An Econometric analysis of deficiencies noted in port state control inspections

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Abstract

The factors to consider in selecting which vessels to board for port state control (PSC) inspections are crucial. This paper tries to identify these factors using 4080 reported PSC inspections from the Swedish Maritime Administration for the period 1996-2001. It relies on count data models and compares results from the Poisson, negative binomial, random effect, and random parameters models. The results suggest that three factors are the main determinants of the number of reported deficiencies: the age at inspection, the flag of registry and the type of ships. Conversely, the year when the inspection occurs does not seem to be a significant factor. Estimations also stress that the relationship between the age at inspection and the number of deficiencies detected is not similar for different vessel types. For instance, the number of deficiencies detected decreases for chemical carriers and ro-ro passenger vessels older than 25 and 22 years old, while for instance the effect is rather small for tanker and bulk carriers and only occurs when vessels are older than 35 years.

Keywords

Formal Safety management, Port State Control, Inspection, Target Factors.

1. Introduction

Port state control (PSC) was developed in the early 1980s to complement existing international maritime safety enforcement mechanisms. 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).

Within the open registry type of ship registration regime, it is not uncommon for a ship to rarely (if ever) visit its port of registry in its service life. Because of this, the degree of enforcement of international standards can vary widely among the various open registries. While the more conscientious open flag states have an inspectorate system under which flag state surveyors and inspectors are stationed or appointed in strategic locations around the world to visit ships under their flags, there are many more ships that are effectively beyond the reach of surveyors and inspectors of the flag state. It was this irregularity that port state control was mainly designed to address.

It was always the prerogative of individual states, under national and international laws, to inspect foreign ships that call at their ports. However, the establishment of the PSC regime has facilitated coordination and harmonization at the regional level of the active exercise of these rights which are implied in various IMO and ILO conventions. The present regime of 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 (Ozcayir, 2001, pp. 115-116).

PSC is often referred to as a fourth safety net for seagoing ships. It was designed to compensate for any eventual shortcomings of the shipowner, flag state, and classification society, in addition to other actors. 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. In the 1990s, the regime of port state control was institutionalized through explicit provisions in at least three of the most important conventions in the international regulatory framework for maritime safety. These are the International Convention for the Safety of Life at Sea (SOLAS), the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), and the International Convention for the Prevention of Pollution from Ships (MARPOL). In addition, the IMO has actively encouraged the establishment of regional agreements on port state control (Memoranda of Understanding on Port State Control also called "MoU on PSC", or simply "MoU"). Aside from administrative and operational functions, the regional agreements set quotas for the minimum percentage of vessels calling within a party's jurisdiction that should be inspected. Together, the MoUs in operation today cover virtually all of the world's seas[1].

A typical PSC inspection begins with a visit by one or more properly qualified PSC inspectors on board a foreign vessel to verify certificates and documents that serve as *prima facie* evidence that the vessel complies with certain IMO and ILO conventions. When a PSC inspector is satisfied that the required certificates and documents are in order and the inspector's attention has not been alerted to any deficiencies, the inspector could end the procedure at once. If suspicion is aroused or if someone files a report alleging that the ship does not comply with regulations, then a more detailed inspection is carried out. A more detailed inspection could lead to the identification of deficiencies to be noted on the inspection report. When serious deficiencies are found that confirm and establish clear grounds for detention, PSC authorities can prevent the vessel from departing until those deficiencies are rectified.

Every PSC inspection generates an inspection report. Each inspection report contains detailed information on flag of registry, IMO vessel number, vessel type, year built or date of inspection among other characteristics. In this paper, we provide an empirical analysis based on PSC inspection reports and investigate whether variables such as vessel age, vessel type, flag of registry, inspection year, and compliance with the International Safety Management (ISM) Code have an impact on the number of deficiencies noted during port state control inspections. Specifically, we use data on 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).

The remainder of the paper is organized as follows. In the next section, we briefly review the literature on PSC. We describe the data in section 3. Our econometric framework is presented in section 4, and we discuss the results from various specifications in section 5. Finally, section 6 presents some conclusions.

2. Literature review

The bulk of the literature written on PSC focuses on the inspection regime's mechanics as well as on its character in international maritime law. Two books provide in particular an extensive coverage of the subject.

Kasoulides (1993) surveys the custom associated with access to ports by foreign ships and the rights of port states in history before reviewing the relevant treaty law that eventually emerged. He then investigates how flag state enforcement has diminished in the face of the proliferation of open registries. This is followed by a discussion of how coastal States have reacted by asserting their rights through the resultant regime of port state control at the regional level. Özçayir (2001) starts by examining the roles of the flag state, the IMO, and the port state vis-à-vis maritime safety, before giving an introduction to PSC. She then 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.

Aside from giving an introduction to the PSC regime, several contributions have shed light on its various aspects. Clarke (1994) answers the questions "who is to blame and what is the cure for substandard ships?" by discussing 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. Detained ships are disallowed from departing until all major deficiencies noted are addressed to the satisfaction of the inspecting authorities.

Cuttler (1995) examines PSC in the context of ship-sourced pollution prevention. She briefly explains how problematic precise quantification of the costs of pollution damage can be under the most important compensation and liability regimes such as the International Convention on Civil Liability for Oil Pollution Damage (CLC) and the US Oil Pollution Act of 1990 (OPA). As a result, taxpayers end up shouldering the costs of liability that exceed the share imposed on polluters. This author warns against excessive reliance "on compensation and liability regimes to remedy environmental damage after the fact" 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).

After having been a strong critic of the effectiveness and utility of PSC early on, Hare (1997) claims that the regime has finally "come of age" and discusses how the proliferation of regional MoUs has significantly diminished the potentials for substandard ships to participate in international commerce. McDorman (2000) describes the international legal basis of PSC and examines 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. The article also discusses the limitations inherent in the PSC regime connected with the fact that the port state has no direct influence over the design and con-

[1] The different MoUs are : Paris MoU – Europe and the North Atlantic; Tokyo MoU – Asia and the Pacific; Acuerdo de Viña del Mar – Latin America; Caribbean MoU – Caribbean Sea region; Abuja MoU – West and Central Africa; Black Sea MoU – Black Sea region; Mediterranean MoU – Mediterranean Sea region; Indian Ocean MoU – Indian Ocean region; Gulf Cooperation Council (GCC) MoU – Arab States of the Gulf.

struction of ships that are being inspected.

Drawing on the implementation of PSC in the UK, Odeke (1997) concludes that despite claims to the contrary PSC should not be considered as interference in international maritime law. Rather, he argues, it should be seen as a strengthening of it. It 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 does not view PSC as a substitute for effective control by states over ships flying their flag. The flag state still bears the heaviest burden and has the greatest potential for compelling a ship to meet international standards. For as long as ships in significant numbers stay beyond the effective control and reach of their flag states, PSC will need to continue serving its vital complementary role.

While the references mentioned so far mainly focus on the mechanism of enforcing port state control, detailed data on PSC remain scarce. Payoyo (1994) conducts an assessment of the PSC regime by analyzing annual statistics generated by the Paris MoU from 1982 to 1992. This author looks at the number of ships involved, number of inspections conducted, number of deficiencies noted, and categories of major deficiencies for the period covered, and performs a calculation of the deficiency and detention rates and analyses of deficiencies linked to violations under the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Merchant Shipping (Minimum Standards) Convention (ILO 147). Payoyo expects statistical information and analysis to play a significant role in the Paris MoU's decision-making process.

An interesting conclusion of this study is that PSC has been a conditional success. On the one hand, Payoyo (1994) 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.

PSC authorities employ a number of devices to keep PSC effective and relevant. One is the use of a boarding priority matrix used in deciding which ships PSC inspectors "should board on any given day, in any given port" (Oczcayir, 2001a, pp. 154-155). The targeting factors considered by port states vary from identity of the owner, flag state, classification society, inspection and detention history, and ship type. Another device employed by regional MoUs is the annual focused or concentrated inspection campaign (CIC). CICs focus on specific issues of vessel safety and help induce better compliance with newly introduced international standards or existing ones where there is a perception that the appropriate attention has not been given by the shipping industry (Oczcayir, 2001b, p. 171-175)[2].

Hence, the analysis of data and statistics is another crucial element in keeping the PSC inspection regime relevant. The Paris MoU, Tokyo MoU, and the US Coast Guard produce annual reports providing descriptive statistics pertaining to the inspection activities of the past year. The analyses derived from these statistics have helped guide these PSC authorities in steering the direction of future programmes. It is in this vein that the present study on determinants of the number of deficiencies noted in PSC inspections in Sweden is conducted.

3. Data

For our empirical analysis, we rely on original data which consist of results from PSC inspections carried out by the Swedish Maritime Administration (SMA) from January 1, 1996 till 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). 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 (from 0 till n deficiencies). The final sample comprises 4080 cases, owing to the fact that a given vessel may have been inspected several times during the period in our sample.

We select as explanatory variables the age of vessel when 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 called 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[3].

[2] Past and current CICs in the European region cover the following areas: 1995 – pilot ladders; 1996 – oil record books; 1997 – working and living conditions; 1998 – ISM Code implementation; 1999 – structural safety of bulk carriers; 2000 – structural safety of oil tankers; 2001 – cargo securing; 2002 – ISM Code implementation; 2003 – passenger ships and cruise liners; 2004 – working and living conditions; 2005 – Global Maritime Distress and Safety System (GMDSS); 2006 – MARPOL Annex I.

[3] ISM Phase 1 or 2 status was considered following a study conducted by Hernqvist for the Swedish (Protection & Indemnity) Club stressing that "vigorous application of the ISM Code can significantly reduce claims exposures" and thus lead

The variables selected and their specific descriptive statistics appear in table 1 in appendixes. Over the 4080 cases, the number of PSC inspections per year ranges from a minimum of 578 in 1998 to a maximum of 762 in 2000. The average number of deficiencies is 1.64 per inspection with a minimum of 1.54 in 2001 and a maximum of 1.77 in 1997. The average age at inspection is 16.88 years, ranging from 16.30 in 1999 to 17.59 in 2001. Concerning the profile of vessels inspected, it appears that 40% were required to comply with the ISM Code by 1998, while 60% did not have to. The rate of vessels that comply with the ISM Code since 1998 is particularly low at the end of the period (21% in 2001).

This element can be explained by the change in the profile of ship type inspected by the Swedish Maritime Administration. The first ship type is general cargo (48% of total vessels inspected) and its share increases from 39% in 1996 to 66% in 2001. However, this ship type did not have to comply with the ISM Code until July 2002 (Phase 2). The second main ship type inspected is bulk carriers (21.4% of the 4080 vessels) which had to comply with the ISM Code in 1998. However, its share shrank back from 33.9% in 1996 to a low 5.8% in 2001.

Looking among the 75 different flags of registry encountered in the data, vessels under the Russian flag represent 13.4% of our sample, followed by the Norwegian flag (9.4%) and the Dutch flag (8.3%). Descriptive statistics evidence a slight decline over time in the number of inspected ships that operate under the Russian, Bahamian and German flags, and an increase for ones under Antigua and Barbuda and The Netherlands.

In table 2, we report frequencies for age at inspection, ship type, flag, ISM status and year of inspection depending on the number of deficiencies. Out of the 4080 PSC inspections, around 56% induce no reported deficiencies and 14% of inspections induce exactly one deficiency. Occurrence of large numbers of deficiencies remains rather frequent, as 5.5% of vessels are characterised by a value comprised between 6 and 10 deficiencies and less than 2% of inspections lead to more than 10 reported deficiencies.

When looking at the different explanatory variables, we note that the Chi-squared statistics are significant at conventional level for age at inspection, type of ship, flag of registry and year of inspection (at the 10% critical value for this covariate). For age at inspection, it appears that the number of deficiencies is null for more than 70% of the ships that are less than 5 years old, while the ratio is 49.70% for those older than 30 years. As expected, more deficiencies are reported when older vessels are inspected. There are also some differences by type of ships, with more deficiencies for passenger and ro-ro passenger ships. Vessels registered in Germany and Denmark more often lead to zero-default inspections. Finally, the dummy variable ISM is not statistically significant according to the Chi-squared test.

4. Econometric methodology

We now turn to an econometric analysis in order to determine the factors that influence the number of deficiencies detected during PSC. As the dependent variable takes discrete values and given the form of its distribution, we decide to rely on count data models (Greene, 2003, Cameron and Triverdi, 1998, Winkelmann, 2000). For the presentation, we denote by n_{it} the number of deficiencies observed for a ship i inspected at date t, where n_{it} is a nonnegative integer count and x_{it} is the set of characteristics of a ship. We include as covariates age at inspection, type of vessel, flag of registry and the year when inspection occurred. We first rely on the basic Poisson regression framework, so that the model we seek to estimate is given by:

$$\Pr(n = n_{it}) = \frac{e^{\lambda_{it}} \lambda_{it}^{n_{it}}}{n_{it}!} \quad (1)$$

In (1), the parameter λ_{it} is both the mean and variance of n_{it}. It can be defined as:

$$\log \lambda_{it} = \beta' x_{it} \quad (2)$$

We take into consideration that the maximum likelihood estimation of a Poisson regression model can be rather restrictive in assuming an equality of mean and variance of the dependant variable. When this assumption does not hold, we use a more flexible specification given by the negative binomial regression model. It introduces an unobserved heterogeneity term into the Poisson process, so that we have:

$$\log \lambda_{it} = \beta' x_{it} + \varepsilon_{it} \quad (3)$$

where $e^{\varepsilon_{it}}$ follows a Gamma distribution with unitary mean and variance α, a parameter that has to be estimated. Hence, the conditional probability distribution for the negative binomial regression specification is:

$$\Pr(n = n_{it}) = \frac{e^{\varepsilon_{it}} e^{\lambda_{it}} (e^{\varepsilon_{it}} \lambda_{it})^{n_{it}}}{n_{it}!} \quad (4)$$

Recalling that we have results from several inspections for some vessels in the data, we can extend the negative binomial model by allowing for either random or fixed effects, a relevant consideration when dealing with repeated observations such as consecutive inspections of an identical vessel. The random effect specification is such that:

$$\log \lambda_{it} = \beta' x_{it} + u_i + \varepsilon_{it} \quad (5)$$

where u_i is a random effect for vessel i such that e^{u_i} follows a Gamma distribution. The over-dispersion parameter is then supposed to be randomly distributed across groups. In random effect count data models, the individual heterogeneity component is assumed to be uncorrelated with the covariates.

When this exogeneity assumption does not hold, one has to rely instead on a fixed effect specification using an unconditional estimator for the binomial model

to a decrease in the number of deficiencies; see Hernqvist M (2000). “ISM Code shows positive effect on insurance claims”, Know How, 2, pp 21-22.

(Hausman, Hall and Griliches, 1984). With the fixed effect model, the sample is restricted to vessels for which a variation in the number of detected deficiencies occurs through the different inspections. Indeed, if the number of deficiencies is always equal to zero at each inspection for a vessel, the latter should not contribute to the likelihood. However, a shortcoming of the fixed effect approach in our context is that the data mainly provide information on time-permanent variables, for instance the type of ship or flag registry. As these variables are likely to be constant across the different inspections, they will also have to be excluded from the set of explanatory variables, so that this framework is not clearly relevant to the PSC data.

Hence, to further account for heterogeneity in the binomial model, we choose to rely on a random parameter approach (Train, 2003). This method consists of adding random parameters to the model. It entails allowing for a specification in which some parameters are random and follow a Normal distribution, while others are not. Interestingly, this random parameter specification provides a generalization of the random effect model, as the latter is in fact equivalent to a random parameters model where the constant is the sole random term. When turning to the data, we estimate the model using recent simulation techniques and we select the number of random draws to 50 (see Greene, 2003, for further details).

5. Estimation results

We first estimate Poisson and negative binomial models on the whole sample of 4080 observations. In so doing, we suppose that the different inspections are independent from each other, an assumption we will relax later on. Four explanatory variables are introduced into the various models, which are age at inspection by class of age, ship type, flag of registry, and date of inspection (introduced in a nonlinear way). We decide not to include the dummy variable ISM 1998, as this variable is clearly not orthogonal to other characteristics as type of vessels or class of age.

The relationship between the age of the vessel at inspection and the number of deficiencies is expected to be positive and increasing with vessel age, all else held constant. At the same time vessels built in different years may vary in design, construction technologies and materials, and operations and could lead to indeterminate results when comparing extreme range age (Talley, Jin and Kite-Powell, 2005).

On the relationship between vessel type and deficiencies, we expect a relative reduction in the number of observed deficiencies for more dangerous or polluting cargo carriers such as chemical or oil tankers and for vessels that had to comply with the ISM Code in phase 1. In the same vein, a relative reduction in the number of deficiencies detected for vessel under North European flags and a relative reduction of the number of deficiencies over the years should be observed. Nevertheless, for the latter a potential increase in the rigidness of PSC inspections may imply an opposite effect (i.e. an increase in detected deficiencies).

According to the estimates reported in table 3 in appendixes, we find very similar results for the Poisson and negative binomial specifications. Signs are identical for all the explanatory variables, while differences concerning the level of significance are mainly observed for year of inspection. In order to select between the Poisson and negative binomial models, we carry out the Cameron and Triverdi (1990) diagnostic test for over/under-dispersion. It tests for the mean-variance equality, i.e. $H_0 : V[n_{it}] = E[n_{it}]$ versus $H_1 : V[n_{it}] = E[n_{it}] + \alpha g(E[n_{it}])$. We obtain values of 9.29 and 10.11 respectively for $g(n_{it}) = \lambda_{it}$ and $g(n_{it}) = \lambda_{it}^2$, so that we have to reject H_0. Hence, in what follows, we rely on results from the negative binomial model as an appropriate specification to explain the determinants of the number of deficiencies.

As we introduce dummy variables for each covariate, we rely on Wald tests to analyse the overall significance of covariate. We find that both age at inspection, type of vessels and flag of registry are significant predictors to explain the number of deficiencies reported at inspection. Conversely, we find a value of 8.66 with 5 degrees of freedom for the date of inspection, insignificant at conventional levels (the corresponding probability value is around 12%). It might be an indication that the severity of the inspections has not changed over time.

Looking into greater detail at the results of the age profile, an inverted U-shaped profile is observed. An increase in the number of deficiencies can be observed for vessels within the [5;10[years range, with about 43% of additional deficiencies compared to the [0;5[category. With respect to the reference category, the number of deficiencies is at its maximum for the [25; 30[age group (110% higher than for [0; 5[group), but we observe that a slight decrease takes place for vessels older than 30 years. This finding could be the result of a “selection effect” which implies that only extremely well maintained vessels older than 30 years old still remain in operation.

Moving to ship type, we find that the passenger ship and the ro-ro passenger vessel categories exhibit higher deficiency rates compared to the other vessels category. For all the other types, they are usually characterized by a lower number of deficiencies. As expected, this result is particularly pregnant for two ship types, i.e. oil tankers and chemical tankers. This could be explained by the relatively more stringent standards being held against the latter ship types as a result of a number of high profile accidents involving those ships that resulted in environmental damage. In fact, in addition to complying with the standards set by their flag states, oil and chemical tankers also have to comply with independent vetting requirements. Vetting allows prospective ship charterers or port authorities to assess the desirability of a tanker based on its performance history.

Concerning flag of registry, the flags that exhibit higher numbers of deficiencies are not among the 10 most important flags calling at Swedish ports we listed, but in the reference category “others”. All flags signs are negative with vessels registered in Northern European countries (Denmark, Germany, The Netherlands, Norway, and Finland) performing particularly well.

Based on the Swedish data, we find that age at inspection, type of vessel and flag are significant predictors when explaining the number of observed deficiencies during PSC. Then, we rely on a decomposition method to determine to which extent the variation in the number of deficiencies can be related to each of these three independent variables (Fields, 2003). We use a linear approximation and decompose the variance of n such as (we drop the subscript for the presentation):

$$V[n] = \sum_k \text{cov}[x^k \hat{\beta}^k, n] + \text{cov}[\hat{\varepsilon}, n] \quad (6)$$

Defining the weights $s[x^k]$ and $s[\hat{\varepsilon}]$ respectively as $s[x^k] = \text{cov}[x^k \hat{\beta}^k, n] / V[n]$ and $s[\hat{\varepsilon}] = \text{cov}[\hat{\varepsilon}, n] / V[n]$, it follows that:

$$\sum_k s[x^k] + s[\hat{\varepsilon}] = 100\% \quad (7)$$

The weights that we derive use the variance as a measurement of dispersion of the dependent variable. The results from the decomposition are given in table 4.

We find that the most important contributor to the number of observed deficiencies is age at inspection (36.8%), followed by flag of registry (33.7%) and then ship type (28.3%). It leads us to two main comments. Firstly, it shows that the number of deficiencies noted at PSC inspections comes from a combination of several factors – age, ship type and flag – rather than from a unique element. Secondly, it indicates that the time when inspection occurred does not really affect the number of deficiencies detected during PSC carried out by SMA from 1996 to 2001. Indeed, we find that the year when the inspection takes place only accounts for 1.3% when explaining the number of deficiencies in PSC.

We then relax the assumption of independence between the different inspections to consider that maritime authorities may have inspected poorly maintained vessels more frequently. We attempt to control for unobserved heterogeneity by adding random parameters to the previous models[4]. For the sake of comparison, we first re-estimate the negative binomial regression, and then estimate the random effect and random parameters models. For the latter specification, we only consider as random parameters the constant, the age at inspection, and the age squared. These three parameters are supposed to follow a Normal distribution and to be uncorrelated. The different estimates are reported in table 5 in appendixes.

Interestingly, adding (uncorrelated) random effects in the negative binomial model is relevant. The likelihood-ratio test of the pooled assumption gives a value of 69.78, significant at the one percent level, meaning that successive inspections for a given vessel should not be treated as independent. Random parameters for age and age squared are quite accurate, as shown by the low magnitude in the variance of the normal distribution for these parameters. However, these two new specifications do not really affect our previous conclusions.

We further examine the inverted U-shaped profile of the number of deficiencies as a function of age at inspection. In figure 1 in appendixes, we plot the age at inspection profiles for the different negative binomial models (standard, random effects and random parameters).

Interestingly, a very similar profile for the shape of the curves is observed for the three regressions. We find a peak in the number of detected deficiencies around 28-30 years old for the negative binomial and random parameters models, while the peak is a bit older for the random effects specification (close to 35 years old). This result may be due to the higher weight devoted to vessels with repeated information. If older vessels are still running after several inspections, this suggests that they are in rather good condition.

Finally, we have estimated specific age profiles according to the type of ship. Owing to the limited number of observations for some types of vessels, we use standard negative binomial models and neglect unobserved heterogeneity. We represent the age profiles for various ship types in figure 2 in appendixes.

We observe that chemical tankers and ro-ro passenger vessels show a different age profile, as most deficiencies are noted on chemical tankers that are around 25 years old and on ro-ro passenger vessels that are around 22 years old. Then, after reaching their respective peaks, the number of deficiencies decreases with vessel age. This is not the case for other vessels such as oil tankers, general cargo ships or bulk carriers for which the number of deficiencies detected consistently increases with vessel age.

6. Conclusion

PSC plays an important role in the enforcement of international vessel safety standards. In this regard, the relevance of the factors to consider in selecting or targeting a vessel for inspection is crucial to ensuring the PSC regime's continued effectiveness. The objective of this paper was to use PSC reports (1996-2002) coming from the Swedish Maritime Administration to estimate the factors that could explain the number of deficiencies noted during PSC inspections. Several count data models were applied to achieve this and three main elements were found to be determinant: the age of vessel at inspection, the type of vessel, and the flag of registry. It is interesting to note that these elements are consistent with those already considered in PSC targeting protocols used around the world. They are an integral part of the formula for calculating a ship's target factor under the Paris MoU (2006) and the boarding priority matrix of the US Coast Guard (2005).

In contrast, the analysis showed that the year when the inspection took place as well phase 1 compliance with the ISM Code are not significant predictors. 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

[4] With respect to the previous regression, we choose to introduce age at inspection in a quadratic form. Also, the year of inspection is no longer included owing to our previous results.

underscores the lack of conclusive statistical evidence to establish a direct link.

The present study showed that the impact of age at inspection on the number of deficiencies noted actually changes depending on the type of vessel under consideration. A positive relationship exists for oil tankers, general cargo ships, and bulk carriers, peaking at around 30 years old. On the other hand, a relative decrease is observed in the number of deficiencies reported for chemical tankers older than 25 years and for ro-ro passenger ships older than 22 years.

The statement that "in an ideal world port state control would not be necessary" (Ozcayir, 2001a, p. 147) is a generally accepted one. It drives home the point that the world is far from ideal and that, as the present study has shown, the world of shipping is populated by vessels with highly divergent safety standards primarily influenced by type, year of built, and flag of registry. Aside from establishing the link between these determinants and the number of deficiencies noted in PSC inspections, the present study also established a thread between the initial and successive inspections conducted on board a given vessel. This observation suggests an effectiveness of the inspection regime that warrants further investigation.

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Appendixes

Table 1. Descriptive statistics of the sample

Variables	1996	1997	1998	1999	2000	2001	Total
Number of deficiencies noted							
Mean	1.59	1.77	1.74	1.66	1.57	1.54	1.64
Standard dev.	4.22	3.88	3.52	3.26	2.94	3.40	3.54
Vessel age at PSC inspection							
Mean	16.66	16.34	17.46	16.30	16.67	17.59	16.81
Standard dev.	9.77	10.10	10.30	9.58	10.12	10.59	10.07
Comply with ISM Code in 1998							
Yes	52.1	50.2	42.0	39.5	34.4	20.9	39.8
No	47.9	49.8	58.0	60.5	65.6	79.1	60.2
Type of ship							
General cargo	39.0	38.0	42.7	48.4	52.9	66.2	48.0
Bulk carrier	33.9	34.7	22.7	18.3	14.0	5.8	21.4
Passenger	6.8	5.8	9.9	5.9	6.3	1.7	6.0
Ro-ro passenger	3.4	3.0	2.9	2.9	4.5	6.7	3.9
Chemical tanker	4.6	3.1	3.3	5.4	4.1	1.5	3.7
Ro-ro cargo	2.6	3.5	4.3	3.6	3.8	4.1	3.7
Oil tanker	1.1	2.7	4.2	4.0	3.7	4.1	3.3
Refrigerated cargo carrier	1.7	3.1	3.1	2.5	2.5	0.5	2.2
Container	1.4	1.3	1.4	1.9	2.8	2.3	1.9
Others	5.5	4.8	5.5	7.0	5.5	7.2	5.9
Flag of registry							
Antigua and Barbuda	5.8	5.8	5.2	6.5	7.0	10.5	6.8
Bahamas	7.2	7.6	7.1	7.2	5.9	3.2	6.4
Cyprus	4.8	4.2	3.5	5.0	3.8	4.1	4.2
Denmark	8.8	7.4	8.0	7.9	7.2	6.2	7.5
Finland	2.5	4.1	4.3	4.1	5.5	4.6	4.2
Germany	9.2	7.2	8.1	7.3	7.1	5.8	7.4
Malta	3.5	3.8	6.4	4.3	3.7	3.0	4.1
Netherlands	5.8	6.8	8.1	9.4	9.8	9.6	8.3
Norway	8.9	9.6	7.6	11.7	9.1	9.3	9.4
Russia	14.6	15.8	15.7	10.3	13.0	11.6	13.4
Others	28.9	27.6	26.0	26.3	28.0	32.1	28.1
Number of observations	651	707	578	725	762	657	4080

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

Table 2. Evidence on the number of deficiencies, by vessels' description

Number of deficiencies	0	1	2	3-5	5-10	≥10	Chi² (prob.)
Vessel age at PSC inspection							
[0 ; 5 [	70.75	11.70	7.92	6.42	2.83	0.38	137.68
[5 ; 10 [	64.14	14.14	8.10	8.97	3.28	1.38	(0.000)
[10 ; 15 [	57.49	13.68	9.77	12.05	4.72	2.28	
[15 ; 20 [	53.70	13.95	10.18	13.53	5.72	2.93	
[20 ; 25 [	51.43	13.47	9.31	15.33	7.02	3.44	
[25 ; 30 [	47.42	15.63	9.77	13.14	9.24	4.80	
[30 ; ∞ [	49.74	14.81	10.32	17.20	5.56	2.38	
Comply with ISM Code in 1998							
No	56.39	13.63	10.09	12.21	5.41	2.28	6.36
Yes	56.29	14.24	8.20	12.52	5.73	3.02	(0.273)
Type of ship							
General cargo	54.98	13.63	10.72	12.86	5.41	2.40	151.57
Bulk carrier	54.06	17.49	8.46	13.03	5.03	1.94	(0.000)
Passenger	48.77	14.34	6.97	10.66	12.30	6.97	
Ro-ro passenger	47.80	10.06	10.69	16.98	6.29	8.18	
Chemical tanker	70.20	9.27	7.28	10.60	1.32	1.32	
Ro-ro cargo	71.14	9.40	4.70	8.72	5.37	0.67	
Oil tanker	64.18	9.70	9.70	11.94	3.73	0.75	
Refrigerated cargo carrier	58.24	10.99	8.79	17.58	4.40	0.00	
Container	67.11	23.68	3.95	2.63	2.63	0.00	
Others	62.81	10.74	8.68	8.68	6.20	2.89	
Flag of registry							
Antigua and Barbuda	56.47	13.67	10.43	13.31	5.04	1.08	171.90
Bahamas	51.15	15.38	9.23	15.38	5.38	3.46	(0.000)
Cyprus	54.91	13.29	7.51	12.14	9.25	2.89	
Denmark	72.08	12.34	4.87	5.19	4.55	0.97	
Finland	56.98	12.21	7.56	12.21	8.14	2.91	
Germany	73.60	12.87	5.94	5.94	0.99	0.66	
Malta	50.00	12.65	16.27	12.65	5.42	3.01	
Netherlands	63.13	14.45	10.03	8.26	3.54	0.59	
Norway	53.51	15.06	10.39	14.03	4.42	2.60	
Russia	49.45	17.52	11.68	12.59	6.57	2.19	
Others	52.00	12.46	9.06	15.51	6.71	4.27	
Year of inspection							
1996	56.99	15.51	11.06	9.83	4.15	2.46	35.34
1997	57.14	12.87	8.91	12.02	5.80	3.25	(0.082)
1998	52.77	16.26	8.48	13.49	6.57	2.42	
1999	57.79	10.62	7.86	15.03	6.07	2.62	
2000	56.04	13.25	11.02	11.42	5.64	2.62	
2001	56.77	15.53	8.52	12.18	5.02	1.98	
All	56.35	13.87	9.34	12.33	5.54	2.57	

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

Table 3. Poisson and negative binomial models for the number of deficiencies

Variables	Poisson		Negative binomial	
	coef	t-test	coef	t-test
Constant	0.034	0.44	0.027	0.15
Vessel age at PSC inspection				
[0 ; 5 [	Ref		Ref	
[5 ; 10 [	0.421***	6.56	0.431***	3.49
[10 ; 15 [	0.633***	10.34	0.639***	5.21
[15 ; 20 [	0.805***	13.74	0.825***	7.04
[20 ; 25 [	0.965***	16.60	0.981***	8.29
[25 ; 30 [	1.063***	17.95	1.100***	8.79
[30 ; ∞ [	0.903***	13.88	0.889***	6.43
Type of ship				
General cargo	-0.081	-1.40	-0.154	-1.13
Bulk carrier	-0.169***	-2.73	-0.238*	-1.65
Passenger	0.583***	8.78	0.546***	3.15
Ro-ro passenger	0.890***	12.33	0.908***	4.73
Chemical tanker	-0.309***	-3.27	-0.495**	-2.43
Ro-ro cargo	-0.352***	-3.74	-0.392*	-1.88
Oil tanker	-0.362***	-3.79	-0.456**	-2.18
Refrigerated cargo carrier	-0.299***	-2.69	-0.352	-1.47
Container	-0.209	-1.25	-0.243	-0.84
Others	Ref		Ref	
Flag of registry				
Antigua and Barbuda	-0.400***	-7.08	-0.314**	-2.43
Bahamas	-0.183***	-3.63	-0.226*	-1.68
Cyprus	-0.048	-0.82	-0.075	-0.50
Denmark	-1.107***	-16.79	-1.052***	-7.94
Finland	-0.478***	-7.81	-0.394**	-2.46
Germany	-0.990***	-13.31	-0.993***	-7.14
Malta	-0.244***	-3.91	-0.236	-1.55
Netherlands	-0.605***	-9.96	-0.568***	-4.52
Norway	-0.581***	-12.31	-0.430***	-3.86
Russia	-0.176***	-4.42	-0.162*	-1.64
Others	Ref		Ref	
Year of inspection				
1996	Ref		Ref	
1997	0.132***	3.13	0.135	1.32
1998	0.071	1.60	0.129	1.19
1999	0.097**	2.28	0.162	1.58
2000	-0.019	-0.45	0.041	0.40
2001	-0.079*	-1.73	-0.095	-0.88
Dispersion parameter			2.707***	27.00
Number of observations	4080		4080	
Log likelihood	-10125.4		-6457.5	

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

Table 4. Decomposition analysis of the factors contributing to the number of deficiencies

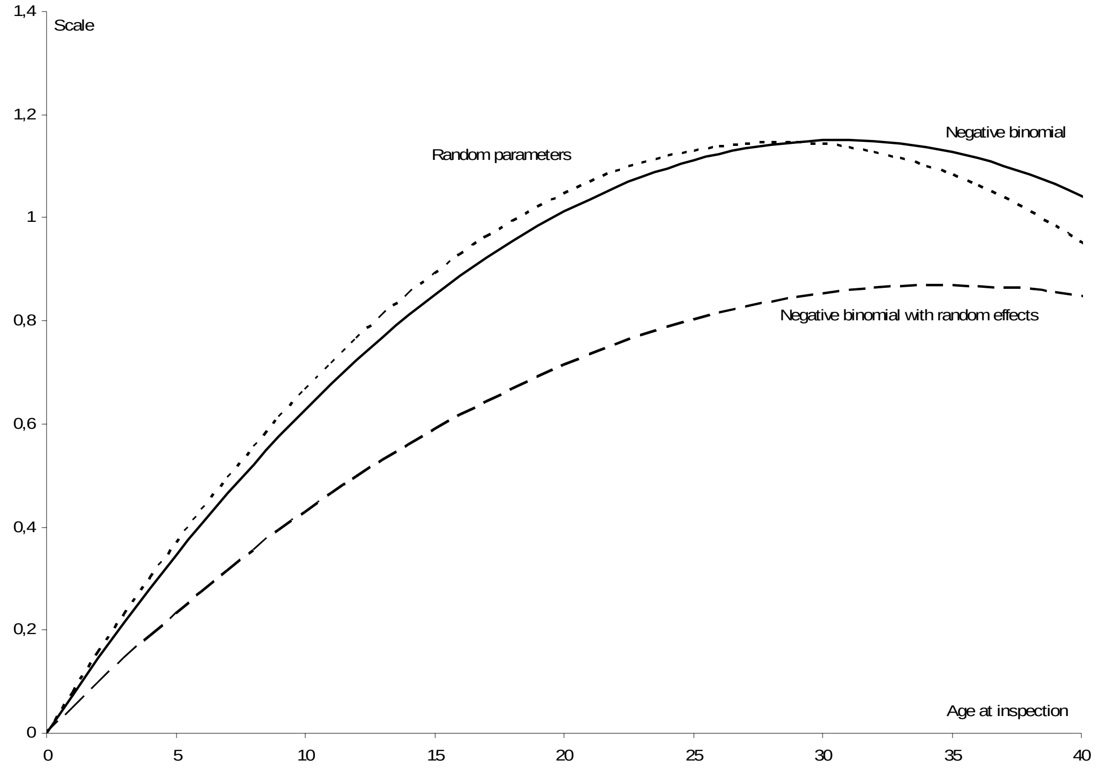
Variables	Percentage contribution of the variable
Vessel age at PSC inspection	36.8%
Type of ship	28.3%
Flag	33.7%
Year of inspection	1.3%
Total	100.0%

Source: Swedish Maritime Administration (SMA) 1996-2001

Table 5. Random effects and random parameters negative binomial estimates for the number of deficiencies

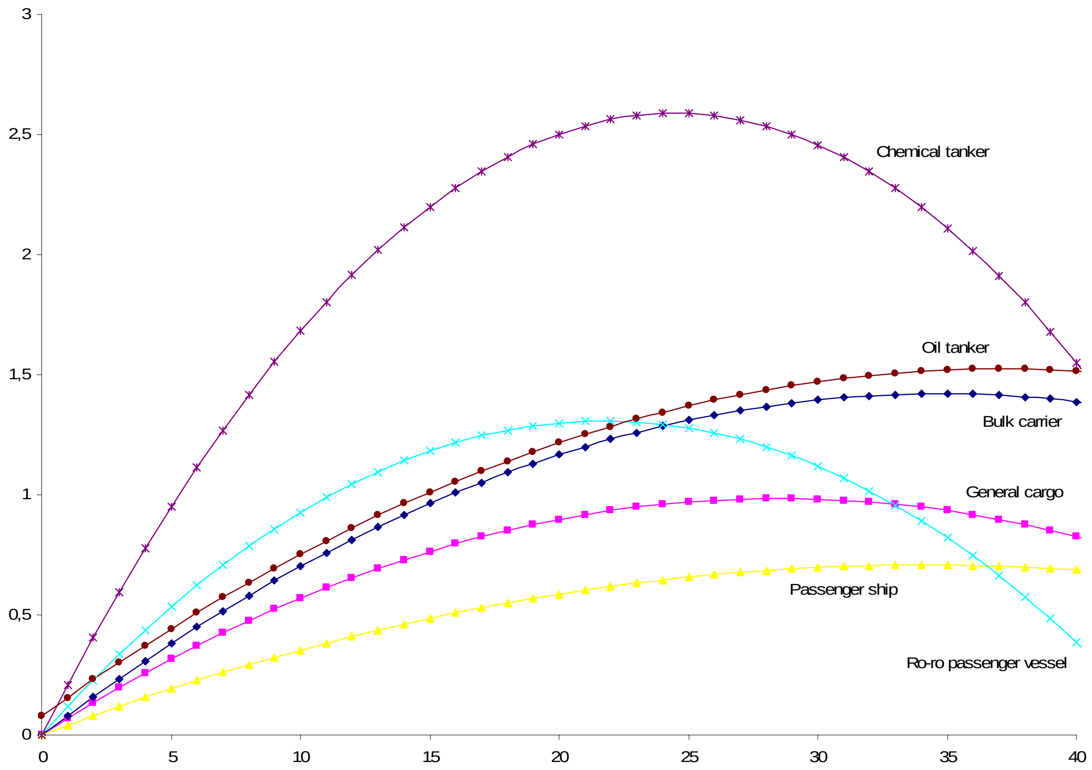
Variables		Random effects		Random parameters	
		coef	t-test	coef	t-test
Constant	Mean	-1.356***	-10.20	-0.268	-3.21
	Variance			0.603	31.19
Age at inspection	Mean	0.050***	6.66	0.076	14.14
	Variance			0.007	6.73
Age² at inspection (/100)	Mean	-0.073***	-4.12	-0.124	-9.54
	Variance			0.010	2.72
Type of ship					
General cargo		0.145	1.31	-0.037	-0.51
Bulk carrier		0.129	1.09	-0.098	-1.25
Passenger		0.380***	2.87	0.637***	6.86
Ro-ro passenger		0.757***	4.92	0.916***	9.24
Chemical tanker		-0.235	-1.36	-0.411***	-3.84
Ro-ro cargo		-0.371**	-2.20	-0.477***	-4.52
Oil tanker		-0.155	-0.84	-0.365***	-3.07
Refrigerated cargo carrier		0.116	0.58	-0.147	-0.98
Container		0.374	1.26	-0.027	-0.14
Others		Ref		Ref	
Flag of registry					
Antigua and Barbuda		-0.265***	-2.73	-0.363***	-4.77
Bahamas		-0.039	-0.36	-0.154*	-1.88
Cyprus		-0.095	-0.72	-0.065	-0.74
Denmark		-0.917***	-8.65	-1.151***	-15.88
Finland		-0.329***	-2.58	-0.323***	-3.59
Germany		-0.841***	-6.48	-1.079***	-13.92
Malta		-0.076	-0.65	-0.186**	-1.98
Netherlands		-0.354***	-3.29	-0.600***	-8.02
Norway		-0.200**	-2.49	-0.413***	-6.65
Russia		-0.074	-0.96	-0.153***	-2.62
Others		Ref		Ref	
Parameters Log-gamma distribution					
A		4.056***	6.94		
b		11.382***	4.87		
Dispersion parameter				0.469***	42.49
Number of observations		4080		4080	
Number of vessels		2131		2131	
Log likelihood		-6442.7		-6457.5	

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



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

Figure 1. Shape of age at inspection profile for the various binomial negative models



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

Figure 2. Shape of age at inspection profile for various types of vessel (binomial negative estimates)