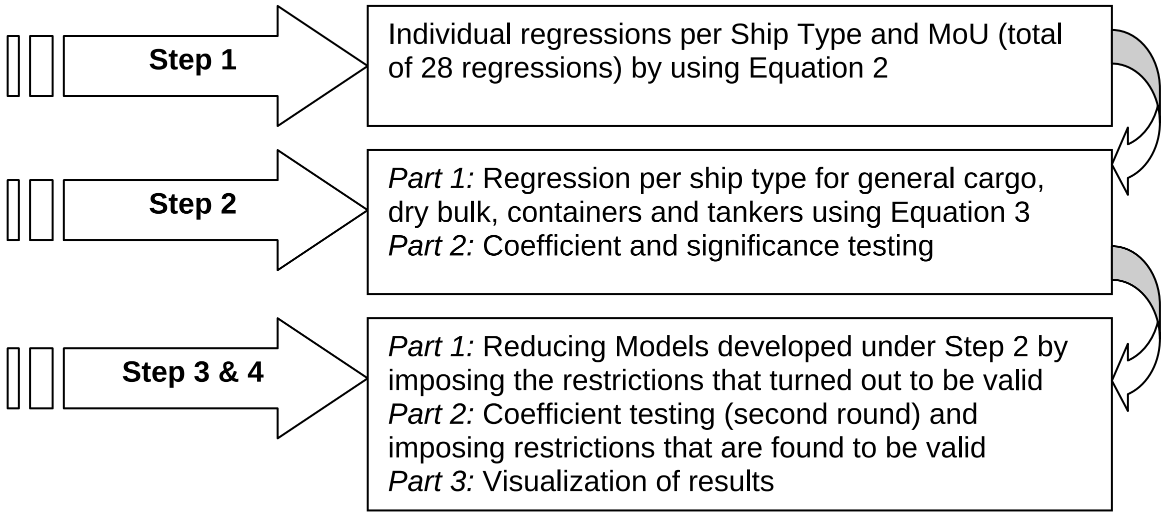


Table 4: Summary of Datasets per MoU and Ship Type

Notation	Number of Variables Start/End.	Paris MoU r=1	Carib. MoU r=2	Viña MoU r=3	Ind.O. MoU r=4	USCG r=5	AMSA r=6
General	424 to 133	GC1	One Model with all 708 observations	GC3	GC4	GC5	GC6
Dry Bulk	390 to 108	DB1		DB3	DB4	DB5	DB6
Container	245 to 72	CO1		CO3	CO4	CO5	CO6
Tanker	299 to 82	TA1		TA3	TA4	TA5	TA6
Passenger	93 to 38	PA1		PA3	PA4	PA5	PA6
Other ST	130 to 35	OT1		OT3	OT4	OT5	OT6
Total	1,581 to 468						
# of Regressions Performed		6	1	4+1	4+1	5+1	4+1
Remark concerning the regression models		All ST	Only one model	No separate model for passenger and other ships types		No separate model for PA	Same as Ind. Ocean MoU

Note: GC = general cargo, DB = dry bulk, CO= container, TA = tanker, PA = passenger, OT = other ship types

The number of variables used in the combined models is split up into the number of variables entered in the model at the beginning and the number that was left in the final models after reduction. The total number of variables for all combined models is 1,581[23] and narrows down to 468 in the final models. The four steps shown in Figure 10 are explained shortly here and the equations used for the regressions are given in each section respectively.

[23] number of total multiplicative dummy variables

Step 1: Individual Regressions

A separate analysis is performed for each dataset listed in Table 4 which adds up to a total of 28 regressions. The models can be written in the form of Equation 1 where the term $x_i\beta$ is given in Equation 2. Table 5 gives a detailed overview of the amount of variables. The notation is as follows: i = individual ship, ℓ = variable groups, n_ℓ = total number of variables within each group of ℓ and k = index from *1 to* n_ℓ

Equation 2: Definition of term $x_i\beta$ of Step 1 Model

$$x_i\beta = \beta_0 + \beta_1 \ln(\mathrm{AGE}_i) + \beta_2 \ln(\mathrm{SIZE}_i) + \sum_{k=1}^{n_3-1} \beta_{3,k}\,\mathrm{CL}_{k,i} + \sum_{k=1}^{n_4-1} \beta_{4,k}\,\mathrm{FS}_{k,i}$$
$$+ \sum_{k=1}^{n_5} \beta_5\,\mathrm{CODE}_{k,i} + \sum_{k=1}^{n_6-1} \beta_{6,k}\,\mathrm{PS}_{k,i} + \sum_{k=1}^{n_7-1} \beta_{7,k}\,\mathrm{OWN}_{k,i}$$

Table 5: Binary Logistic Models: List of Total Variables Used per MoU

				Paris MoU	**Caribbean MoU**	**Viña del Mar**	**Indian Ocean MoU**	**USCG**	**AMSA**
	ℓ	***Total Number of Variables***		**n_ℓ**	**n_ℓ**	**n_ℓ**	**n_ℓ**	**n_ℓ**	**n_ℓ**
Code		**Detained**		**1**	**1**	**1**	**1**	**1**	**1**
AGE	1	Vessel Age	C	1	1	1	1	1	1
SIZE	2	Vessel Size	C	1	1	1	1	1	1
CL	3	Classification Societies	D	29	10	26	19	22	15
FS	4	Flag States	D	83	16	62	47	72	45
CODE	5	Deficiency main codes	C	26	26	26	26	26	26
PS	6	Port States or Ports *)	D	20	8	11	5	47	15
OWN	7	Ship Owner Countries	D	6	6	6	6	6	6
		Total for each MoU		**166**	**68**	**133**	**105**	**175**	**109**

C = continuous, D = dummy of categorical variables

**) for the USCG and AMSA, ports are used instead of port states*

For the step 1 model, a separate regression was performed for each ship type and MoU individually – a total of 28 regressions. For the Caribbean MoU, the dataset cannot be split up according to the ship types due to the low number of observations but one regression using the total dataset is performed including a dummy variable for each ship type. The same method is also used for passenger vessels and other ship types with a slightly modified version which will be explained under the step 2 models.

Step 2: Hypothesis and Coefficient Testing

For the step 2 model, the dependent variables were multiplied (based on the outcome of the step 1 model) by ship type and PSC regime (r) to create multiplicative dummy variables. The total dataset was then divided into six datasets (one for each ship type) and a separate regression was performed on each ship type based on Equation 3. The variables are listed in detail in Table 6 for further reference. In this equation, the notation for individual ship i is dropped for sake of simplification The rest of the notation is as follows: ℓ represents the variable groups, n_ℓ is total number of variables within each group of ℓ (0-7), k is an index from 1 to n_ℓ, r represents a respective PSC regime (1 to 5) and n_r is the total number of PSC regimes (5).

Equation 3: Definition of term $x\beta$ of Step 2 Model

$$x\beta = \sum_{r=1}^{n_r} \beta_{0,r}\mathrm{REG}_r + \sum_{r=1}^{n_r} \beta_{1,r}\ln(\mathrm{AGE})_r + \sum_{r=1}^{n_r} \beta_{2,r}\ln(\mathrm{SIZE})_r + \sum_{r=1}^{n_r}\sum_{k=1}^{n_3-1} \beta_{3,k,r}\mathrm{CL}_{k,r}$$
$$+ \sum_{r=1}^{n_r}\sum_{k=1}^{n_4-1} \beta_{4,k,r}\mathrm{FS}_{k,r} + \sum_{r=1}^{n_r}\sum_{k=1}^{n_5} \beta_{5,k,r}\mathrm{CODE}_{k,r} + \sum_{r=1}^{n_r}\sum_{k=1}^{n_6-1} \beta_{6,k,r}\mathrm{PS}_{k,r}$$
$$+ \sum_{r=1}^{n_r}\sum_{k=1}^{n_7-1} \beta_{7,k,r}\mathrm{OWN}_{k,r}$$

Table 6: Binary Logistic Models: List of Variables Used per ST - step 2 Models

		All variables are multiplicative dummies with the exception of the passenger ship and other ship types		**General Cargo**	**Dry Bulk**	**Container**	**Tanker**	**Passenger**	**Other ST**
	ℓ	***Total Number of Variables***		***n_ℓ***	***n_ℓ***	***n_ℓ***	***n_ℓ***	***n_ℓ***	***n_ℓ***
Code		**Detained**		**1**	**1**	**1**	**1**	**1**	**1**
REG	0	PSC Regime	D	5	5	5	5	5	5
AGE	1	Vessel Age	C	5	5	5	5	1	1
SIZE	2	Vessel Size	C	5	5	5	5	1	1
CL	3	Classification Societies	D	73	61	36	41	15	16
FS	4	Flag States	D	140	121	51	82	24	36
CODE	5	Deficiency main codes	C	107	101	81	93	19	18
PS	6	Port States or Ports *)	D	65	71	43	57	23	47
OWN	7	Ship Owner Countries	D	23	20	18	10	4	5
		Total for each ST		**424**	**390**	**245**	**299**	**93**	**130**

C = continuous, D = dummy of categorical variables

As mentioned earlier, the model for the passenger ships and other ship types is not based on multiplicative dummy variables due to lack of data. Those models follow the same type of model of Equation 2 based on one total dataset for all passenger vessels or other ship types respectively with the difference that no constant was used in the model but five variables indicating the respective regimes as shown in Equation 3.

In order to see if the coefficients across the PSC regimes vary, the Wald-Test for Testing Restrictions[24] was performed on the results obtained from the models and based on the following hypothesis on a subset of the matrix where ℓ represents the variable groups and n_r is the total number of PSC regimes (5).

H_o: coefficients within each variable group ℓ across the PSC regimes r do not vary
H_a: coefficients within each variable group ℓ across the PSC regimes r do vary
H_o: coefficients within each variable group ℓ across the PSC regimes r are not significant
H_a: coefficients within each variable group ℓ across the PSC regimes r are significant

[24] For further detail on the Wald Test for a Subset of Coefficients, please refer to Greene H.W., Fourth Edition, Econometric Analysis, Fourth Edition, page 825.

Step 3 & 4: Reduction of Models and Visualization of Results

The models per ship type are reduced to the final models as explained in Figure 10 using a significance level of 5% where the results can be seen in Table 10 for further reference. After the final reduction of the model, the coefficients were tested again in a second round applying the hypothesis developed under step 1 at a 5% significance level and restrictions were imposed when found to be valid. The last step is to visualize the results obtained under step 3 by calculating out the estimated probabilities using Equation 1.

3.2. Step 1 Results: Per MoU and Ship Type

Table 7 gives an overview of the classification tables of the individual regressions that were performed on each dataset. The results then provide the basis for the creation of the dummy variables used in step 2. The cut off rate used for each of the models is based on the detention rate which varies accordingly per MoU and ship type and is listed in Table 8 for each ship type and MoU and for each ship type as a total. The latter is used in step 2 to produce the classification tables.

One can see that the hit rate for detained vessels varies and that the Caribbean Model due to its low number of observations shows less predictive accuracy with 57% hit rate for out of sample forecasting. Container vessels also show lower hit rates for all MoU's compared to the other main ship types (general cargo, dry bulk and tankers) but in general, the hit rates are found to be acceptable for the amount of data and variables.

Table 7: Step 1: Classification Tables

Ship Type	Hit Rates for detained (%)	Paris %	Carib %	Viña %	Indian %	USCG %	AMSA %
General	selected	81.4	90.9*)	85.3	83.5	93.3	80.8
	unselected*)	79.2	57.1*)	84.9	75.6	69.8	65.8
Dry Bulk	selected	81.3	90.9*)	85.3	90.5	88.9	81.9
	unselected*)	79.1	57.1*)	89.1	81.3	66.1	76.2
Container	selected	85.6	90.9*)	95.3	94.4	90.9	80.8
	unselected*)	68.5	57.1*)	80.0	57.1	64.7	75.0
Tanker	selected	82.3	90.9*)	91.2	90.7	87.0	81.0
	unselected*)	81.8	57.1*)	79.2	84.1	66.7	65.4
Passenger	selected	77.4	90.9*)	86.9*)	86.8*)	89.2*)	78.0*)
	unselected*)	80.7	57.1*)	89.6*)	76.2*)	84.4*)	76.0*)
Other ST	selected	85.6	90.9*)	86.9*)	86.8*)	84.4	78.0*)
	unselected*)	80.0	57.1*)	89.6*)	76.2*)	68.3	76.0*)

**) unselected means out of sampling forecasting*

Table 8: Cut Off Rates (based on observed detention rate) per ST and MoU

		Cut Off Rate for Classification Table					
Ship Types	**Total**	**Paris**	**Carib**	**Viña**	**Indian**	**USCG**	**AMSA**
General Cargo	0.080	0.097	0.051*)	0.046	0.121	0.023	0.065
Dry Bulk	0.046	0.076	0.051*)	0.021	0.072	0.015	0.053
Container	0.020	0.029	0.051*)	0.019	0.056	0.009	0.066
Tanker	0.031	0.046	0.051*)	0.023	0.090	0.008	0.038
Passenger	0.034	0.057	0.051*)	0.03*)	0.099*)	0.014*)	0.053*)
Other Ship Types	0.037	0.064	0.051*)	0.03*)	0.099*)	0.020	0.053*)

**) based on total dataset*

Based on these outcomes, multiplicative dummy variables are computed for each variable and ship type (e.g. ship type general cargo Paris MoU*Classification Society ABS) and the datasets for the ship types of each MoU (e.g. all general cargo ships) are aggregated to one dataset which ends of with 4 datasets (general cargo, dry bulk, container and tanker) to be the basis for the next step.

3.3. Step 2 Results: Coefficient Testing (Performed in 2 Rounds)

Based on Equation 3, the models are estimated and the coefficients are tested according to the set of hypotheses explained earlier at a 5% significance level. The result can be seen in Table 10 for detailed reference. The testing was performed in two rounds – first if the coefficients vary significantly across the MoUs and second, if they are zero.

One of the most interesting findings in performing the testing is that the main differences across the regimes are based on the port states and the individual deficiency codes and not necessarily the flag states or classification societies. The next sections will impose the restrictions that were found to be valid and will after reducing the models and performing a second test round; visualize the main findings for the probability of detention across the regimes.

3.4. Step 3 Results: Final Models per Ship Type

As a first step, the models were estimated without QML[25] and with QML using Huber/White standard errors and covariance at the time the program first found a solution. The results were compared to identify significant differences in the coefficients and the results can be seen in Table 9 which lists the variables at the time the matrix first solved, the amount of variables which changed significance and the amount of variables which are changed in the final models.

Table 9: Variables changed based on QML versus non QML estimation

Variables at the time matrix first solved	Total Variables	#of Variables changed	% Variables changed	Final # of Variables changed in reduced Model
General Cargo	422	15	3.6%	9
Dry Bulk	389	35	9.0%	2
Container	244	18	7.4%	2
Tanker	298	25	8.4%	1
Passenger	92	4	4.3%	0
Other Ship Types	129	6	4.7%	0

One can see that the significance of some of the variables changed especially for the dry bulk model. In order to give a certain allowance for a possible misspecification of the assumption of the underlying function, QML was used for the final models and both probit and logit was estimated and the results are shown in Table 11.

[25] Quasi Maximum Likelihood – Huber/White standard error & covariance

Table 10: Step 2: Results – Testing of Equality of Coefficients across the Regimes

		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
	Age	5	0.6373	0.0000			5	0.0982	0.0000			5	0.0710	0.0000			5	0.8234	0.1127		
	Size	5	0.0088	0.0000	3	0.5480	5	0.1023	0.0091			5	0.3409	0.0575			5	0.4766	0.0014		
ABS	American Bureau of Shipping	5	0.0772	0.1308			5	0.5606	0.4055			5	0.4414	0.5769			4	0.3808	0.5311		
BV	Bureau Veritas	5	0.1724	0.2491			5	0.0844	0.1323			4	0.5116	0.4663			4	0.2712	0.2489		
CCS	China Classification Society	3	0.6979	0.4107			4	0.6253	0.5339												
CRR	Croatian Register of Shipping						2	0.0821	0.1120												
DNV	Det Norske Veritas	5	0.0103	0.0398	2	0.0678	5	0.5740	0.5134			5	0.3149	0.0163			3	0.0215	0.0520		
GL	Germanischer Lloyd	5	0.0950	0.1329			4	0.7495	0.8373			4	0.0819	0.1147			5	0.1782	0.2770		
HIN	Honduras Inter. Naval Surve IB	2	0.2920	0.5739																	
IBS	Isthmus Bureau of Shipping	2	0.3591	0.6488																	
INS	Intern. Naval Surveys Bureau	2	0.5745	0.3432			2	0.0817	0.1699												
IRS	International Register of Shipping	3	0.1126	0.1850																	
KRS	Korean Register of Shipping (South)	4	0.0429	0.0187			4	0.4843	0.0814								2	0.7279	0.0648		
LLR	Lloyds Register of Shipping (UK)	4	0.0225	0.0118	3	0.0166	5	0.1848	0.1138			5	0.3123	0.0513			4	0.0048	0.0086		
NCL	No Class Recorded	2	0.5890	0.6730			2	0.3809	0.2977								2	0.9436	0.7701		
NKK	Nippon Kaiji Kyokai (Japan)	5	0.0602	0.0487	2	0.3993	5	0.4899	0.2805			5	0.2254	0.1098			4	0.1388	0.1688		
PRS	Polski Rejestr Statkow (Poland)	4	0.0039	0.0095			4	0.2166	0.1854												
RIN	Registro Italiano Navale (Italy)	4	0.1280	0.1920			3	0.8010	0.8510			4	0.4145	0.3450			2	0.8327	0.5954		
RMS	Russian Maritime Register of Shipping	5	0.4846	0.4135			4	0.4306	0.4947			4	0.1455	0.2370							
AG	Antigua and Barbuda	4	0.4843	0.1403			2	0.0700	0.1910								4	0.5624	0.6223		
AN	Antilles Netherland	3	0.9356	0.1754																	
BO	Bolivia	3	0.0054	0.0018																	

		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
BS	Bahamas	5	0.1997	0.1331			5	0.8318	0.2093			4	0.2212	0.1177			4	0.6959	0.8277		
BZ	Belize	2	0.8025	0.5183																	
BR	Brazil						3	0.0053	0.0015	2	0.0000										
CN	China	3	0.2580	0.4361			4	0.9370	0.8278												
CY	Cyprus	5	0.3959	0.0075	3	0.2039	5	0.4504	0.0045			5	0.1961	0.1088			5	0.5748	0.6927		
DE	Germany																2	0.9846	0.4926		
DK	Denmark	4	0.7012	0.7039								3	0.1124	0.0758							
EG	Egypt						2	0.3386	0.0721												
ET	Ethiopia	2	0.5550	0.8109																	
GE	Georgia	2	0.2856	0.0056																	
GI	Gibraltar	2	0.3590	0.0319																	
GR	Greece	2	0.4302	0.5718			5	0.8824	0.2218			3	0.0255	0.0005	2	0.4256	2	0.5040	0.0844		
HK	Hong Kong	4	0.0185	0.0139			5	0.3508	0.1159			3	0.3795	0.5830							
HR	Croatia						3	0.0896	0.1644												
IM	Isle of Man	2	0.4037	0.6447			2	0.2903	0.0536												
IN	India						3	0.9131	0.0156			3	0.3649	0.2113							
IR	Iran	2	0.6848	0.0898			2	0.7926	0.0426												
IT	Italy						3	0.5387	0.0231			2	0.6204	0.6199							
KH	Cambodia	3	0.2656	0.0010																	
KP	North Korea	2	0.2083	0.0071																	
KR	South Korea						3	0.4980	0.0036												
KY	Cayman Islands	3	0.9684	0.1840			4	0.5588	0.0644			3	0.5814	0.5005							
LR	Liberia	5	0.3578	0.3847			5	0.4012	0.0426			5	0.0677	0.0787	2	0.6365	4	0.3077	0.2907		
MH	Marshall Islands	3	0.6486	0.7862			4	0.7396	0.1916			5	0.4354	0.5560							
MT	Malta	5	0.2081	0.0116			5	0.1607	0.0018			4	0.0059	0.0004	4	0.5280	3	0.8521	0.2151		
MY	Malaysia						3	0.6034	0.0262			3	0.4863	0.3045			2	0.6049	0.0711		
NL	Netherlands	4	0.7683	0.2810			2	0.1530	0.0105			2	0.6718	0.5635			3	0.2780	0.2876		
NO	Norway	3	0.5029	0.6256			3	0.3497	0.3450			4	0.0069	0.0137							
PA	Panama	5	0.0271	0.0000	4	0.0789	5	0.5310	0.0091			5	0.0002	0.0000	2	0.6303	5	0.2594	0.0906		
PH	Philippines	4	0.2720	0.0578			4	0.6348	0.0255												
PL	Poland						2	0.0758	0.0310												
RU	Russian Federation	2	0.8107	0.0001								2	0.1928	0.0577							

		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	**Variable**	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Coefficient Testing	Significance	# of variables	Test of Equality of Coefficients
SE	Sweden	3	0.0842	0.1747																	
SG	Singapore	2	0.7601	0.4617			4	0.5192	0.0097			4	0.3096	0.0103			4	0.2952	0.4082		
TH	Thailand	3	0.7485	0.5057			3	0.1885	0.3382												
TR	Turkey	2	0.1148	0.0000			5	0.8337	0.0200												
TW	Taiwan						2	0.7650	0.0936												
UA	Ukraine	2	0.8116	0.0008			2	0.4498	0.0890												
UK	United Kingdom											2	0.4595	0.4395			2	0.9237	0.7673		
VC/SV	St. Vincent & the Grenadines	5	0.0398	0.0000	2	0.0544	5	0.1528	0.0541			2	0.1568	0.0013			2	0.0005	0.0001		
VU	Vanuatu	4	0.2089	0.0715																	
100	Ship's certificates and documents	5	0.0000	0.0000	3	0.0010	5	0.0000	0.0000	4	0.0709	5	0.6376	0.0000			5	0.6486	0.0000		
200	Crew certificates	5	0.0000	0.0000	5	0.0000	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0045
300	Accommodation	5	0.0535	0.0024			5	0.0601	0.6440	2	0.7453	4	0.0261	0.0117	2	0.0212	3	0.0182	0.0101		
400	Food and catering	4	0.1765	0.2878			4	0.1936	0.1469			3	0.9917	0.6672			2	0.2989	0.0357		
500	Working spaces and accident prevention	4	0.1480	0.0028	3	0.0056	3	0.3941	0.4846			2	0.4734	0.6762			2	0.8167	0.4619		
600	Life saving appliances	5	0.0010	0.0000	3	0.0056	5	0.0000	0.0000	5	0.0000	5	0.0000	0.0000			5	0.4078	0.0000		
700	Fire Safety measures	5	0.0040	0.0000	4	0.0012	5	0.0000	0.0000	5	0.0000	5	0.3463	0.0000			5	0.0000	0.0000	3	0.0513
800	Accident prevention (ILO147)	5	0.4718	0.5230			5	0.0218	0.0420			3	0.2629	0.4037			2	0.3488	0.6226		
900	Structural Safety	5	0.0000	0.0000	5	0.0000	5	0.0064	0.0000	4	0.6498	5	0.0423	0.0000	3	0.0640	5	0.0077	0.0000	4	0.0112
1000	Alarm signals	5	0.6793	0.0000			5	0.8309	0.8068			3	0.6520	0.0938							
1100	Cargoes	5	0.0006	0.0000	3	0.0003	5	0.2135	0.1793			3	0.7232	0.1457			4	0.5996	0.4934		
1200	Load lines	5	0.0000	0.0000	4	0.8410	5	0.1465	0.0000	2	0.2331	5	0.3015	0.0003			5	0.1293	0.0000		
1300	Mooring arrangements (ILO 147)	5	0.0490	0.0029	2	0.5029	5	0.5774	0.6491			5	0.0009	0.0000	2	0.0012	4	0.2829	0.2674		
1400	Propulsion & aux.	5	0.1237	0.0000	3	0.1201	4	0.2512	0.0000			5	0.3776	0.0004			5	0.0905	0.0000	3	0.8884
1500	Safety of navigation	5	0.0001	0.0000	3	0.0666	5	0.0116	0.0004	2	0.2082	5	0.2830	0.0311			5	0.3467	0.4816		
1600	Radio communications	5	0.0316	0.0000	4	0.0055	5	0.0082	0.0000	4	0.0004	5	0.0022	0.0017	3	0.0000	4	0.7991	0.0000		
1700	MARPOL annex I (Oil)	5	0.0094	0.0000	4	0.2540	5	0.0125	0.0000	5	0.0167	5	0.0034	0.0000	3	0.0000	5	0.0134	0.0000	4	0.2317
1800	Gas and chemical carriers											4	0.0052	0.0005	2	0.2751					
2000	Operational deficiencies	5	0.0021	0.0035	3	0.0005	4	0.0000	0.0000			5	0.0174	0.0144			4	0.5767	0.4367		
2100	MARPOL related op. def.	4	0.1970	0.2691			3	0.7468	0.8013			2	0.6432	0.6629			2	0.5142	0.0001		

		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
2200	MARPOL annex III (Package)																				
2300	MARPOL annex V (Garbage)	3	0.4652	0.0477			2	0.0544	0.0390			2	0.0118	0.0024	2	0.0015	2	0.1572	0.3281		
2500	ISM related deficiencies	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0000	4	0.0000	0.0000	3	0.1034	4	0.0020	0.0000	3	0.0001
OOR	Owner from Old Open Registry Country	4	0.0158	0.0341			3	0.6703	0.7165			3	0.1912	0.3330			2	0.8593	0.0010		
IOR	Owner from Intern. Open Registry Country	5	0.0796	0.0888	2	0.4555	4	0.1134	0.0954								3	0.0025	0.0042		
TMN	Owner from Traditional Maritime Nation	5	0.0173	0.0151	2	0.0079	5	0.8201	0.4477			4	0.4494	0.2132			5	0.0192	0.0339		
EMN	Owner from Emerging Maritime Nation	5	0.0325	0.0600			5	0.4915	0.4562								5	0.0215	0.0416		
UNK	Owner Unknown	4	0.0040	0.0009	2	0.0019	3	0.0053	0.0145			3	0.4341	0.4774			3	0.0146	0.0311		

Note: the number of variables depicts the number of variables that were in the test in each round. The first round of testing was performed after the program found a solution the first time and the second round of testing was performed after the model was reduced to only significant variables.

Table 11 lists the number of observations that were used in each model, outliers that were identified and eliminated, the Mc Fadden[26] R^2 and the hit rates with the respective cut off values used to produce the of the classification tables for each model, the Hosmer-Lemeshow-Statistic (HL) and its p-value. The HL test is a goodness of fit test which compares the expected values with the actual values by group. Its null hypothesis *(h_o)* assumes little difference of the expected versus actual values and therefore a good fit of the model to the data. The alternative hypothesis (*ha*) represents not a good fit of the model to the data.

Table 11: Summary of Key Statistics and Classification Table

	General		Dry Bulk		Container	
# observations in final model	0 =	60893	0 =	45571	0 =	17785
	1 =	5580	1 =	2206	1 =	426
	Total=	66473	Total=	47777	Total=	18211
# outliers	132		184		6	
Cut Off	0.0842		0.0462		0.0240	
	LOG	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**
Mc Fadden R2	0.433	0.438	0.411	0.419	0.448	0.459
% Hit R. y=0	87.59	86.39	87.55	86.84	90.49	90.12
% Hit R. y=1	82.26	83.33	84.18	85.58	85.92	87.32
% Hit R. Tot	87.14	86.12	87.39	86.78	90.38	90.05
HL-Stat. df=8	130.74	51.83	67.16	47.45	17.82	15.28
p-value	0.0000	0.0000	0.0000	0.0000	0.0226	0.0539
	Tanker		**Passenger**		**Other ST**	
# observations in final model	0 =	32985	0 =	5907	0 =	9699
	1 =	1060	1 =	211	1 =	374
	Total=	34045	Total=	6118	Total=	10073
# outliers	82		12		4	
Cut Off	0.0312		0.0345		0.0372	
	LOG	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**
Mc Fadden R2	0.424	0.435	0.332	0.427	0.388	0.399
% Hit R. y=0	88.81	88.39	84.54	86.58	88.20	87.74
% Hit R. y=1	86.60	87.26	86.73	90.45	83.69	86.36
% Hit R. Tot	88.74	88.36	84.62	86.70	88.04	87.69
HL-Stat. df=8	31.15	19.74	7.53	4.94	16.38	10.55
p-value	0.0001	0.0113	0.4803	0.7640	0.0372	0.2284

The Mc Fadden R^2 and the hit rate are acceptable for the amount of observations used in each model. Outliers were identified at each step and the model was reduced at a 5% significance level where most variables are significant at a 1% level. Not much difference between logit and probit can be identified and the logit models are used for the visualization of the results.

3.5. Step 4: Visualization of Results

This section will visualize the findings in graphical form through the creation of ship profiles and the grouping of the main deficiency codes into eight main deficiency groups shown in Table

[26] The Mc Fadden R2 is not provided by the model automatically and was therefore computed separately. For further details on this statistics, refer to Franses, P.H. and Paap, R. (2000). *Quantitative Models in Marketing Research.* Script from Erasmus University Rotterdam. Page 76

12. The grouping of the codes reflects the similarity of the deficiency codes by their nature (e.g. operational deficiencies, management related deficiencies, crew related deficiencies, etc.).

In visualizing the results, three approaches are used. First, each ship type is analyzed for each MoU. Second, the difference in the contribution towards the probability of detention is shown across the MoU's and finally, an overall view is presented based on average probabilities.

Table 12: Grouping of Deficiency Codes for Visualization

Deficiency Main Group	Description of Codes within the Main Group	
Management	ISM related deficiencies	Code_2500
	ISPS related deficiencies (not used)	Code_2700
Equipment/Machinery	Propulsion & Aux. Machinery	Code_1400
Working & Living Conditions	Accommodation	Code_0300
	Food & Catering	Code_0400
	Working spaces, accident prevention	Code_0500
	Accident prevention	Code_0800
	Mooring Arrangements	Code_1300
Safety & Fire Appliances	Life saving appliances	Code_0600
	Fire safety measures	Code_0700
	Alarm Signals	Code_1000
Stability/Structure	Stability/Structure/Equipment	Code_0900
	Load Lines	Code_1200
	Bulk Carriers, additional safety measures	Code_2600
Navigation & Communications	Safety of Navigation	Code_1500
	Radio communications	Code_1600
Certificates	Ship's certificates	Code_0100
	Crew certificates	Code_0200
Ship & Cargo Operations	Carriage of Cargo & Dang. Goods	Code_1100
	Marpol I: SOPEP, Oil Record Book	Code_1700
	Oil, Chemical Tankers and Gas Carriers	Code_1800
	Marpol II: P&A Manual, Cargo Record B.	Code_1900
	SOLAS related operational deficiencies	Code_2000
	Marpol related operational deficiencies	Code_2100
	Marpol III: Packaging, Documentation	Code_2200
	Marpol V: Garbage Management	Code_2300

3.6. Individual Results per Ship Type

In order to visualize the results of the regressions, ship profiles are created and the corresponding probability of detention is computed and shown in Figure 11 to Figure 16 for each ship type and MoU. Due to the amount of graphs, only one ship type per MoU is shown here.

The steeper the curve of the graph, the higher the contribution of the deficiency group towards the probability of detention. In essence, it reflects the ship profiles that trade in the area as well as the emphasis that was placed on certain deficiencies during an inspection. For the general cargo ship that can be seen in Figure 11 for the Indian Ocean MoU, 3 deficiencies in the area of certificates leads to a high probability of detention (0.9). The deficiency groups related to safety and fire and to certificates show the highest contribution towards detention followed by deficiencies related to navigation and communications, stability and structure and ship and cargo operations.

Figure 11: Probability of Detention - General Cargo

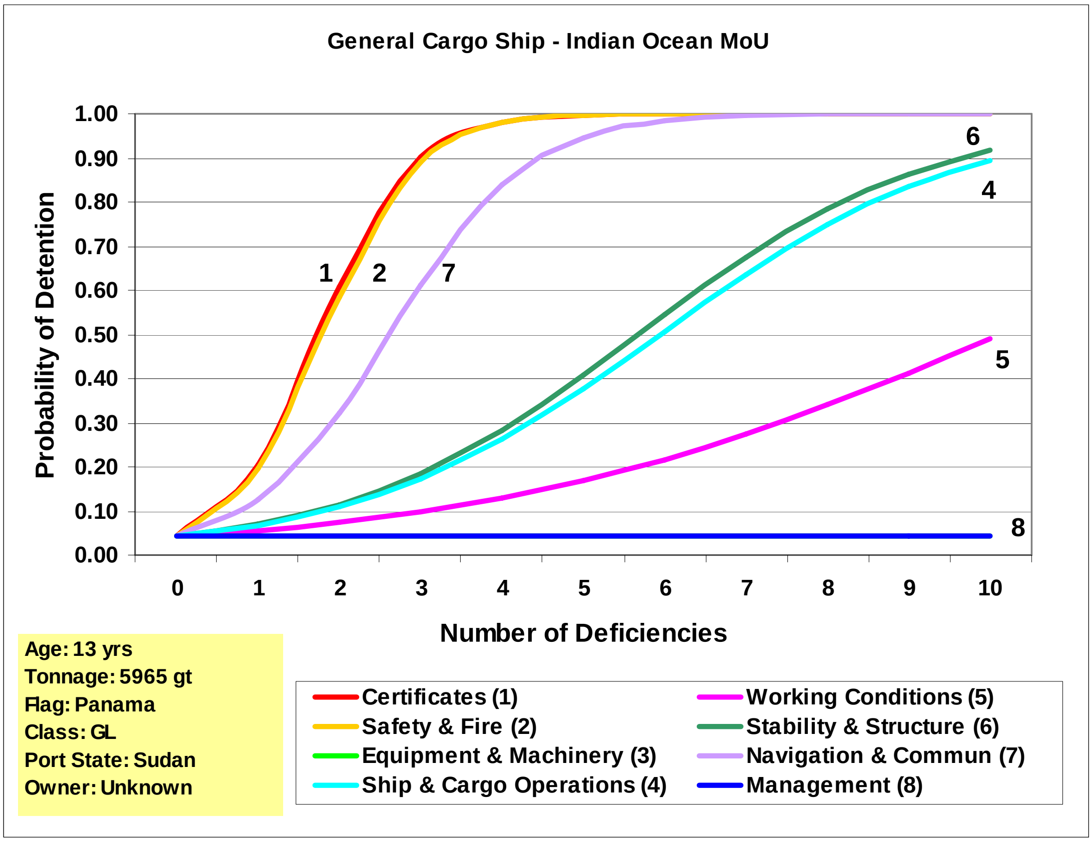
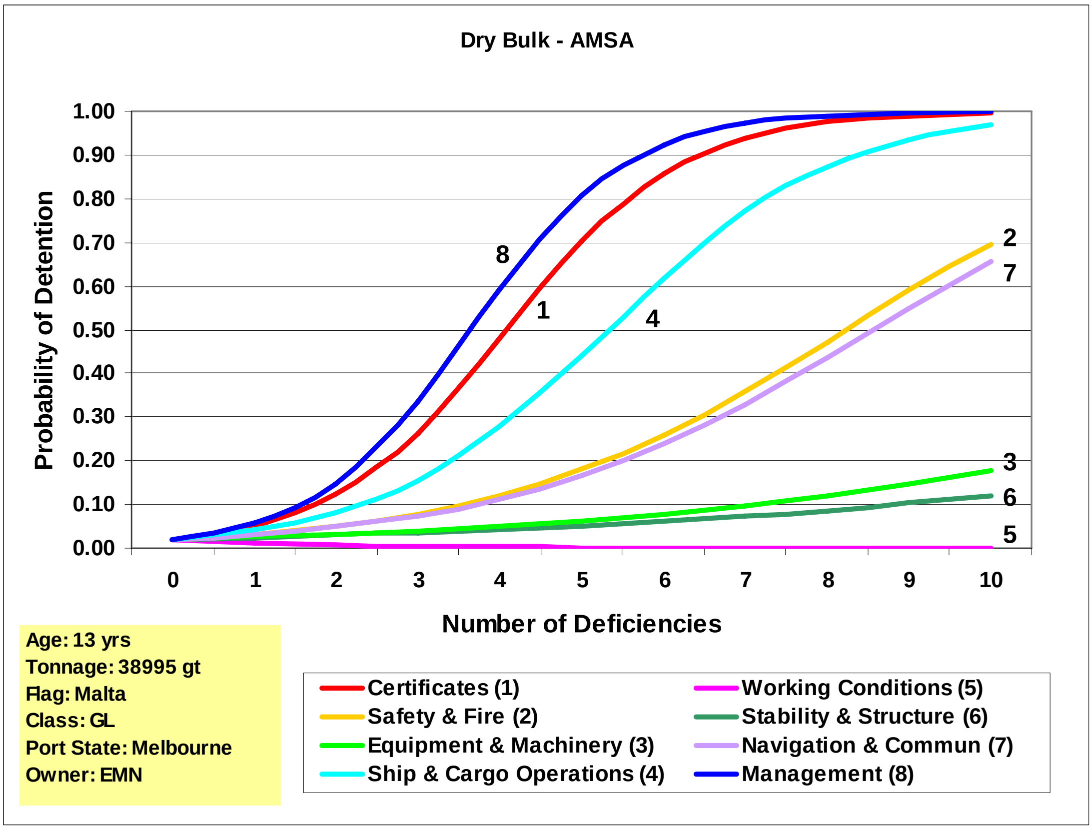


Figure 12: Probability of Detention – Dry Bulk

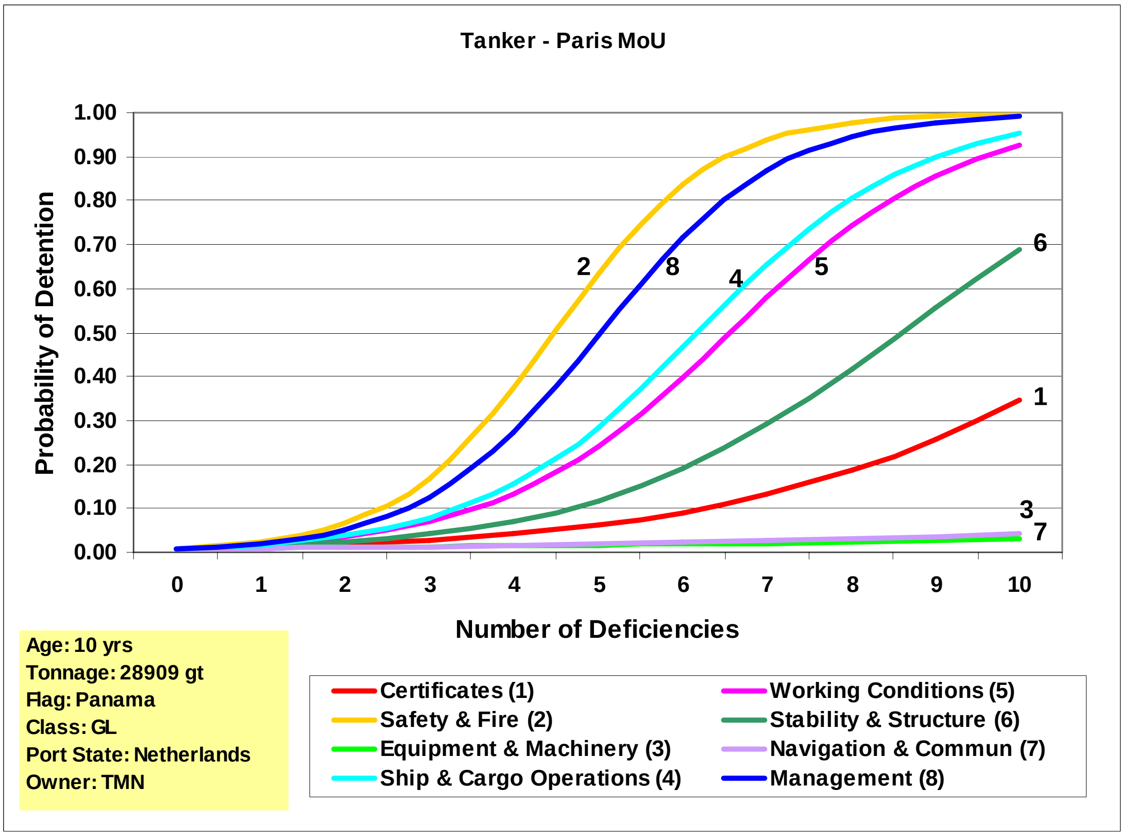


Overall, the graphs show the differences between the regimes and the ship types. For the dry bulk carrier in the next graph for AMSA, the highest contribution can be found with ISM related deficiencies (Management) followed by certificates and ship and cargo operations. ISM related deficiencies reflect how the safety management system is implemented onboard while the deficiency group ship and cargo operations reflect the actual execution of the management system. The same applied for one of the most important deficiency groups – safety and fire appliances.

Figure 13 shows the tanker for the Paris MoU region and Figure 14 shows the container vessel for the USCG. For the first graph, the most important deficiency group is safety and fire appliances followed by ISM related deficiencies (Management) and ship and cargo operations. The picture is similar to the AMSA picture for dry bulk carriers. Interesting to notice is that the group living and working conditions also show a higher contribution than with other ship types which is counter intuitive since tankers seem to have a better ship profile to start with than for instance general cargo ships or dry bulk carriers.

For the container vessel, the most important deficiency group is the certificates followed by the group safety and fire and then stability and structure. The last group is also interesting to see for this particular ship type and there is no real explanation on why this particular deficiency group would show a relative high contribution. Container ships are normally younger and better maintained vessels.

Figure 13: Probability of Detention – Tankers



The last two graphs show the results for the passenger vessel and other ship types. The models for those two groups were produced under a slightly different method due to the lack of observations and detention and are therefore not as accurate as the previous models.

Figure 14: Probability of Detention – Container

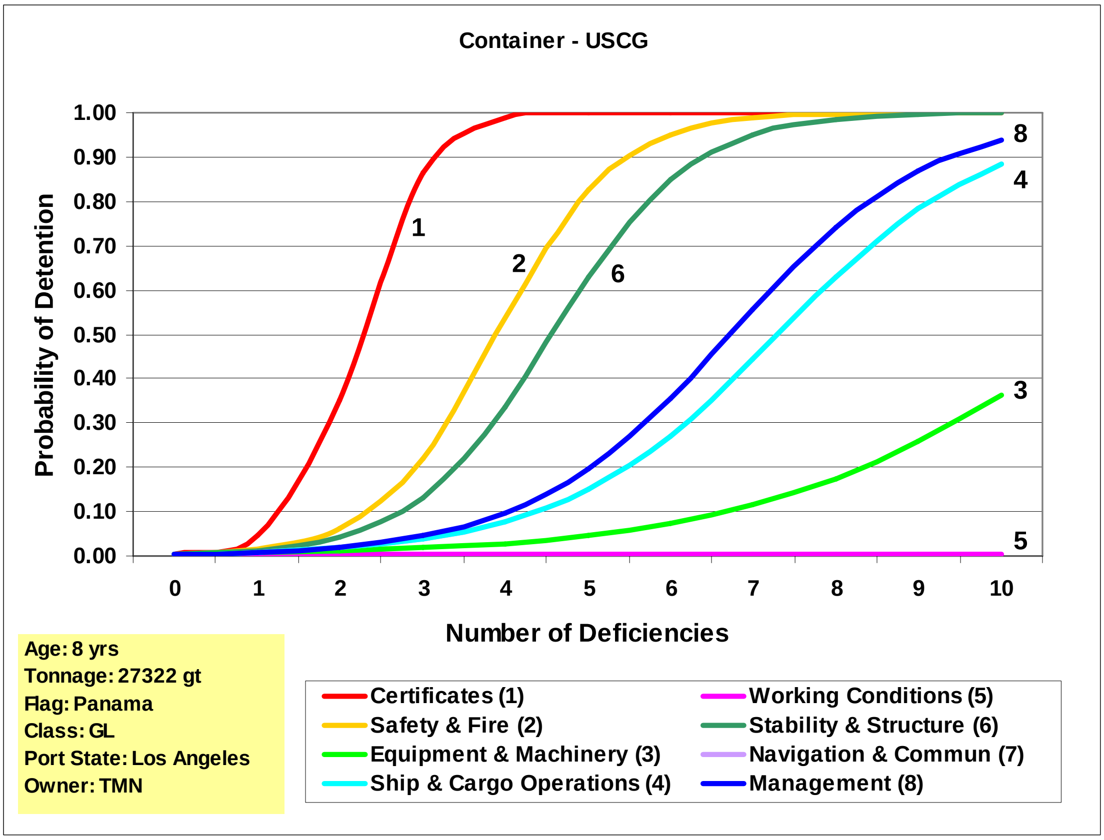
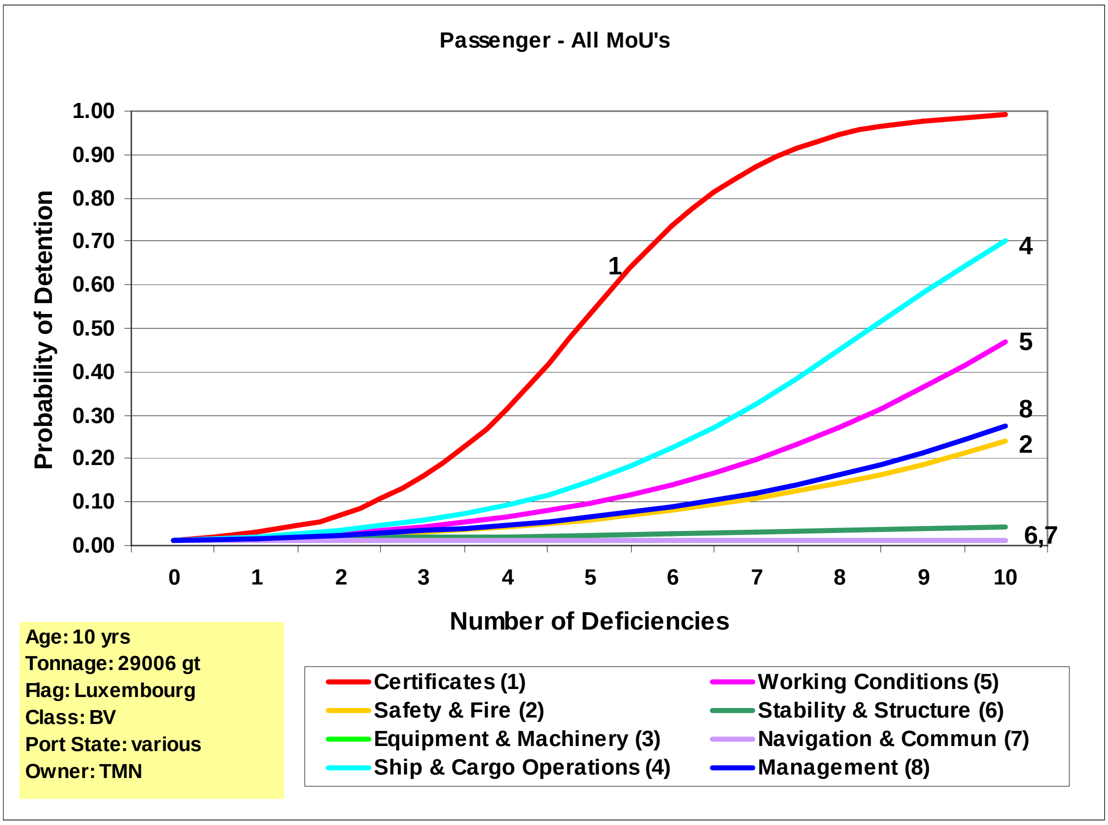
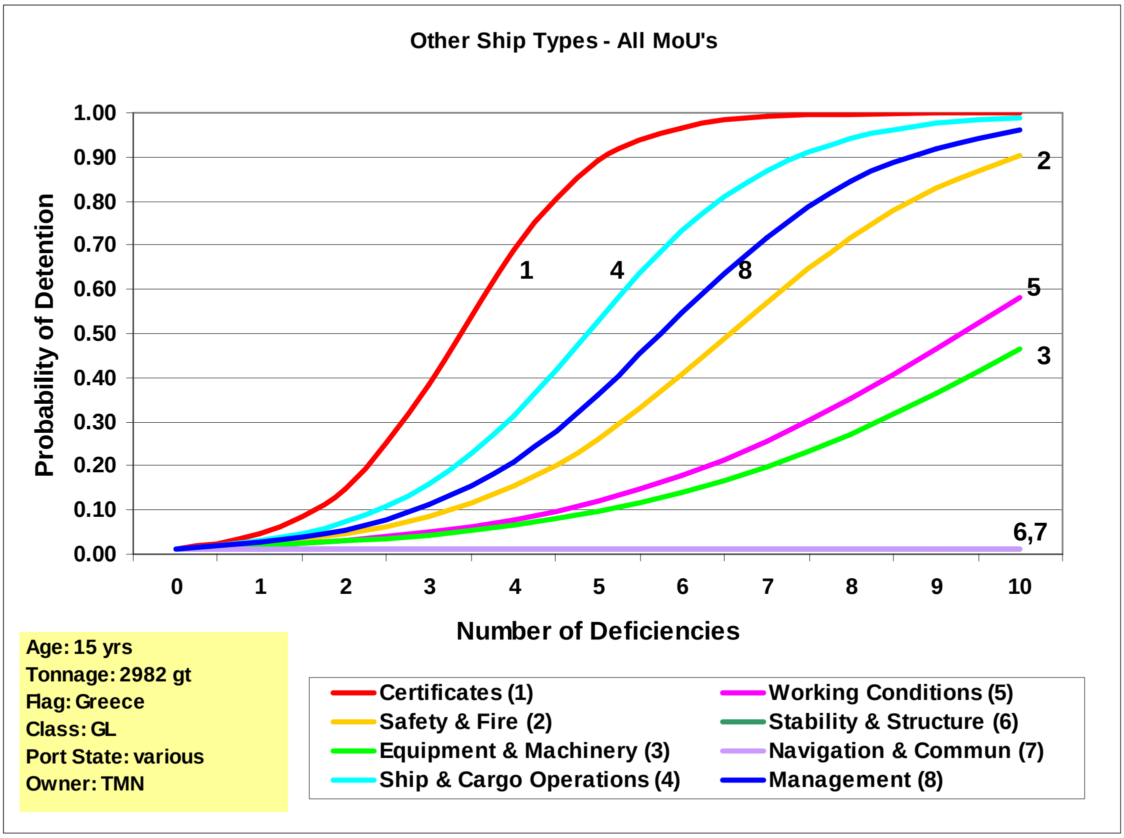


Figure 15: Probability of Detention – Passenger Vessels



Interesting to see is a relatively high contribution of work related deficiencies which might mean that these areas are inspected more with passenger vessels and a relatively low contribution of safety & fire appliances related deficiencies which might indicate that passenger vessels perform better in this area than other vessels due to the relative importance and stringent requirements thereof.

Figure 16: Probability of Detention – Other Ship Types



The results of the other ship types are similar to general cargo, dry bulk and tankers but also show a higher contribution towards detention with codes in the area of working and living conditions. This group of ship types consists primarily of offshore supply vessels and mobile offshore vessels, special purpose vessels and factory ships which might explain the higher contribution of working related deficiencies. The next section will show the results for the regression that was performed for the Caribbean MoU which had to be excluded from the rest of the regressions due to the insufficient amount of data per ship type.

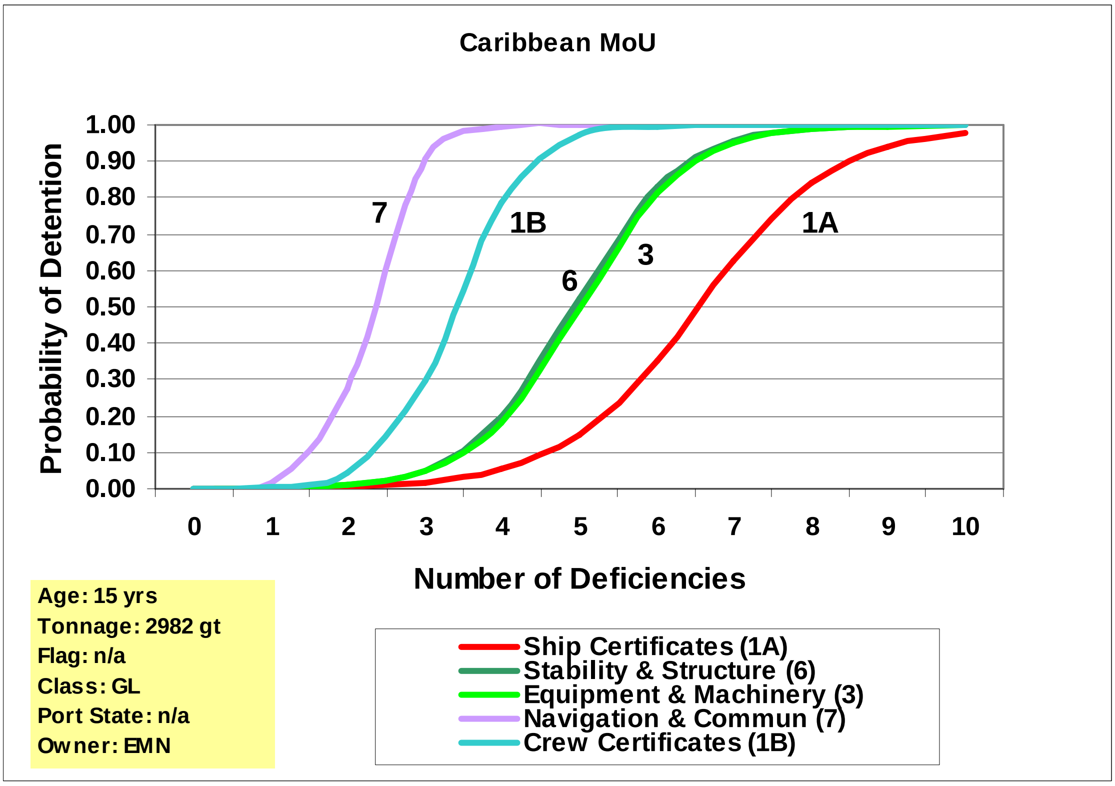
3.7. Results for the Caribbean MoU

Due to the lack of data, this section is difficult to analyze for the Caribbean MoU. Only one model for the whole dataset could be produced where few variables (deficiency codes) and one classification society remains significant. No difference can be seen based on flag, size or age or ship type. Owners from traditional maritime nations and emerging maritime nations seem to perform better than the other owner groups.

Interesting to see is the high contribution for the deficiency code 1500 (safety of navigation) followed by crew certificates (200) and the deficiency groups for stability and structure and equipment & machinery. Ship certificates (100) also show a relatively high contribution. The rest of the deficiency codes are not significant.

Since it is difficult to analyze each of the graphs individually and to compare the differences, the next section will produce a series of graphs that allows doing so and should visualize the differences of the contributions of the deficiencies across the regimes.

Figure 17: Probability of Detention – Caribbean MoU



Note: Deficiency Group "certificates" split into crew and ship certificates

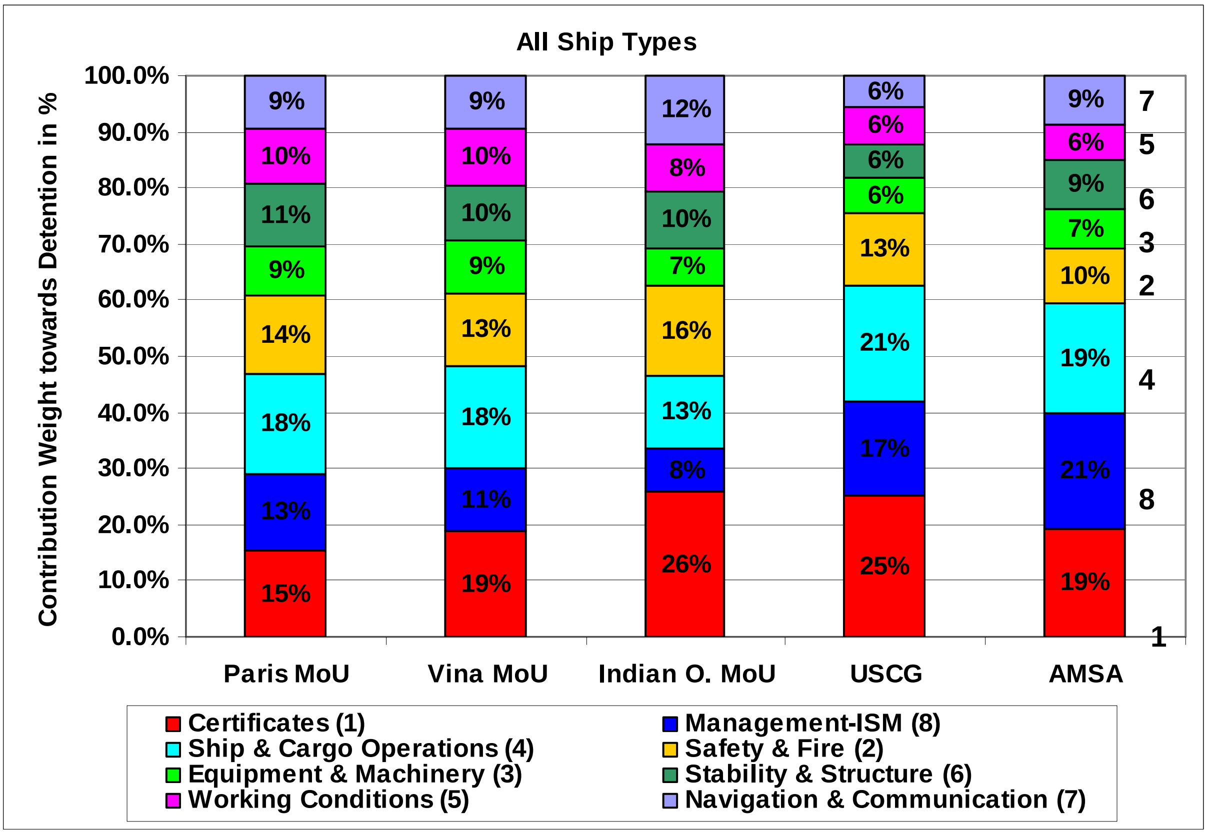
3.8. Differences in Deficiencies across the MoU's

Figure 18 provides an overall overview of the percentage contribution of the deficiency groupings towards the probability of detention per regime. The same basic ship profile was used for all regimes in order to calculate the probability of detention. The resulting factor is then converted into a percentage to the total weight of all deficiency codes towards the probability of detention.

The resulting percentages not only take into account the differences within each regime but also show the percentage weights of the deficiency groups across the regimes. The graph below can be read as follows. From the total contribution of the deficiency groups towards detention for the USCG, 25% of weight towards detention derives from deficiencies within the area of certificates, 17% within the area of the ISM code (Management), 21% from deficiencies within ship & cargo operations etc. The lower the percentage, the lower the overall weight of this deficiency group towards detention.

The graph should not be understood as a ranking of quality of the inspections but it should merely give an insight into the different emphasizes with respect to the deficiencies and reflects to a certain extent the average performance of all ships. Looking at the overall graph in total, one can see that there are some differences across the regimes but these are not extremely significant when aggregated by all ship types.

Figure 18: Contribution Weight towards Detention: All Ship Types



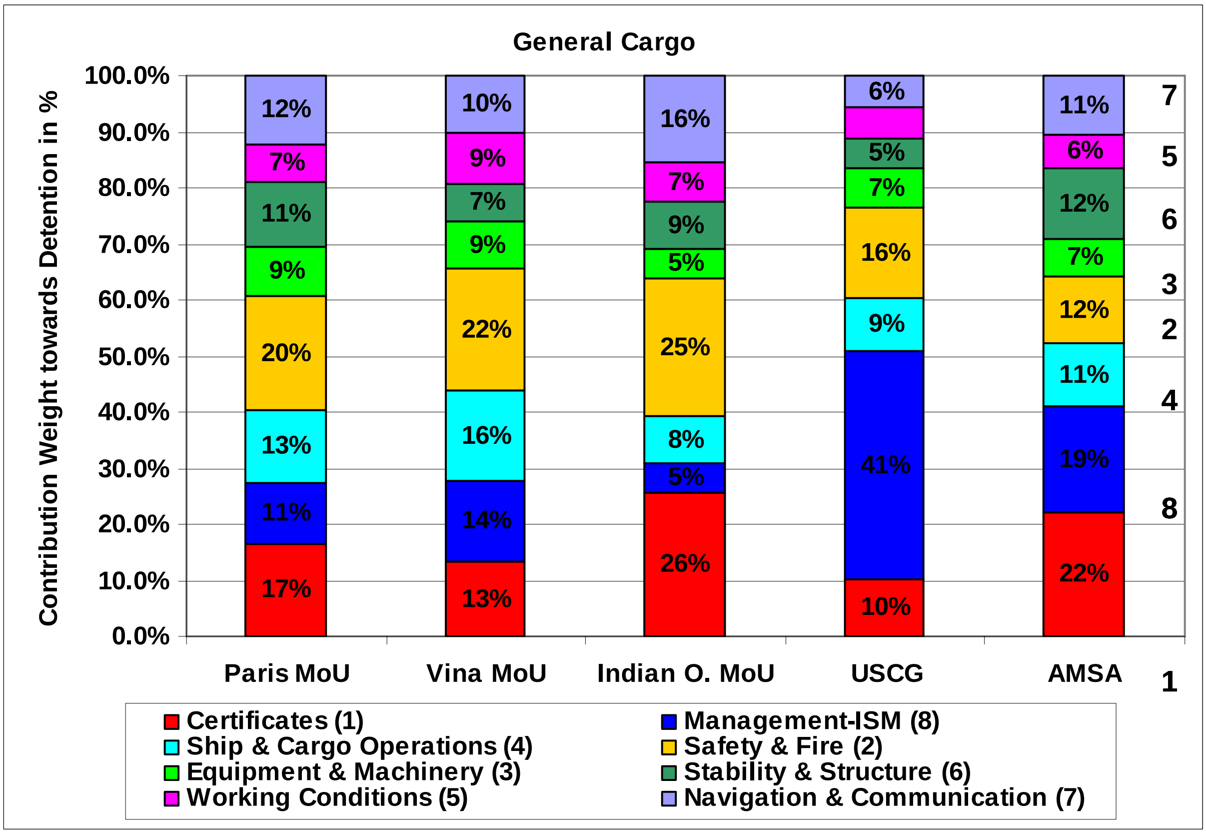
The actual differences can best be seen when looking at each ship type separately and is shown in Figure 19 to Figure 23. All graphs show a higher percentage for the deficiency groups' certificates, ship and cargo operations, the ISM code and safety & fire which is not surprisingly.

The weight of these groups changes with respect to the regimes which might reflect the different emphasis and the trade flows. *Certificates* are always inspected and are one of the underlying factors for constituting "clear grounds". *Safety and fire appliances* are always part of the round that is performed during an inspection where life boats and their equipment, launching equipment, lifejackets, immersion suits and fire fighting equipment and systems are checked. This group also contains the testing of the emergency fire pump which is not always performed but can be a detainable item if not working.

Ship and cargo operations are a combination of SOLAS and MARPOL operational related deficiencies where items such as the 15 ppm Alarm (oil water separator), the oil record book, SOPEP[27] and garbage management can be found as well as fire and abandon ship drills can be found. In addition, for tankers this group of deficiencies can be more important due to the more complex cargo operations on chemical tankers, gas carriers and oil tankers. This group of codes is expected to show higher percentages for the USCG since ships have to perform fire and safety drills during inspections. Failure to comply with the drills to the satisfaction of the inspector will show up under this code as well as under the ISM (Management) code.

[27] Ship Oil Pollution Emergency Plan

Figure 19: Contribution Weight towards Detention: General Cargo



Interesting to notice is the relative high contribution of *ISM (Management)* related deficiencies for some ship types and regimes. As mentioned previously, this group of codes represents the safety management system while the group of codes within ship and cargo operations and safety & fire appliances represents the actual implementation in daily shipboard operations. One regime might put more emphasis on the actual implementation while others will check both aspects. If many deficiencies are found which show a lack of maintenance and/or a lack of the implementation of operations onboard, it will also be reflected in this group of deficiencies. The difference in this group across the regimes also reflects the philosophy in inspecting and recording ISM related deficiencies.

The relative low weight percentage for the deficiencies within *stability & structure* is also not surprising since it includes such items as ballast water tank or cargo holds inspections which is difficult to be performed during normal cargo operations. Some regimes might have a different policy with reference to entering enclosed spaces during an inspection. This group of deficiencies only shows a higher contribution for dry bulk and container vessels.

The deficiency groups dealing with *working and living conditions* which is a group of codes related to the ILO varies across the ship types and regimes. The same applies for the group of codes for *navigation and communication*. For passenger vessels and tankers, the first group shows a higher contribution compared to container vessels and dry bulk vessels while for the second group, dry bulk and general cargo seems to perform worst with respect to navigational items. Also these two groups of codes vary the most across the regimes which indicates the different ship profiles as well as the different emphasis that is given during an inspection.

Figure 20: Contribution Weight towards Detention: Dry Bulk

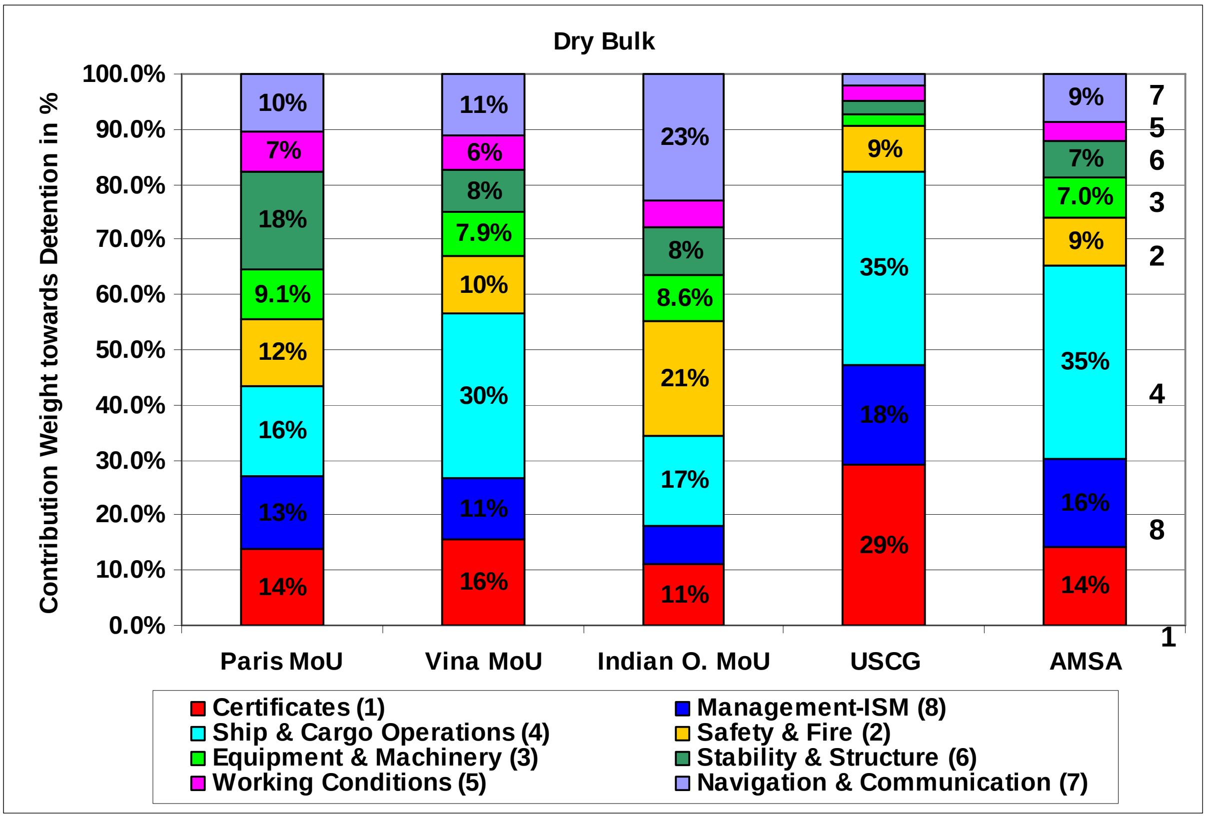
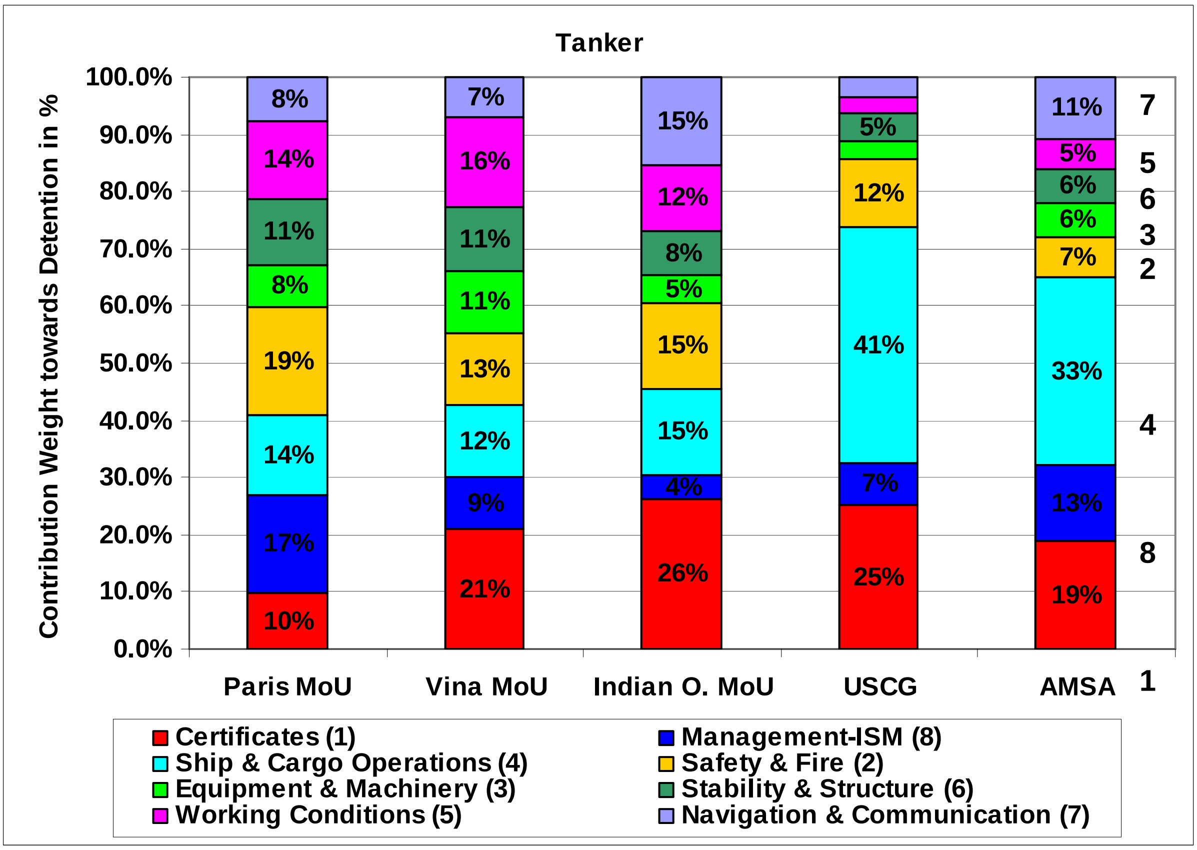


Figure 21: Contribution Weight towards Detention: Tanker



The lowest contribution for all ship types and regimes can be found for *equipment and machinery* which is also not surprisingly. The engine room and its machinery is normally part of an inspection round but is not core emphasis of a port state control inspection.

Figure 22: Contribution Weight towards Detention: Container

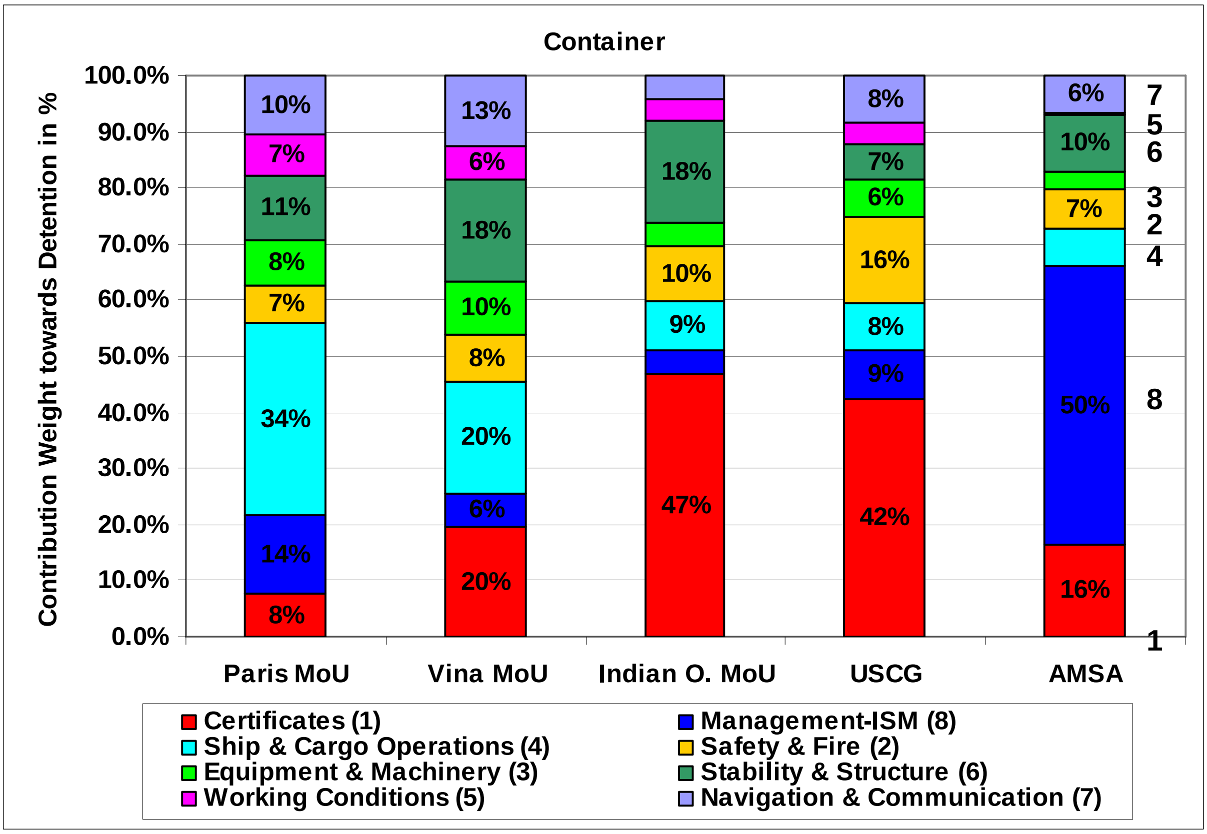
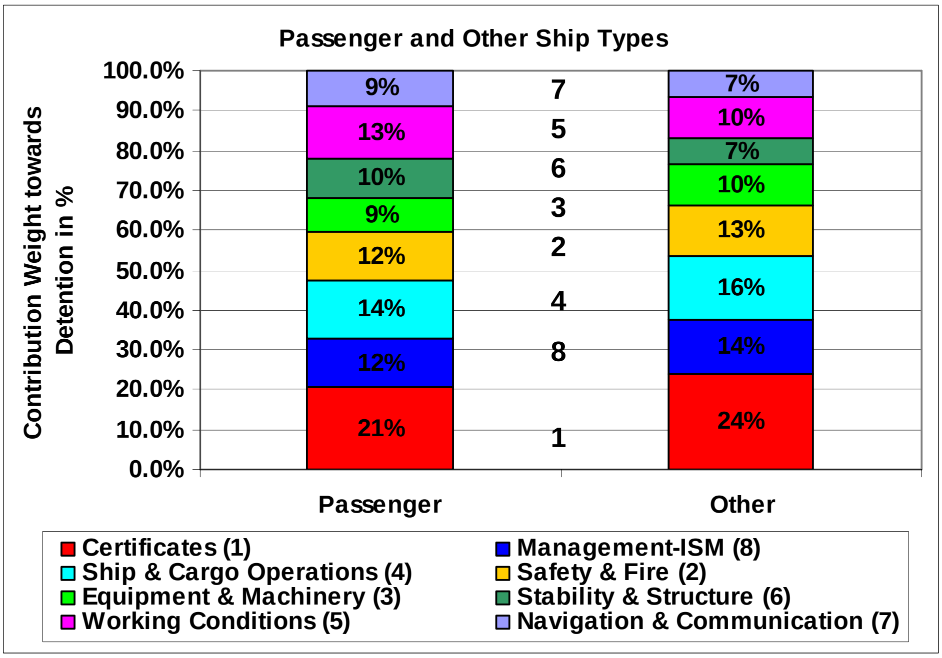


Figure 23: Contribution Weight towards Detention: Passenger and Other Ship Types

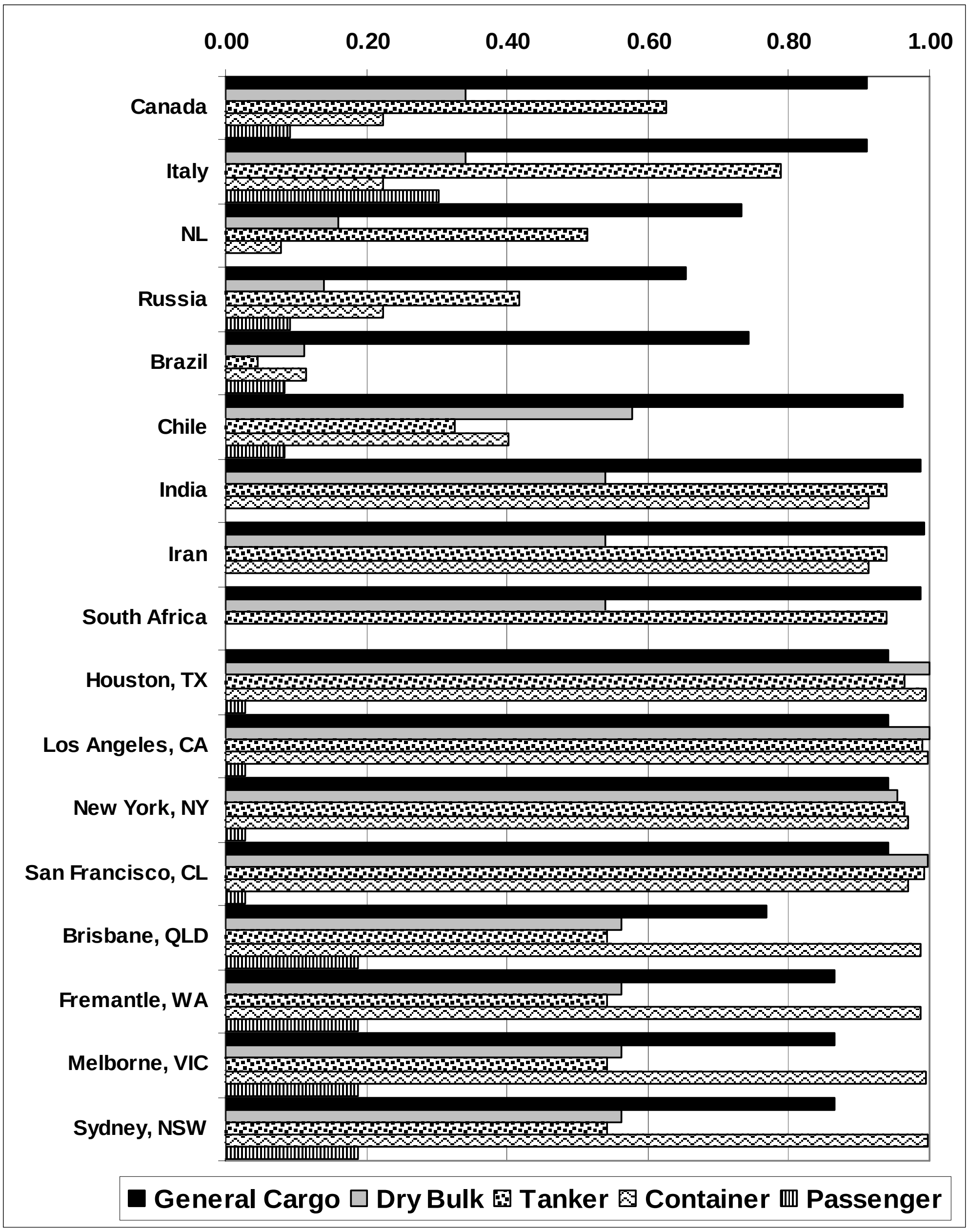


3.9. Differences in Port States

This section will look at the probability of detention showing the differences based on selected ports for several regimes for the five major ship types. Not all cargo types are handled in each port or port state. The same ship profile was used for all ship types with the exception of tonnage and is as follows where the result can be seen in Figure 24:

1. Age: 13 years
2. Gross Tonnage: from 5,900 gt (general cargo), 38,995 gt (dry bulk), 27,322 gt (container), 28,909 gt (tanker and passenger)
3. Class: Det Norske Veritas
4. Flag: Panama
5. Owner: Traditional Maritime Nation
6. Deficiencies: certificates (1), safety & fire appliances (3), ISM code (1), equipment & machinery (1)

Figure 24: Probability of Detention and Selected Port States



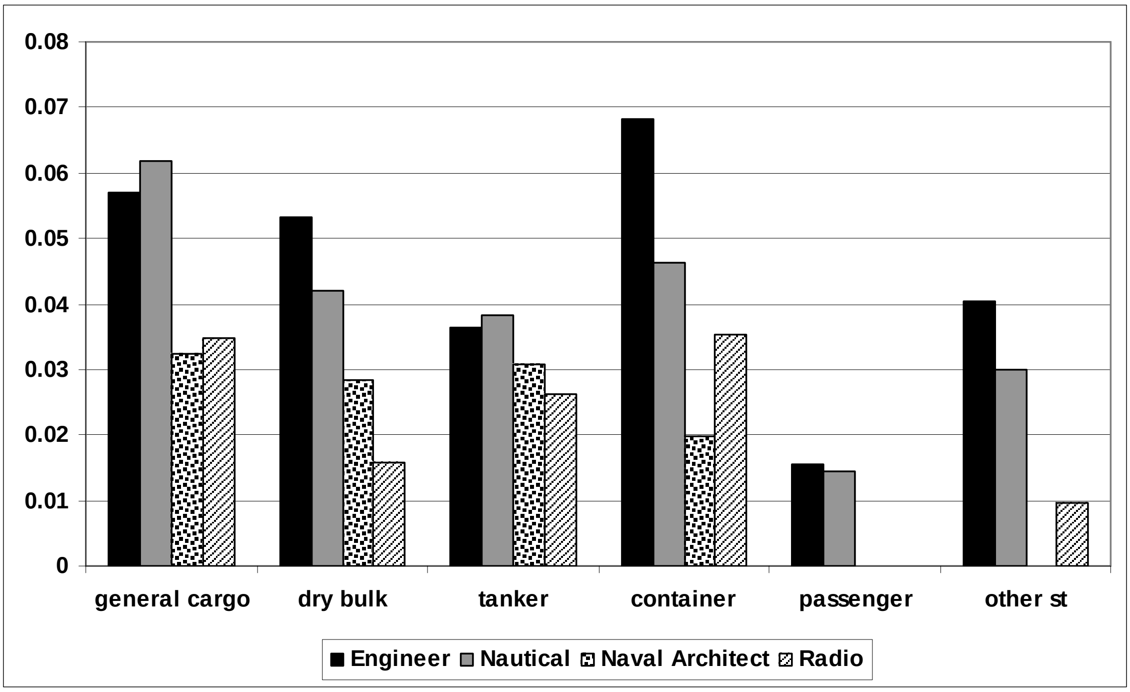
General cargo ships tend to have the highest probability of detention across all regimes with the exception of AMSA. The other ship types vary. The USCG shows higher probabilities for all ship types with the exception of the passenger vessel. The probability of detention does not vary much from port to port for both the USCG and AMSA while it can vary for the other regimes. This is understandable since it compares countries with a group of several countries. This shows that there is room for harmonization of inspections across the countries of the regimes as well as across the regimes.

It further shows that the worst performing ship type is the general cargo ship which is not surprisingly since it is also a ship type which is not inspected by any of the vetting inspection systems. The probability of detention of the ship type tanker varies the most across regimes followed by dry bulk carriers. Tankers are extensively inspected by the vetting inspection companies but depending on the deficiency found, might easily be detained due to the potential high risk impact, an oil tanker or chemical tanker could have if it is found to be sub-standard. The same should technically apply to passenger vessels but in this category, political considerations might also play a rule and ships are less likely to be detained.

3.10. Average Probabilities based on Inspector's Background

The next series of graphs gives an insight into the probability of detention given the port state control's inspector previous background. This information was only available for one of the regimes and is therefore only based on this particular regime. The requirements of becoming a port state control officer varies across the regimes but most regimes with the exception of the USCG require previous sea going experience or a background as a naval architect. Figure 25 shows the average probability of detention per ship type and the inspector's background while Figure 26 gives the breakdown per deficiency category. It is based on 16,773 inspections from the time period 1999 to 2004 where 682 records are unknown and therefore left out of the total data to be drawn from.

Figure 25: Average Probability of Detention per Inspector's Background

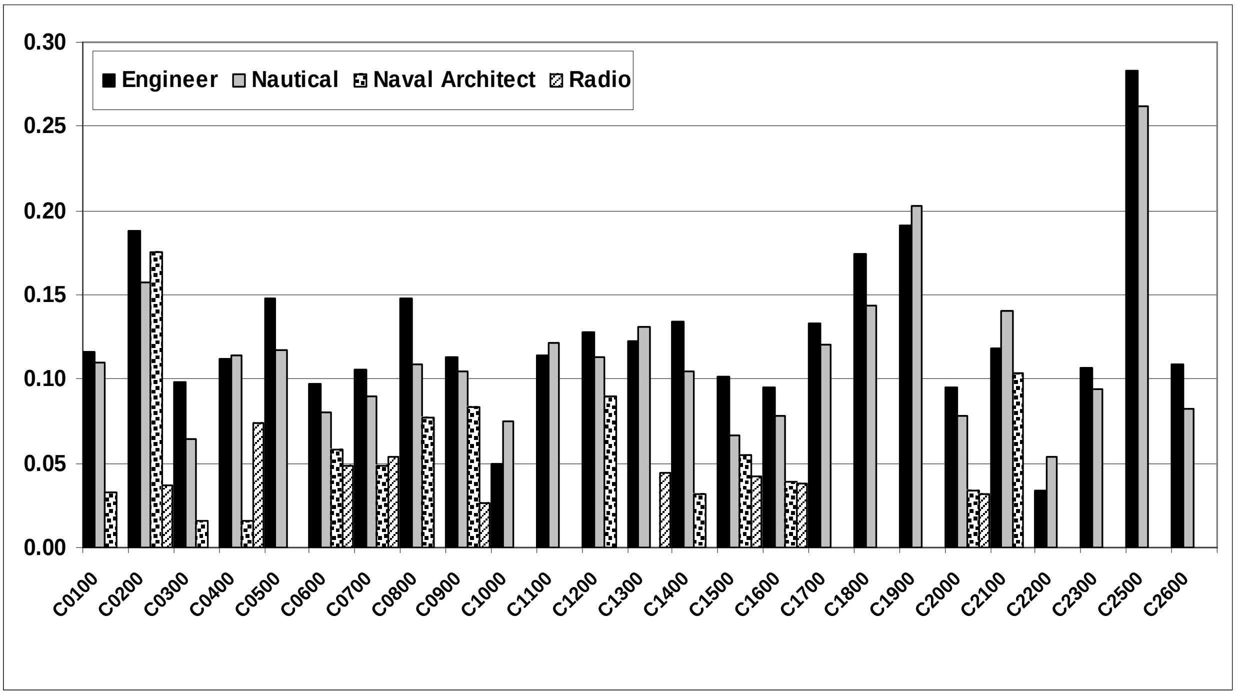


Note: based on averages of the estimated probabilities obtained from the models

The graphs show that the average probability of detention varies amongst the different backgrounds of the port state control officers with respect to ship types where the largest difference is around 5% on container vessels between inspectors with an engineering background versus a naval architect background. Looking at the deficiency codes itself, one can notice that most of the time the probability of detention of inspectors with an engineering background seems to be slightly higher compared to a nautical background. For the other two groups, the results are to be interpreted with caution since not much data is available for these two groups.

The two main groups are inspectors with either a nautical background or an engineering background. The difference between these two groups can be up to 4% for code 800 (Accident prevention) but most of the time lies between 1 to 3%. What is interesting to observe is that inspectors with engineering background do not necessarily show a lower probability in deck related deficiencies such as code 1500 (safety of navigation) or 1600 (radio communications) while it does show a difference in code 1400 (propulsion and aux. machinery) in comparison to inspectors with a nautical background.

Figure 26: Average Probability of Detention per Inspector's Background



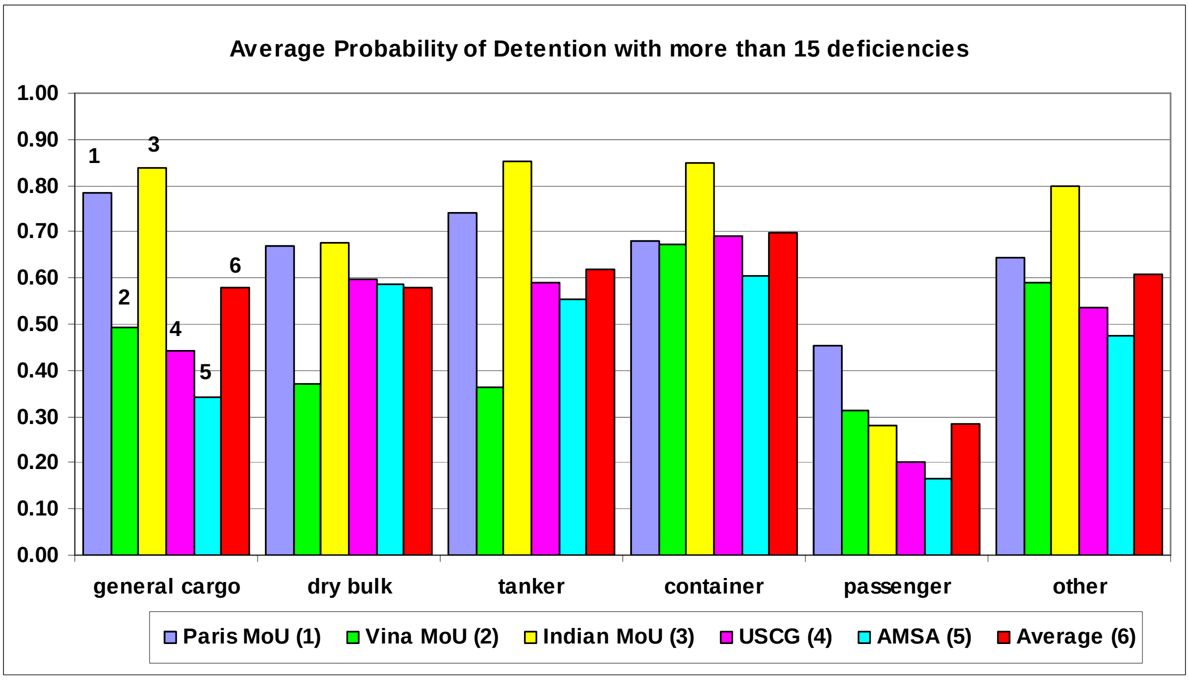
Note: based on averages of the estimated probabilities obtained from the models

This analysis can conclude that there are differences which are expected to exist but that this type of analysis would require further insight and better underlying data collection for the other two groups (naval architect and radio) in order to make a final conclusion on the subject in question. It is a first insight into trying to explain the differences in the probability of detention and the use of the deficiency codes towards it.

3.11. Overall View Based on Average Probabilities

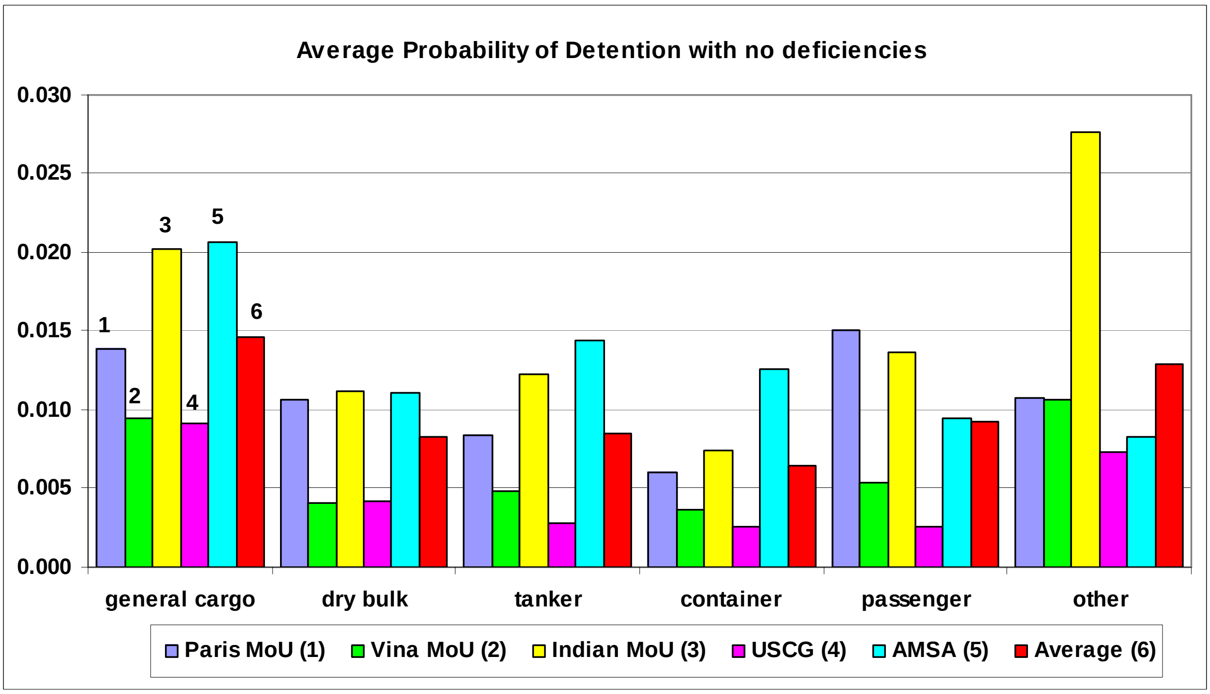
The final section will provide an overall view of the probability of detention based on all ships in the total inspection dataset with more than 15 deficiencies and with no deficiencies and their estimated average probabilities. The results are based on 5,212 ships and 98,953 ships respectively and are shown in Figure 27 and Figure 28.

Figure 27: Probability of Detention per Ship Type (> 15 deficiencies, 5,212 ships)



Note: based on averages of the estimated probabilities obtained from the models

Figure 28: Probability of Detention per Ship Type (No deficiencies, 98,953 ships)



Note: based on averages of the estimated probabilities obtained from the models

The difference across the regimes is primarily based on the contribution of the deficiency codes and the port states. While some differences can be found in flag and class, age and vessel size are not the major factors contributing the difference. The graphs should not be used as a measurement of the quality of the inspections. It shows the differences with respect to detention in mainly the deficiency codes as well as the port states. The results for passenger vessels and other ship types are a less accurate measurement due to the fact that only one model per ship types could be formed and not for each MoU. It therefore cannot distinguish the differences based on class, flag, age, size and deficiencies across the MoU's but only gives an overview of the differences based on the port states and a variable indicating the regime (e.g. passenger vessel coming into MoU 1).

The basic probability based on zero deficiencies can be understood as the portion of the probability based on the ship profile and lies between 0.5% and 1.5% for most ship types and regimes. Only other ship types for the Indian Ocean MoU shows a higher percentage. The picture then changes when looking at ships with more than 15 deficiencies where the average probability increases accordingly due to the factor associated with the deficiencies.

4. Conclusions on PSC

About half of the world fleet (47%) is subject to port state control. Out of these 47%, most ships inspected are general cargo ships (36%) followed by dry bulk (26%), tankers (19%), containers (10%) and passenger vessels and other ship types. Out of the total inspections, 54% are inspections without deficiencies and 5% end up in a detention while aggregated by ship, the 53.8% decreases to 16.3% and detention increases from 5.44% to 24.6% of all inspected vessels for the time frame 1999 to 2004. 66% of the ships detained (1999 to 2004) have been detained once and 6% have been detained four or more times. The average amount of inspection frequency lies by 7 over the time period 1999 to 2004. This amount might be higher in reality since data from some regimes could not be obtained and not the whole time frame can be covered by all regimes who did supply data. Around 68% of the ships with deficiencies have 1 to 5 deficiencies and 6% show more than 15 deficiencies.

The basic ship profiles given by age, size, flag, class and ownership do not vary significantly across the regimes with respect to the probability of detention. Most differences across the regimes can be found within the use of deficiencies towards detention and the port states. When aggregated by ship types, the differences average out but looking at the ship types individually, one can see that certain codes show higher contributions compared to each other within each of the regimes. The basic ship risk profile for all regimes is between probabilities of detention of 0.5% to 1.5%.

Highest contribution can be found for the deficiency groups' certificates, ship and cargo operations, the ISM code and safety & fire appliances while lowest contribution is found for machinery and equipment. Ship and cargo operations seem to be more important for tankers while stability and structure are highest for dry bulk carriers and containers.

Interesting to notice is the relative high contribution of ISM (Management) related deficiencies for some ship types and regimes. This group of codes represents the safety management system while the group of codes within ship and cargo operations and safety & fire appliances represents the actual implementation in daily shipboard operations. One regime might put more emphasis on the actual implementation while others will check both aspects. The deficiency groups working conditions and navigation and communication show the highest variation across the regimes.

The difference between the probabilities of detention given a certain background of an inspector is reflected for certain deficiency codes but not necessarily as one would expect intuitively. For inspectors with nautical background versus engineer background, the differences in the probability of detention can be up to 4% for code 800 (Accident prevention) but most of the time lies between 1 to 3%. What is interesting to observe is that inspectors with engineering background do not necessarily show a lower probability in deck related deficiencies such as code 1500 (safety of navigation) or 1600 (radio communications) while it does show a difference in code 1400 (propulsion and aux. machinery) in comparison to inspectors with a nautical background.

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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