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On the effectiveness of port state control inspections

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Abstract

This paper uses 4080 observations from the Swedish Maritime Administration (1996–2001) to test how vessel's characteristics influence the length of time between two port state control inspections (PSC) along with the number of deficiencies detected during PSC. It also investigates whether a ship that has undergone PSC inspection at a certain time exhibits a reduction in the total number of deficiencies detected during the next control. Estimates from Poisson models stress that the age of the vessel, ship type, and flag of registry appear to be significant predictors. Subsequently, the analysis on 874 repeated inspections shows that following a PSC inspection, the reported deficiencies during next inspection is reduced by 63%.

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1. Introduction

The present regime of port state control (PSC) traces its origins from a memorandum of understanding signed in The Hague between eight North Sea states in 1978 that "laid down a general surveillance procedure aimed at verifying that a number of requirements derived from various international agreements were met and that conditions on board ships were not hazardous to safety or health" (Kasoulides, 1993, p. 142). Serious maritime accidents, particularly the *Amoco Cadiz* oil spill, led to a new memorandum of understanding signed in 1982 in Paris that expanded not only the scope of the agreement, but the membership as well (Özcayir, 2001, pp. 115–116).

Seven of the most important conventions in the international regulatory framework for maritime safety serve as the bases upon which the regime of PSC has been institutionalized. These are the International

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Convention for the Safety of Life at Sea (SOLAS), International Convention for the Prevention of Pollution from Ships (MARPOL), International Convention on Load Lines (LOADLINES), International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), Convention on the International Regulations for Preventing Collisions at Sea (COLREG), International Convention on Tonnage Measurement of Ships (TONNAGE), Merchant Shipping (Minimum Standards) Convention (ILO 147). This was in reaction to the generally-held belief that many flag states are unable to adequately perform their mandated duties of ensuring that ships flying their flag comply fully with international safety standards formulated under the auspices of the International Maritime Organization (IMO) and the International Labour Organization (ILO). As such, PSC is merely a complement, not a substitute, to effective maritime safety administration by the flag state. While it was originally intended as an interim measure, trends and developments in international enforcement indicate that PSC is here to stay.

Every PSC inspection generates an inspection report that, *inter alia*, contains detailed information on the deficiencies noted (including 0 for no deficiency) together with relevant vessel particulars such as the flag of registry, IMO vessel number, vessel type, year built, and date of inspection. In this study, we assume one of the effects of PSC inspections as improving performance at subsequent inspections, manifested by a decrease in terms of the number of deficiencies noted. Conversely, we assume that vessels exhibiting an increase in the number of deficiencies noted at subsequent inspections are indicative of lack of significant effect of the PSC regime.

This study uses data related to PSC inspections carried out on foreign vessels that called at Swedish ports during the years 1996–2001. Swedish PSC statistics were selected because of the comprehensiveness of the data available from the Swedish Maritime Administration (SMA hereafter) that comprises more than 9002 inspection reports with the possibility of building a sample of 874 observations where a corresponding comparison of two successive inspections is made possible. Effectiveness is defined in this paper as the likelihood for PSC inspections to register a lower number of deficiencies in "t" compared to "$t-1$".

The remainder of the paper is organized as follows. In the next section, we briefly review the literature on the effectiveness of PSC. We then describe the data in Section 3 and we investigate in Section 4 the relationships between the length of time between two inspections, the number of deficiencies and the profile of the vessels inspected. In Section 5, we apply a dynamic approach and consider only vessels with repeated inspections to test for the effectiveness of PSC. Finally, Section 6 presents a number of conclusions.

2. Literature review

While literature is available on the reasons why PSC inspections should be implemented and how they should be implemented, there is a lack of conclusive statistical analysis on the effectiveness of such inspections.

For instance, Kasoulides (1993) stresses how flag state enforcement has diminished in the face of the proliferation of open registries and why coastal States have reacted by asserting their rights through the resultant regime of port state control at the regional level. Özçayir (2001) reviews relevant issues such as the pivotal role of the ISM Code, the function of classification societies, and the implications of the *Erika* incident in shaping practices in European PSC today, along with the practice of PSC in different regions or jurisdictions. Clarke (1994) discusses how the ineffectiveness of flag states has given port states no other choice than to "take active steps to help themselves." Kiehne (1996) focuses on the sanctions available to PSC authorities in respect of the foreign ships being inspected, ranging from instructions to rectify deficiencies (i.e., with immediate effect before departure, within two weeks, or at the next port of call) to outright detention. Cuttler (1995) examines PSC in the context of ship-sourced pollution prevention and calls upon states to focus greater attention on the potential benefits of developing a pro-active framework such as PSC "to prevent accidents and pollution before they happen" (Cuttler, 1995, p. 199).

Hare (1997) offers one of the first contributions on the effectiveness of PSC in showing how the proliferation of regional MoUs has significantly diminished the potentials for substandard ships to participate in international commerce. McDorman (2000) examines also how regional PSC agreements and harmonized inspection procedures have contributed towards levelling the playing field among different ports. Owen (1996) gives a detailed description of the practice of PSC in the Paris MoU and discusses the limitations inherent in the

PSC regime connected with the fact that the port state has no direct influence over the design and construction of ships that are being inspected.

Drawing on the implementation of PSC in the UK, Odeke (1997) states that PSC enhances maritime safety and pollution prevention and slowly eliminates the unfair advantage associated with operating cheaper, substandard ships. Bell (1993) further presents the UK government's views on the relationship between flag state implementation and PSC. The UK shares the internationally held view that the flag state still bears the heaviest burden and has the greatest potential for compelling a ship to meet international standards. Payoyo (1994) conducts an assessment of the PSC regime by analyzing annual statistics generated by the Paris MoU from 1982 to 1992. One interesting conclusion by the author of this study is that PSC has been a conditional success. On the one hand, Payoyo claims that substandard shipping continues to thrive in spite of the inspection regime. On the other hand, he also points to significant accomplishments such as the collection of baseline data on substandard ships in the region, increased effectiveness in the enforcement of international standards, and closer regional cooperation resulting in the more efficient employment of maritime safety enforcement resources. This observation jibes with a study by Mejia (2005) on the effects of the ISM Code within the context of PSC. While Mejia hints at the Code's positive potential, he also underscores the lack of conclusive statistical evidence to establish a direct link.

It is in this vein that the present study assesses the effectiveness of PSC as an instrument for promoting maritime safety. This is undertaken using data from the SMA and testing whether a ship that has undergone port state control inspection at a certain date or year exhibits a reduction in the number of deficiencies noted at its next inspection.

3. Descriptive statistics of the sample

The analysis is conducted using original data consisting of results from PSC inspections carried out by the Swedish Maritime Administration (SMA) from January 1, 1996 to December 31, 2001. Every PSC boarding generates a detailed inspection report containing the following information on foreign vessels calling ports in Sweden: ship's name, flag of registry, date of registry, call sign, International Maritime Organization (IMO) vessel number, vessel type, gross tonnage, year built, date of inspection, place of inspection, nature of deficiencies and action taken by the inspecting authority.

The SMA data consists of a total of 9002 inspection postings, corresponding to specific deficiency notations (including the 0 value for no deficiency). Out of 9002 inspections, 25.5% result in no deficiencies being reported. The three most frequent deficiencies reported are related to fire prevention (3.24% of all sample), ventilation, fire-dampers, valves, quick closing devices, means of control (2.88%) and oil record book (2.37%). The data indicates that deficiencies were rectified within 14 days in 33% of the cases, before departure from the port in 13.47% of the cases, and immediately in 12.73% of the cases. Overall, only 2.33% of inspections result in detention.

We decide to define in this paper the effectiveness of PSC as the likelihood for PSC inspections to register a lower number of deficiencies in "t" compared to "$t-1$", regardless of the nature of deficiencies. Rearranging the original sample where each deficiency is counted as one observation, we define as a nonnegative integer count data the number of deficiencies observed (DEF) for a particular vessel during one inspection, whatever the nature of deficiencies may be (ranging from 0 to n deficiencies). The sample then comprises 4080 cases, owing to the fact that a given vessel may have been inspected several times during the period in our sample. The number of vessels in the sample is equal to 2131.

Rearranging this latest sample, we also track vessels over time in order to select the number of deficiencies observed during an inspection for a vessel in t (DEF_t) in comparison to the number that was detected in $t-1$ (DEF_{t-1}). A vessel appears therefore in the final sample only if it has been inspected at least n times over the whole period (from 1996 till 2001), with $n > 1$, owing that a vessel inspected n times, will generate $(n-1)$ observations. This final sample comprises 2788 observations (4080 − 1292, see the paragraph below) corresponding to 839 vessels (2131 − 1292).

Table 1 presents descriptive statistics on the 4080 inspections. Amongst them, 1292 inspections (32%) will not be part of our sample retained for the dynamic analysis as only one inspection has been carried out during the study period. These represent 60% of the vessels. For 1.3% of the cases (54 times over 4080 observations),

Table 1
Description of the number of inspections

Number of inspections	Number of observations		Number of vessels	
	N	%	*N*	%
1	1292	31.7	1292	60.6
2	820	20.1	410	19.2
3	507	12.4	169	7.9
4	368	9.0	92	4.3
5	325	8.0	65	3.1
6	216	5.3	36	1.7
7	189	4.6	27	1.3
8	168	4.1	21	1.0
9	81	2.0	9	0.4
10	60	1.5	6	0.3
More than 10	54	1.3	4	0.2
All	4080	100.0	2131	100.0

Source: Swedish Maritime Administration (SMA) 1996–2001.

the number of inspections on the same vessel has been more than 10. It concerns only 0.2% of vessels (4 over 2131 vessels).

We first investigate the pattern of the number of inspections along with the number of deficiencies. We used as explanatory variables the age of vessel when the inspection took place, the type of vessel (10 categories), the flag of registry (11 categories) and the year of inspection (from 1996 to 2001). We also built a dummy variable ISM98 (either Yes or No) to detect a potential effect of the implementation of the International Safety Management (ISM) Code. "Yes" corresponds to vessels required to comply with the ISM Code by July 1998, compared to those that do not have to comply until July 2002 ("No"). The former are passenger ships of all tonnage including passenger high-speed craft, oil tankers, chemical tankers, gas carriers, bulk carriers, and cargo high-speed craft of 500 gross tonnage and upward. ISM Phase 1 or 2 status was considered following a study conducted by Hernqvist (2000) for the Swedish (Protection & Indemnity) Club stressing that "vigorous application of the ISM Code can significantly reduce claims exposures" and thus lead to a decrease in the number of deficiencies.

The descriptive statistics provided in Table 2 makes it possible to distinguish between single and multiple inspections. Overall, the average number of deficiencies detected is 1.64, while it appears that the mean is 1.83 when only one inspection occurred and 1.56 when more than one inspection occurred. It may suggest that a direct relationship between the number of deficiencies detected for a vessel and the number of inspections undergone does exist. This issue will be discussed in detail in later sections.

The profile of vessels subjected to inspections shows that the mean age of vessels at inspection is about 16.8 years and that 27% of inspections concern vessels less than 10 years old, around 40% more than 20 years old and 9.3% more than 30 years old. Furthermore, Table 2 shows that the majority of repeated PSC inspections were conducted on non-ISM vessels (62%). The bulk of inspections involved general cargo vessels (48%) and bulk carriers (21%) with an emphasis on the former. Among vessels that underwent more than one inspection, general cargo vessels account for 51%.

Passenger and ro-ro passenger ships are more often subject to repeated inspections (13.4% of the sample against 2.2% only for single inspection). Similar comments exist for vessels under Russian registry (13.4% of inspections and 14.3% for more than one inspection), Norwegian registry (13.4% of inspections and 14.3% for more than one inspection), Danish registry (7.5% of inspections and 8.3% for more than one inspection), and German registry (7.4% of inspections and 8.8% for more than one inspection).

4. Evidence on inspections and deficiencies

We first investigate the pattern of inspections by testing for the relationship between the number of inspections and the vessel's profile. Specifically, we wonder whether age, type or flag of registry influence the

Table 2
Descriptive statistics of the sample

Variables	Only 1 inspection	More than 1 inspection	All
Number of deficiencies noted at PSC			
Mean	1.83	1.56	1.64
Standard deviation	4.22	3.18	3.54
Vessel age at time of PSC (%)			
[0; 5[	15.9	11.7	13.0
[5; 10[	14.5	14.1	14.2
[10; 15[	15.7	14.7	15.0
[15; 20[	20.0	16.4	17.6
[20; 25[	16.9	17.2	17.1
[25; 30[	8.6	16.2	13.8
[30; ∞[	8.4	9.6	9.3
Compliance with ISM Code in 1998 (%)			
Yes	44.6	37.5	39.8
No	55.4	62.5	60.2
Type of ship (%)			
General cargo	40.7	51.4	48.0
Bulk carrier	28.9	18.0	21.4
Passenger	1.6	8.0	6.0
Ro-ro passenger	0.6	5.4	3.9
Chemical tankers	4.9	3.2	3.7
Ro-ro cargo	2.8	4.1	3.7
Oil tanker	6.1	2.0	3.3
Refrigerated cargo carrier	3.6	1.6	2.2
Container	1.7	1.9	1.9
Others	9.0	4.5	5.9
Flag of registry (%)			
Antigua and Barbuda	5.5	7.4	6.8
Bahamas	5.6	6.7	6.4
Cyprus	5.6	3.6	4.2
Denmark	5.9	8.3	7.5
Finland	1.6	5.4	4.2
Germany	4.4	8.8	7.4
Malta	5.6	3.4	4.1
Netherlands	7.4	8.8	8.3
Norway	8.6	9.8	9.4
Russia	11.6	14.3	13.4
Others	38.3	23.4	28.1
Number of observations	1292	2788	4080

Source: Swedish Maritime Administration (SMA) 1996–2001.

frequency of PSC inspections. A first possibility to study this relationship would be to work at the vessel level (with the sample of 2131 ships) and to estimate a linear regression of the number of inspections for a vessel as a function of observable characteristics. However, a problem with this methodology is that only the type and flag of registry can be controlled for in the regression, since age at inspection is by definition a time-varying variable.

Instead, we choose to focus on determining the length of time between two inspections. The selection of the sample is as follows. First, we select the 2788 observations (4080 − 1292) related to repeated inspections, corresponding to 839 vessels. Second, since we are interested in the length of time between two inspections, we exclude the first inspection for each vessel (this is the starting date), so that the size of the sample reduces to 1949 observations (2788 − 839). The dependent variable is simply the duration between two successive inspections, expressed in years, and we estimate a Cox proportional hazards model. Since the sample includes multiple observations for some vessels, we turn to a clustering method to compute the standard errors.[3]

Proportional hazard estimates (column 1 in Table 3) stress that the length of time between two inspections does not really depend on the vessel age when the inspection took place. The length of interval is reduced for bulk carrier, passenger, ro-ro passenger, ro-ro cargo and container vessels. It also appears that vessels under the Malta flag face shortened durations between successive inspections, while the opposite hold for vessels registered in Finland.

In addition to the previous covariates, we then introduce the number of deficiencies detected during the very last PSC inspection as lagged value (column 2 in Table 3). Hence, only vessels that have been inspected at least twice are considered and the number of observations is reduced from 4080 to 1949. Our results stress that the lagged value is highly significant in the proportional hazards specification. According to the data, a high record in reported deficiencies tend to decrease the length of time before next inspection. At first sight, this is not a surprising finding. For instance, inspectors may decide to supervise more often vessels with bad records.

Nevertheless, the number of deficiencies may not be exogenous in the regression. For instance, if the number of defaults is itself correlated with vessels' characteristics, then the estimate associated to this covariate is likely to be biased.

An instrumental variable approach was then used. For each inspection, we compute the predicted number of defaults and introduce its lagged value into the inspection equation.[4] Again, we find a positive coefficient for the instrumented estimate, highly significant (column 3 in Table 3). It may suggest that inspectors are likely to schedule more frequent inspections on vessels that logged more deficiencies during the previous inspection.

It leads us to investigate the factors that play on the number of deficiencies or faults detected at a given date.[5] As the dependent variable takes discrete values and given the form of its distribution, we decide to rely on count data models and estimate first a Poisson model. The number of deficiencies at a given date is expressed as a function of age at inspection, type of vessel and flag of registry. The results are described in Table 4, column 1.

An inverted U-shaped profile is observed for age at inspection. The fact that less deficiencies are found for older vessels may be due to a selection effect, such that only vessels in good state can be still operated after two or three decades. It also appears that the passenger ship and the ro-ro passenger vessels exhibit more deficiencies compared to the other vessels category. All the other types are characterized by less deficiencies with respect to the reference category. The magnitude of this negative effect is especially large for oil tankers and chemical tankers. Finally, the number of deficiencies detected is smaller than the category "others" when vessels are registered in Antigua and Barbuda, Bahamas, Denmark, Finland, Germany, Malta, The Netherlands, Norway and Russia.

Nevertheless, it could be argued that the estimation of a single equation on the whole sample of vessels is not necessarily appropriate in our context. It may be for instance that there exists a group of vessels which are subject to more controls because inspectors feel that these vessels are potential target. Then, we adopt a more complex strategy to account for ship heterogeneity in the sample. Specifically, we rely on a latent class Poisson model using a panel data estimator (see Heckman and Singer, 1984).

Unobserved heterogeneity in the distribution of the number of defaults is assumed to impact the mean of the parameter of the Poisson model. The latent class model allows to account for an unobserved stratification

[3] For instance, we have two observations for a vessel inspected three times. The first one corresponds to the duration between the first and the second inspection, and the second one corresponds to the duration between the second and the third inspection.

[4] The predicted value of the lagged number of deficiencies is obtained through a negative binomial model, where the number of deficiencies is expressed as a function of age at inspection (quadratic profile), type of ship, flag of registry and year of inspection. One problem is that the characteristics of the different ships are mainly permanent, so that the relevance of the instruments remains questionable. Unfortunately, there are no other suitable instruments in our data.

[5] For a more detailed analysis on these data, see Cariou et al. (in press). The authors estimate several Poisson and negative binomial models on the number of deficiencies, and show how age at control, type of vessels and flag of registry affect the condition of the ships as reported in PSC. It also stresses, in line with results from this paper, that the fact to be subject to different regulations (comply with the International Safety Management code ISM in 1998 instead of 2002) does not play a significant role on the number of detected deficiencies.

Table 3
Cox proportional hazard estimates of duration between successive inspections

Variables	(1)	(2)	(3)
Constant	1.902***	4.200***	4.318***
	(4.14)	(4.16)	(4.20)
Vessel age at time of PSC	−0.007	−0.011	−0.047***
	(0.82)	(1.32)	(5.03)
Vessel age squared (/100)	−0.001	0.007	0.048***
	(0.07)	(0.41)	(2.74)
Type of ship			
General cargo	0.079	0.135	0.139
	(0.55)	(0.94)	(1.05)
Bulk carrier	0.315**	0.404***	0.379**
	(2.01)	(2.61)	(2.56)
Passenger	0.508***	0.519***	−0.138
	(3.19)	(3.25)	(0.80)
Ro-ro passenger	0.310*	0.327**	−0.456**
	(1.93)	(2.03)	(2.48)
Chemical tankers	−0.126	−0.021	0.070
	(0.65)	(0.11)	(0.38)
Ro-ro cargo	0.407**	0.486***	0.536***
	(2.20)	(2.61)	(3.05)
Oil tanker	0.138	0.208	0.313*
	(0.77)	(1.11)	(1.79)
Refrigerated cargo carrier	0.129	0.198	0.227
	(0.55)	(0.83)	(0.98)
Container	0.451**	0.519**	0.368*
	(2.15)	(2.48)	(1.77)
Others	Ref.	Ref.	Ref.
Flag of registry			
Antigua and Barbuda	0.158	0.204**	0.352***
	(1.61)	(2.09)	(3.56)
Bahamas	0.203	0.268*	0.293*
	(1.32)	(1.72)	(1.78)
Cyprus	−0.018	−0.070	0.018
	(0.15)	(0.55)	(0.15)
Denmark	0.006	0.067	0.621***
	(0.06)	(0.71)	(4.77)
Finland	−0.239**	−0.203*	0.027
	(2.18)	(1.76)	(0.24)
Germany	−0.046	0.025	0.374***
	(0.46)	(0.24)	(3.02)
Malta	0.593***	0.640***	0.713***
	(3.35)	(3.50)	(3.91)
Netherlands	−0.170	−0.098	0.066
	(1.59)	(0.90)	(0.58)
Norway	0.078	0.118	0.251**
	(0.80)	(1.15)	(2.42)
Russia	−0.044	−0.044	0.059
	(0.51)	(0.49)	(0.68)
Others	Ref.	Ref.	Ref.
Number of defaults in $t-1$		0.065***	
		(7.68)	
Number of defaults in $t-1$ – predicted value			0.380***
			(6.91)
Number of observations	1949	1949	1949
R^2	0.14	0.15	0.16

Source: Swedish Maritime Administration (SMA) 1996–2001.
Standard errors are cluster-adjusted (at the ship level).
Significance levels are respectively 1% (***), 5% (**) and 10% (*).

Table 4
Poisson models of number of defaults

Variables	Poisson model	Latent class model	
		Class 1	Class 2
Constant	0.029	1.673***	−0.678***
	(0.44)	(12.35)	(−5.40)
Vessel age at time of PSC	0.069***	0.021***	0.040***
	(16.25)	(2.84)	(7.00)
Vessel age squared (/100)	−0.107***	−0.008	−0.041***
	(10.89)	(−0.47)	(−3.41)
Type of ship			
General cargo	−0.118**	0.014	0.255**
	(2.02)	(0.14)	(2.11)
Bulk carrier	−0.154**	0.131	0.181
	(2.51)	(1.28)	(1.44)
Passenger	0.579***	−0.169	0.707***
	(8.78)	(−1.60)	(5.22)
Ro-ro passenger	0.858***	0.507***	0.999***
	(11.96)	(4.44)	(7.27)
Chemical tanker	−0.313***	−0.023	−0.432**
	(3.32)	(−0.16)	(−2.18)
Ro-ro cargo	−0.362***	−0.094	−0.528***
	(3.85)	(−0.65)	(−2.70)
Oil tanker	−0.368***	−0.233	−0.317
	(3.86)	(−1.45)	(−1.60)
Refrigerated cargo carrier	−0.279**	−0.502***	−0.357
	(2.53)	(−2.95)	(−1.53)
Container	−0.250	−0.281	0.263
	(1.51)	(−0.72)	(1.06)
Others	Ref.	Ref.	Ref.
Flag of registry			
Antigua and Barbuda	−0.414***	−0.842***	−0.517***
	(7.33)	(−8.62)	(−4.36)
Bahamas	−0.166***	0.747***	0.260***
	(3.31)	(7.36)	(3.54)
Cyprus	−0.030	−0.091	−0.197*
	(0.51)	(−1.00)	(−1.64)
Denmark	−1.099***	−0.897***	−1.439***
	(16.73)	(−9.35)	(−10.64)
Finland	−0.465***	0.214*	−0.085
	(7.60)	(1.89)	(−0.94)
Germany	−0.986***	−0.875***	−1.141***
	(13.32)	(−7.83)	(−8.75)
Malta	−0.234***	−0.446***	−0.196***
	(3.77)	(−4.75)	(−1.70)
Netherlands	−0.591***	−0.610***	−0.594***
	(9.76)	(−5.83)	(−5.51)
Norway	−0.560***	−0.424***	−0.596***
	(11.96)	(−5.95)	(−6.70)
Russia	−0.173***	−0.274***	−0.161**
	(4.40)	(−3.65)	(−2.23)
Others	Ref.	Ref.	Ref.
Estimated probability for class membership		0.163	0.837
Number of observations	4080	4080	
Number of vessels	2131	2131	
Log likelihood	−10148.7	−8094.4	

Source: Swedish Maritime Administration (SMA) 1996–2001.
Significance levels are respectively 1% (***), 5% (**) and 10% (*).

of the data. The distribution of the heterogeneity is approximated and the sorting of observations into classes is endogenous and generated during the estimation process. The final selection on the number of groups to select is then done according to the probability of each individual group.

Here, we then come to the selection of two groups to fit the data from the SMA data.[6] The latent class model then provides differentiated effects for observed characteristics between both groups of vessels. To assess the relevance of latent class effects, we compute a simple likelihood ratio test following Heckman and Singer (1984), which involves the log likelihood of the latent class model and the log likelihood of the Poisson model with no latent class sorting. Results from the test indicate that it matters to account for latent heterogeneity. Estimated prior probabilities for class membership are respectively equal to 16.3% for the first group and 83.7% for the second group (see Table 4, column 2).

For the vessels endogenously classified within the first group (Latent class 1), the number of deficiencies detected is higher than for the vessels aggregated within the second group (Latent class 2). The former exhibits a mean of 6 deficiencies (with a standard deviation of 6.67) while the latter has a mean of only 0.8 deficiencies. Furthermore, vessels belonging to the first group are older with an under-representation of bulk carriers and an over-representation of passenger ships and of vessels under Bahamian flag.

The two latent classes share common features when looking at flag of registry. The number of deficiencies detected is smaller than the category ‘‘others’’ when vessels are registered in Antigua and Barbuda, Denmark, Germany, Malta, The Netherlands, Norway and Russia. Turning to ship types, the number of deficiencies detected is significant and larger within group 1 for ro-ro passenger vessels, while it is smaller for refrigerated cargo carriers. Within latent class 2, general cargo, passenger ships and ro-ro passenger vessels exhibit more deficiencies, with a converse observation for chemical and ro-ro cargo ships. Finally, the profile of the vessel age when PSC occurred is much flatter for vessels belonging to the first class than for the second.

The above puts our results squarely in line with previous works (Cariou et al., in press) that identify the following factors as being significant predictors of the number of deficiencies detected at PSC inspections: age of the vessel at the time of inspection, ship type, and flag of registry.

5. The pattern of deficiencies with repeated inspections

We finally rely on a dynamic approach to analyse the effectiveness of PSC inspections and retain in our final sample the vessels that went though successive inspections to track whether the number of deficiencies detected on board a vessel in t decreases in comparison to its record in $(t-1)$. Our sample comprises 839 vessels that have undergone PSC inspection by the SMA at least twice during the period 1996–2001.

The basic descriptive statistics on the deficiency profile over time are analysed in the context of three configurations: (i) vessels for which no deficiencies were ever reported during PSC inspections (never deficient); (ii) vessels which alternatively exhibited no or some deficiencies during PSC inspections (sometimes deficient); and (iii) vessels for which at least one deficiency was always noted during PSC inspections (always deficient). The results are shown in Table 5.

The majority of vessels (58.6%) belong to the intermediate category, while only 14.3% of them are reported as always having at least one deficiency during PSC inspections. 27.1% of the vessels consistently received clean reports (no deficiency) at PSC inspections during the period covered by this study. The age of the vessel at the time of inspection, ship type, and flag of registry appear to be significant predictors to explain the deficiency trajectory of groups of vessels according to the Chi^2 test. Conversely, the ISM Code status is barely relevant in explaining the number of deficiencies.

As expected, the younger the vessel, the higher its probability to belong to the ‘‘never deficient’’ category. On the other hand, the probability of belonging to the ‘‘always deficient’’ category is highest (28.8%) for

[6] The estimation of a latent class model with three groups induces a much lower probability for one of the group, which is about 5 points of percentage. Nevertheless, one can also account for unobserved heterogeneity with a latent class model and specify the class probabilities as a function of one or several covariates. For the sake of robustness, we have estimated a latent class model with the class probabilities as a function of the number of defaults. The corresponding results (not reported) are very similar to those reported in Table 4, where the class probabilities are constant.

Table 5
Ship-level analysis of deficiency trajectory

Number of deficiencies	Never deficient	Sometimes deficient	Always deficient	Number of observations	Chi^2 (prob.)
Vessel age at time of PSC (%)					
[0; 5[	43.8	52.3	3.8	130	54.99
[5; 10[	28.5	62.6	8.9	123	(0.000)
[10; 15[	24.8	62.0	13.2	121	
[15; 20[	24.7	63.3	12.0	158	
[20; 25[	24.2	56.8	18.9	132	
[25; 30[	15.3	55.9	28.8	111	
[30; ∞[	26.6	54.7	18.7	64	
Compliance with ISM Code in 1998 (%)					
No	29.4	54.6	16.0	469	7.31
Yes	24.0	63.8	12.2	370	(0.026)
Type of ship (%)					
General cargo	27.0	57.1	15.8	366	53.02
Bulk carrier	21.7	64.3	13.9	230	(0.000)
Passenger	7.5	75.5	17.0	53	
Ro-ro passenger	15.0	75.0	10.0	20	
Chemical tanker	54.0	37.8	8.1	37	
Ro-ro cargo	52.6	31.6	15.8	38	
Oil tanker	37.5	58.3	4.2	24	
Refrigerated cargo carrier	46.7	40.0	13.3	15	
Container	38.9	55.6	5.6	18	
Others	21.0	63.2	15.8	38	
Flag (%)					
Antigua and Barbuda	23.1	61.5	15.4	52	60.39
Bahamas	12.2	70.7	17.1	41	(0.000)
Cyprus	22.2	66.7	11.1	36	
Denmark	41.2	51.5	7.3	68	
Finland	20.9	72.1	7.0	43	
Germany	44.3	53.4	2.3	88	
Malta	24.0	64.0	12.0	25	
Netherlands	37.5	55.0	7.5	80	
Norway	20.7	53.7	25.6	82	
Russia	19.1	60.3	20.6	141	
Others	25.1	57.4	17.5	183	
All (%)	27.1	58.6	14.3	839	–

Source: Swedish Maritime Administration (SMA) 1996–2001.

vessels in the penultimate age category, i.e., between [25; 30[years old, and not for [30; ∞[years old. This might be explained by a selection effect that implies that only extremely well maintained vessels older than 30 years still remain in operation. As a variable, the ISM Code is hardly significant and suggests surprisingly that vessels that did not have to comply with ISM in 1998 are less often deficient (29% without any deficiency) than those (24%) that were required to do so. This result can give rise to two different interpretations: either the targeting of ISM was relevant in focusing on vessel with more deficiencies, or the ISM Code has not succeeded in reducing the number of deficiencies noted on targeted vessels. Unfortunately, no element in our analysis provides us with a clear answer.

Chemical tankers (54.1%), ro-ro cargo ships (52.6%), refrigerated cargo carriers (46.7%) and containerships (38.9%) have the highest proportion of vessels belonging to the "never deficient" category. Conversely, passenger ships (17%), general cargo ships (16%), and ro-ro cargo ships (16%) have a relatively high probability of having deficiencies reported in comparison with other categories of vessels. Finally, German- (44%) and Danish-flagged (41%) vessels are more likely to log zero deficiency ("never deficient") at inspections compared, for instance, to Bahamas-flagged (12.2%) vessels.

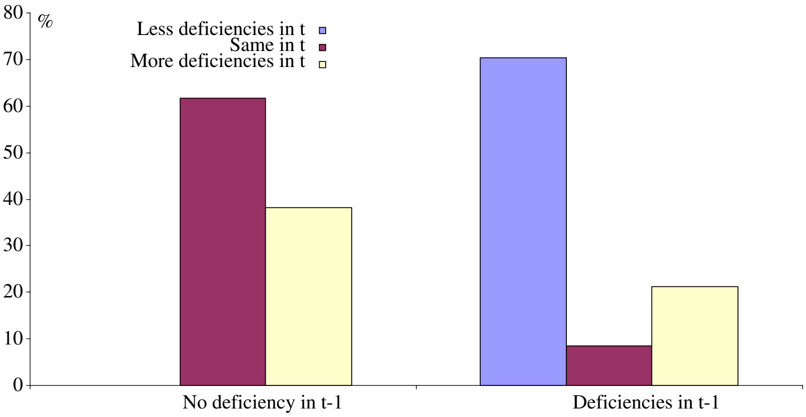

Fig. 1. Evolution of deficiency profile over time.

This study posits that a decrease in the number of deficiencies noted on board a vessel during an inspection in t, compared to deficiencies noted during the inspection immediately preceding it $(t-1)$, is a strong indicator of the effectiveness of the PSC inspection regime. Each pair of inspections comprises of $t-1$ and t, gives rise to one single observation. The final sample comprises 1949 observations. We also take the ageing of vessels over time into consideration as a potential factor against a reduction in the number of deficiencies.

Fig. 1 represents the results from the two situations drawn from our data. For vessels with zero deficiency detected in $(t-1)$ (see the left hand side of Fig. 1), the report on the subsequent inspection in t is characterized by one of two configurations: the same result or at least one deficiency noted. The analysis shows that 61.8% of vessels without noted deficiencies in $(t-1)$ also exhibit zero deficiency in t. The balance of 38.2% comprises vessels for which at least one deficiency was noted during the subsequent inspection.

For vessels that had at least one deficiency noted in $(t-1)$ (see the right hand side of Fig. 1), the report on the subsequent inspection in t is characterized by one of three configurations: fewer, the same, or more deficiencies. The analysis shows that 70.4% of the vessels have fewer deficiencies noted in t than in $(t-1)$. This suggests a strong degree of effectiveness of the PSC inspection regime. Furthermore, among the 70.4%, which correspond to 615 observations, it appears that 429 of them have no deficiency noted in t. Finally, 8.5% of the vessels that had deficiencies in $(t-1)$ have the same number of deficiencies noted in t, while 21.2% instances resulted in more deficiencies being noted in t.

We finally speculate whether the vessels' characteristics could explain the results presented above. The analysis is restricted to the sample of 874 observations that had reported deficiencies in $(t-1)$. The results for age of the vessel at time of inspection, compliance with the ISM Code, ship type, and flag of registry are shown in Table 6.

Among these four covariates, only the age of vessel at inspection is statistically significant according to the Chi-squared statistics. The results indicate that the percentage of vessels that had fewer deficiencies compared to the latest inspection is above 63% for all age categories. This ratio is particularly high (around 85%) for vessels in the [5; 10[year old category. Once again, the age categories with the highest percentage of vessels (around 26%) exhibiting more deficiencies in t than in $(t-1)$ are the [15; 20[and [25; 30[year old categories. A last, albeit more anecdotal, result is that 100% of containerships have always had fewer deficiencies in t than in $t-1$.[7]

[7] Nevertheless, the number of observations remains limited. In the same vein, there is also evidence of a very high proportion of chemical tankers and oil tankers with fewer deficiencies.

Table 6
Evolution of deficiencies and vessels' characteristics

Evolution of deficiencies	Fewer deficiencies	Same	More deficiencies	Number of observations	Chi^2 (prob.)
Vessel age at time of PSC (%)					
[0; 5[	77.4	6.4	16.2	62	26.27
[5; 10[	85.1	7.9	6.9	101	(0.010)
[10; 15[	72.1	4.6	23.3	129	
[15; 20[	63.2	10.4	26.4	144	
[20; 25[	72.1	8.5	19.4	165	
[25; 30[	65.7	8.1	26.2	172	
[30; ∞[	64.4	12.9	22.8	101	
Compliance with ISM Code in 1998 (%)					
No	69.1	10.0	20.8	557	4.99
Yes	72.6	5.7	21.8	317	(0.082)
Type of ship (%)					
General cargo	67.5	10.6	21.9	483	26.63
Bulk carrier	71.5	8.1	20.3	123	(0.205)
Passenger	72.5	4.4	23.1	91	
Ro-ro passenger	68.1	5.8	26.1	69	
Chemical tanker	80.0	0.0	20.0	15	
Ro-ro cargo	69.2	11.5	19.2	26	
Oil tanker	91.7	0.0	8.3	12	
Refrigerated cargo carrier	80.0	20.0	0.0	10	
Container	100.0	0.0	0.0	6	
Others	84.6	0.0	15.4	39	
Flag of registry (%)					
Antigua and Barbuda	59.7	12.5	27.8	72	26.02
Bahamas	69.4	8.3	22.2	72	(0.165)
Cyprus	75.0	10.0	15.0	40	
Denmark	77.8	11.1	11.1	45	
Finland	75.5	0.0	24.5	49	
Germany	88.1	7.1	4.8	42	
Malta	63.9	13.9	22.2	36	
Netherlands	72.6	6.4	21.0	62	
Norway	66.7	12.2	21.1	90	
Russia	67.4	9.8	22.7	132	
Others	70.9	6.0	23.1	234	
All (%)	70.4	8.5	21.2	874	

Source: Swedish Maritime Administration (SMA) 1996–2001.
The sample comprises only vessels presenting at least one deficiency during initial inspection.

6. Conclusion

In recognition of PSC's importance in enforcing international vessel safety standards, port states invest a great deal of time, effort, and resources to promote effectiveness in the implementation of this regional inspection regime. Assessments serve as a periodic review of the regime's purpose, an encouragement to its continued implementation, an instrument in identifying success and failure, as well as a tool to distinguish one from the other (Osborne and Gaebler, 1992). In this regard, the paper offers a twofold contribution to the literature. Firstly, it gives a substantial contribution to the determination of target factors that may lead to an enhanced implementation of PSC. Secondly, it presents a way to tackle the issue of the effectiveness of controls within a model using repeated inspections that can be used to differentiate, for instance, the effects of the age of vessels at inspection from the effects of the fact that the vessel had previously been inspected or not.

The main results of the analysis, established by a positive thread between the initial and subsequent inspections conducted on board a given vessel, point to a degree of effectiveness of the PSC inspection regime, irrespective of the vessel's age at the time of inspection. The strongest indication from this study is the high percentage (more than 63%) of vessels exhibiting a reduction in the total number of reported deficiencies between earlier and subsequent inspections. This is an encouraging sign in an imperfect world that depends on the uniform enforcement of international safety regulatory regimes for the prevention and mitigation of the adverse effects of accidents at sea. The approach adopted in this article considers the effectiveness of controls through the reduction in the total number of deficiencies detected, regardless of their nature. Subject to the availability of appropriate data, this approach should be complemented in the future by further studies that consider the potential preventive nature and long term effectiveness of repeated port state control inspections upon the seriousness of deficiencies detected.

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