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Vessels at risk and the effectiveness of Port State Control inspections

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Vessels at risk and the effectiveness of Port State Control inspections

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Abstract

Port state control regimes have been established more than 30 years ago to help prevent accidents in shipping. These controls are obviously not sufficient to correct or prevent all hazards leading to an accident, but they have played a major role in the general reduction of the number of maritime accidents observed during the last decade. Using data on 42,000 vessels/inspections carried out from 2002 to 2009 by 18 state members of the Indian Ocean Memorandum of Understanding, this paper focuses more closely on the type of deficiencies found during inspections and on changes in these deficiencies over time and between successive inspections.

1.0 INTRODUCTION

Accidents in shipping are caused by the combination of different factors related to, for instance, human error, inclement weather, and technical failure, among numerous others (Jin, Kite Powel, Talley 2008). Port state control regimes, established more than 30 years ago to help prevent such accidents, are defined as “the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules”.

These regulations are contained mainly in provisions under the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS), the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended (STCW), the International Convention for the Prevention of Pollution from Ships, 1973, as amended (MARPOL), the International Convention on Load Lines, 1966 (Load Lines), the International Convention on Tonnage Measurement of Ships, 1969 (Tonnage 69), the Convention on the International Regulations for Preventing Collisions at Sea 1972, as amended (COLREG 72), and the Merchant Shipping (Minimum Standards) Convention, 1976 (ILO Convention No. 147).

These controls are obviously not sufficient to correct or prevent all hazards leading to an accident, but it is posited that they have played a major role in the general reduction of the number of maritime accidents observed during the last decade. The separation between the flag state (flag of registry of the ship), primarily responsible for ensuring the vessel’s compliance with regulatory obligations, and the port state, with a mandate to inspect vessels calling in its ports, lends credibility to the control regime. Furthermore the publication of open and free sources of information on the condition of a vessel gives the possibility for shippers, maritime administrators, and academics to enhance and share general knowledge on individual vessels representing a risk to safety at sea.

This chapter first reviews a series of prior studies on how PSC data is used for the identification of vessels at risk. Then, it provides an original contribution aimed at estimating through an econometric analysis, how the contribution of PSC could be assessed using data on 42,000 vessels/inspections carried out from 2002 to 2009 by 18 state members of the Indian Ocean Memorandum of Understanding (MoU). With respect to the previous studies on this issue, this chapter focuses more closely on the type of deficiencies found during inspections and on changes in these deficiencies over time and between successive inspections.

2.0. VESSELS AT RISK USING PSC DATA: A SURVEY

PSC traces its origins from a memorandum of understanding signed in The Hague between eight North Sea states in 1978. Since then, nine regional MoUs[1] comprising almost all maritime countries in the world have been established to share knowledge and pool resources to inspect vessels that could represent a risk to safety and security at sea. One of the main contributions of these MoUs has been to set up, at a regional level, common criteria or target factors to identify the vessels that should be inspected and based on what practitioners consider as decisive factors to identify vessels at risk. When looking first at these practices, the following conclusions can be drawn.

[1] These 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.

Firstly, the notion of vessels at risk has to be understood as vessels with a high probability of being detained. The reason for such focus is the limited resources in number and time available for inspectors, and their associated cost (Knapp 2007). The authorities in charge of inspection then concentrate most of their effort on vessels that might record deficiencies which pose a clear hazard (i.e., providing grounds for detention) to safety, health, or the environment. Therefore, in deciding which ships to inspect, as in any risk assessment based both on the probability for a risk to occur and its potential consequences, and in a world of limited resources, priority is to be given to high risk vessels.

Secondly, the factors playing on the probability for a vessel to represent a risk at sea, using the terminology of the Paris MoU, can be grouped into two main categories: generic and historic parameters. For the former, the main determinants are the ship's flag of registry, the performance of the classification society or of the recognized organization, the vessel type, and age at inspection. For the latter, the decisive factors are whether the vessel is entering the region for the first time, has been inspected during the last six months, has been detained during a former inspection, the number of deficiencies recorded during last inspection, and actions taken to correct outstanding deficiencies.

Thirdly, with the development over time of more accurate knowledge and information on inspections, new and simplified criterion must be developed and applied in the future. This is reflected in the new Paris MoU inspection regime to be implemented in January 2011 that includes additional generic and historic parameters related to, for instance, the performance of companies involved in the operation of a vessel. The seven criteria[2] to select vessels selected for inspection will be the type of ship, its age, flag, recognized organization, company performance, and number of deficiencies and detentions recorded within the last 36 months.

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[2] With various weights. For more details: http://www.parismou.org/ParisMOU/New+Inspection+Regime/Ship+Risk+Profile/default.aspx

Turning now to economic studies by academics on vessels at risk using PSC data, the focus has been mainly on ways to assess their effectiveness in various ways. First of all on their main objective which is the identification of vessels with a higher probability to be detained due to non-compliance with international regulations, when one could argue that the objective should be to detect vessels with a higher probability to be involved into accidents. Although there are interesting findings on the potential relationship between black-listed flags and casualty rates (Knapp 2007) or on differences between characteristics of vessels at risk using PSC versus casualty data (Degré 2008), the quality of data on casualty, the difficulty in linking the causes of an accident with records from earlier PSC inspections, as well as the difficulty in identifying cases when an accident did not occur because of potential actions taken during an earlier PSC have so far limited the relevance of such analyses.

Another main focus of previous studies has been to investigate the relevance of target factors as applied by inspecting authorities (Knapp 2007, Cariou, Mejia, and Wolff 2007, 2008a, 2008b, 2009, Li, Tapiero, and Yin 2009), to which extent and why results vary from one regional MoU to another (Knapp and Franses 2007, 2008) or amongst countries belonging to a given regional MoU (Cariou and Wolff 2010b). On this issue, if most criteria to retain to identify vessels at risk (age, vessel type…) are very often confirmed by econometric analysis on PSC data, the concern is more on the weight to be given to the various factors. Apart from the Australian Safety Maritime Agency[3], these weights are mainly derived from *ad hoc* expert judgment. Finally, a last recent area of research has been on understanding the effect of PSC over time and on strategies of flag- and class-hopping that may be adopted by shipping operators to avoid controls (Cariou and Wolff, 2010a).

The following sections of this chapter provide an original contribution on how to assess the effectiveness of PSC when differentiating amongst the various types of deficiencies. To do so,

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[3] http://www.amsa.gov.au/Shipping_Safety/Port_State_Control/

a dataset from inspections that took place within the regional Indian Ocean MoU (or IO-MoU) will be used to identify the main factors influencing the various deficiencies recorded during a PSC inspection and then, through a simple dynamic model, to investigate whether a state dependence exists in the probability to observe a given deficiency over time through successive inspections.

2.0. DESCRIPTIVE STATISTICS ON DEFICIENCIES

The dataset we used is made of 42,071 PSC vessel inspections carried out from January 1, 2002 to December 31, 2009 by the 18 countries belonging to the Indian Ocean regional MoU.[4] Every PSC boarding generates a detailed report with information on ship's name, IMO number, flag of registry, recognised organization, vessel type, gross tonnage, deadweight tonnage, year built, type of inspection, date of inspection, date of detention, date of release from detention, place of inspection, inspecting authority, and nature of deficiencies.

Since the data cover a period of eight years, we first describe in Table 1 and Figure 1 the changes in the number of deficiencies and detention rate over time and for the main types of vessels. The mean number of deficiencies per vessel is 2.9 for the entire period, with a maximum of 3.4 in 2008 and a minimum of 2.3 in 2002. No deficiency is recorded in 46.2% of cases. The mean detention rate is 8.4%, with a maximum of 10.0% in 2008 and a minimum of 5.6% in 2002. On average, the data suggest that the trend associated with both deficiencies and inspections is slightly increasing over time.

Insert Table 1 around here

Insert Figure 1 around here

[4] In January 2010, the countries were Australia, Bangladesh, Djibouti, Eritrea, Ethiopia (observer), India, Iran, Kenya, Maldives, Mauritius, Mozambique, Myanmar, Oman, Seychelles, South Africa, Sri Lanka, Sudan, Tanzania and Yemen. For more information on the Indian Ocean MoU, see http://www.iomou.org/

Due to the trade pattern of countries located in the Indian Ocean region, the main vessels inspected are bulk carriers (46.5% of all vessels inspected), general cargo ships (16.8%), tankers (10.2%), and containerships (9%); the "other" vessel types represent less than 5% of inspections in number. Gas carriers (66.8%), oil tankers (62.1%) and refrigerated cargo carriers (60.4%) are the vessel types most likely to record no deficiency. At the same time, refrigerated cargo carriers and general cargo/multi-purpose ships are more often reported with large numbers of deficiencies (at least 5).

For bulk carriers, the condition of vessels appears to be relatively stable with a mean number of deficiencies always comprising between 2 and 3 over the period, and a detention rate between 5-10% every year. Figure 1 also shows interesting patterns with some vessel types (general cargo/multi-purpose ship, Ro-Ro cargo ship or refrigerated cargo carriers) with sensibly higher detention rates, and more specifically from 2006 to 2009.

To analyse the potential differences in terms of deficiencies recorded, 8 categories have been created from the initial data with results presented in Table 2 and Figure 2. These categories are respectively related to certificates, working and living conditions, safety and fire appliances, stability and structure, ship and cargo operations, equipment and machinery, navigation and communication, and management. According to the data, 28.6% of all deficiencies are related to safety and fire appliances, 18.8% on stability and structure and 12.6% on ship and cargo operations. Furthermore, 34.7% of vessels inspected have at least one deficiency related to safety and fire appliance, 25.6% to stability and structure.

Insert Table 2 around here

Insert Figure 2 around here

23,674 inspections (56.2% of all inspections from 2002 to 2009) took place in Australia. According to inspections carried out in that country, 31.8% of all deficiencies are related to safety and fire appliances (Figure 2), followed by navigation and communication (19.8%). In

India (12.1% of inspections), deficiencies related to safety and fire appliances are relatively less frequent (13.6%), while stability and structure deficiencies (21.8% compared with 18.8% for all inspections) are a more common feature for vessels inspected in its ports.

By age at inspection, the various categories represent from 15% (more than 25 years old) to 20.2% (5-9 years old) of all inspections. A tendency exists for the number of deficiencies related to certificates or stability and structure to increase with age. Finally, vessels flying the flag of Panama which accounts for 28.1% of inspections do not present any specific pattern compared to the mean values of deficiencies, as opposed to Russian flagged vessels that record proportionally more deficiencies related to certificates, working and living conditions, and stability and structure.

Finally, Table 3 presents the three most common types of deficiency per vessel either as a single type (for instance safety and fire appliances alone) or as the combination of various deficiencies (for instance a portfolio of occurrence of safety fire appliances together with navigation and communication). For all categories of vessels, deficiencies related to safety and fire appliances, alone or together with stability and structure or navigation and communication, always come as the first type of deficiencies detected. This result should not come as a surprise knowing that deficiencies in this category are usually the ones providing grounds for detention, and consequently, the ones on which inspectors are more likely to concentrate due to their importance and the limited time available for inspection.

Insert Table 3 around here

3.0 ECONOMETRIC ANALYSIS OF DETERMINANTS OF DEFICIENCIES

In what follows, we attempt to explain how the characteristics of the vessels influence the probability to observe a specific deficiency among vessels in bad condition. We therefore exclude all the vessels without deficiency and work at the deficiency level from the sample.[5] Specifically, we estimate a set of Probit models to identify the main determinants for each category of deficiency. We present in Table 4 the marginal effects from these Probit models for the 8 generic categories of deficiencies. These effects indicate the influence of individual variables (age, flag, vessel type, recognized organization, inspecting authorities and year - not reported) on the probability to record a given type of deficiencies amongst all deficiencies detected.

Insert Table 4 around here

The estimated probability of deficiencies related to safety and fire appliances is 28.4% (the corresponding proportion observed from the data is 28.6%), 18.1% for stability and structure (instead of 18.8%) and 12.4% for ship and cargo operation (instead of 12.6%) when considering the three main types of deficiencies. The analysis of the influence of the vessel characteristics on the probability to record a specific deficiency amongst all deficiencies detected provides several interesting findings.

Concentrating first on the influence of age, the reference category of vessels (less than 5 years old) exhibits a higher probability of a deficiency related to the certificates, to ship and cargo operations, to navigation and communication, and to management (negative signs for other age categories) than older vessels. In contrast, age plays a positive influence for working and living conditions, safety and fire appliances, stability and structure, equipment and machinery. This first result suggests a differentiated influence of the age of vessel, and confirms that its influence mainly plays on the general condition of a vessel (stability and structure for instance). When the vessel is relatively new, documentation (certificates), navigation and

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[5] A vessel with several deficiencies contributes for several observations in our sample. Our sample is retrieved from data on 121,319 deficiencies detected during the 42.071 inspections from 2002 to 2009. Standard errors are clustered at the vessel level when estimating the regressions.

communication equipment and management (ISM related deficiencies) are the main types of deficiencies detected.

Across the various types of deficiency, the flag of registry of a vessel has a limited impact on the probability to record a specific deficiency, with the notable exception of Russian vessels for which a relatively better situation exists for working/living condition (+4.6% compared with the reference category of “other” flags) and relatively worst for safety and fire appliances (-4.9%) and equipment and machinery (-3.1%). Turning to the influence of the vessel type, and concentrating on the most recurrent sources of deficiencies, the probability to have a deficiency related to safety and fire appliance is higher when the vessel is a woodchip carrier (+9.9%), gas carrier (+6.5%) and chemical carrier (+6%). This result is interesting since it shows, especially when considering the risk of a fire, that more efforts are probably deployed by inspectors on specific vessels for which the consequences of an incident might be more severe. As a consequence, more deficiencies are likely to be detected given these increased efforts. Another illustration can be found in the specific case of refrigerated cargo carriers for which ship and cargo operation (+4.7%) and equipment and machinery (+3.3%) are important to insure the continuity of the “cold chain.” Again, these vessels are probably subject to more stringent inspections and regulations.

When considering the influence of the recognized organization, the societies identified in our sample achieve relatively higher performance compared to smaller societies gathered within the “other” category. This is particularly true for certificates and management related deficiencies and for the China Classification Society. Finally, a differentiated impact according to where the inspection takes place exists. For instance, the probability to record a deficiency on safety and fire appliances is higher when inspections are taking place in Australia (+9.4%), South Africa (+6.3%) or India (+5%) than in other places, while opposite conclusions hold for instance for stability and structure related deficiencies (-6.7% in

Australia for instance). The observation of country-specific effects is puzzling but could simply suggest that Port State authorities identify specific priorities when inspecting a vessel calling at one of their ports.

To conclude, this descriptive analysis provides an insight into the influence of the various parameters on the type of deficiencies detected. Furthermore, it shows how the outcome of the inspection, most probably due to the focus of the inspector, is in a way influenced by the potential consequences from a deficiency. The safety and fire related deficiencies for gas carriers or chemical carriers and of ship and cargo operations for refrigerated cargo ship represent here some illustrations.

4.0 ECONOMETRIC ANALYSIS OF A STATE DEPENDENCE ON DEFICIENCIES OVER TIME

An element which has not been subject to much attention in the previous literature is the existence of a state dependence in the vessel conditions, and more broadly on transition states (see Cariou, Mejia, Wolff 2008a for an exception). This is especially relevant when considering the various types of deficiencies. In what follows, we inquire into how inspections influence the dynamics of deficiencies over time.

To do so, we focus on the different type of deficiencies using data at the vessel level. We seek to estimate the influence of the various characteristics on the probability for a vessel to record a given deficiency in t. Apart from the former parameters (vessel age, type…), we introduce additional historical parameters. In particular, we control for the state of the vessel during the previous inspection (in t-1) and construct a dummy variable which is equal to one when the same deficiency was recorded during a former inspection (and 0 otherwise).

This implies that our sample was selected in order to consider only vessels subject to at least two inspections during the period of observation. This reduces the size of our sample from

42,071 to 28,330 vessels. Results on the various transition states between two successive inspections (t-1 and t) are presented by type of vessels in Figure 3. When a vessel did not record any deficiency in t, only two initial states exist in a former inspection: either the same number in t-1 (no deficiency or Nt=Nt-1), or more deficiencies in t-1 (Nt>Nt-1). Now, when the vessel is found with deficiencies in t-1, three possibilities exist in t: fewer deficiencies (Nt<Nt-1), same number (Nt=Nt-1), or more deficiencies (Nt>Nt-1).

Insert Figure 3 around here

Results for all vessels show that around 55% of vessels without deficiency in t did not have any deficiency in t-1. For vessel with deficiencies in t, more than 60% of vessels had more deficiencies in t-1, around 10% the same number and 30% had more deficiencies in t-1. These numbers evidence a positive trend of improvement in the condition of vessels between two successive inspections (which was expected). Two additional results are of interest. First, this pattern holds for the various types of vessels, which are always in relatively good condition when inspected. Secondly, there are few differences in the “effectiveness” of the controls. For instance, gas carriers and Ro-Ro cargo ships in bad condition in t-1 record in more than 70% of cases less deficiencies in t, but the proportion is about 55% for general cargo/multi-purpose ships[6].

Insert Figure 4 around here

We perform the same analysis by types of deficiency in Figure 4. We again find evidence of a state dependence effect. For instance, in more than 80% of the cases, a vessel without deficiency on certificates will never have any of deficiency belonging to this category during the next control. Similar conclusions hold for working and living condition, equipment and machinery or management. Concerning the other categories of deficiency, such as for instance

[6] When considering the vessels that have no deficiency in t-1, we find that bulk carriers have the highest propensity to record more deficiencies in t (50% remain with no deficiency in t, but 50% of them have more deficiencies in t).

safety and fire appliances, or navigation and communication, we find a more contrasted pattern. The proportion of vessels without deficiency both in t-1 and t is around 50%, 40% with a deficiency either in t or t-1, and 10% with the same deficiency both in t-1 and t.

To further understand the impact of the vessel characteristics on the transition from one state to another one, we estimate Probit regressions to explain the probability for a vessel to have a specific deficiency as a function of the lagged existence of that deficiency for the 8 categories of deficiencies. The corresponding marginal effects are presented in Table 5.

Insert Table5 around here

As suggested by our previous descriptive results, the econometric analysis confirms the presence of a strong state dependence in the vessel condition over time. The intensity of the state dependence is measured through the lagged value of deficiency[7]. This relative persistence in the condition of vessels is particularly strong for working and living condition (+16.4%), safety and fire appliances (+16.9%), stability and structure (+15.7%), and ship and cargo operations (+15.6%). Conversely, it is less important for more administrative related duties like certificates or management, the lagged coefficient being not significant in the Probit regression for the latter category. This result could be expected for vessels in bad condition, where the status might have a tendency to remain fairly stable, while in the case of management and documentary deficiencies, compliance might be more volatile but easier to correct over time.

Another interesting finding from our estimates is, apart from the initial condition of a vessel, the relative importance of two additional characteristics: the age and the type of vessel. For the former, older vessels have a higher probability to record deficiencies related to the general seaworthiness of a vessel (+40.4% for stability and structure, +30.6% for equipment and machinery when the vessel is more than 25 years old). Furthermore, the older vessels are

[7] The lagged value associated to the vessel condition is introduced in an exogenously way in the regression.

more likely to keep the same type of deficiency in t that was already found in t-1. This finding holds for deficiencies related to certificates, safety and fire appliances, stability and structure (at the 10% level), and navigation and communication. The correction of such deficiencies is undoubtedly more expensive for older vessels.

Concerning the type of vessel, gas carriers have a lower probability to have a specific deficiency, regardless of the type of deficiency. The inverse is observed for bulk carriers and general cargo/multi-purpose ships. However, when considering the crossed terms given by type of vessel, a negative coefficient is found for bulk carriers with respect to certificates, working and living conditions, safety and fire appliances, stability and structure, and ship/cargo operations. This means that bulk carriers are more likely to improve their condition with respect to these categories between two successive inspections. For Ro-Ro cargo ships and oil tankers, deficiencies associated to equipment and machinery and navigation and communication are more likely to increase over time which suggests that problems associated with these types of deficiencies are more difficult to solve or that a ship-owner is ready to take the risk of not correcting the deficiency as it will unlikely to lead to a future detention.

5.0 SUMMARY

The review of studies on PSC inspections and their use to identify vessels at risk shows that if a general consensus exist on the main factors influencing the probability for a vessel to be detained during an inspection, several complex issues to investigate remains. The weight to be given to the various factors, the harmonization of controls within and amongst various regional PSCs is clearly one of them.

This chapter provides an investigation on another complex issue, the effectiveness of PSC. Despite the fact that a general consensus exists on the fact that more than 30 years after their creation, PSCs have played a major role in the enhancement of safety at sea in general, only few studies have tackled the complex issue of measuring the effectiveness of PSCs. In presenting one way of doing so, through the persistence of deficiencies over time for a given vessel in general and by type of deficiencies, this chapter provides various preliminary answers and advocates for more research on understanding in which ways PSC are playing a decisive role for shipping safety.

References

Cariou, P., Mejia, M.Q.Jr., Wolff, F-C., (2007) An econometric analysis of deficiencies noted in Port State Control inspections. *Maritime Policy and Management* ***34*** (3): 243-258.

Cariou P., Mejia, M.Q.Jr., Wolff, F-C., (2008a) On the effectiveness of port state control inspections. *Transportation Research Part E* ***44***: 491-503.

Cariou, P., Mejia, M. Q. Jr., Wolff, F-C., (2008b) Port state control inspection and vessel detention, Port State Control. In Talley W.K. (eds) *Maritime Safety, Security and Piracy.* Informa LLP.

Cariou, P., Mejia, M.Q. Jr. M., Wolff, F-C., (2009) Evidence on target factors used for port state control inspections. *Marine Policy* **33**(5): 847-859.

Cariou, P., Wolff, F-C. (2010a) Do Port State Control influence Flag and Class-Hopping phenomena in Shipping. *Journal of Transport Economics and Policy*, forthcoming.

Cariou, P., Wolff, F-C., (2010b) La détention des navires par les Etats du Port: Une application uniforme des règles ? *Annuaire de Droit Maritime Océanique*, under review.

Degré, T. (2008) From Black-Grey-White detention-based lists of flags to Black-Grey-White casualty-based lists of categories of vessels, using a multivariate approach. *The Journal of Navigation* **61**(3): 485-497.

Jin, D., Kite Powel, H., Talley, W.K. (2008) US ship accident research. In Talley W.K. (eds) *Maritime Safety, Security and Piracy.* Informa LLP.

Knapp, S., (2007) *The econometrics of maritime safety – recommendation to enhance safety at sea*. Doctoral Thesis, Erasmus University, Rotterdam.

Knapp, S, Franses, PH. (2007) A global view of port state control: econometric analysis of the differences across port state control regimes. *Maritime Policy and Management* **34**: 453-484.

Knapp, S, Franses, PH. (2008) Econometric analysis to differentiate effects of various ship safety inspections. *Marine Policy* **32**: 653-662.

Li, K. X., Tapiero, C. S., Yin, J. (2009) Optimal Inspection Policy for Port State Control (PSC). *Proceedings of the International Association of Maritime Economists 2009*, Copenhagen, 23-26 June.

Table 1. Number of deficiencies during inspection, by type of vessel

Type of vessel	Number of deficiencies detected during the inspection					
	0	1	2	3	4	≥5
Bulk carrier	42.4	12.9	15.7	13.0	8.4	7.6
General cargo/multi-purpose ship	36.0	12.5	13.3	12.9	10.7	14.6
Oil tanker	62.1	10.1	9.7	7.6	4.8	5.7
Containership	57.4	12.5	12.0	8.2	5.4	4.6
Chemical tanker	50.2	12.4	12.8	10.8	5.6	8.3
Vehicle carrier	56.9	14.0	13.4	6.9	5.2	3.6
Woodchip carrier	45.6	18.4	19.3	10.6	3.6	2.4
Refrigerated cargo carrier	60.4	7.0	7.8	8.5	5.9	10.4
Ro-Ro cargo ship	55.2	7.3	9.1	11.2	7.9	9.3
Gas carrier	66.8	12.0	11.0	6.6	2.1	1.5
Other	42.4	12.0	14.0	12.5	9.7	9.4
All	46.2	12.4	13.9	11.5	7.8	8.2

Source: own calculations, Indian Ocean MoU 2002-2009

Table 2. Type of deficiency, by year of inspection

Year of inspection	2002	2003	2004	2005	2006	2007	2008	2009	All
Distribution of deficiencies (in %)									
Certificates	7.2	6.3	5.9	4.5	4.2	4.4	4.9	4.9	5.2
Working/living conditions	7.1	6.0	6.5	7.5	8.5	6.2	7.4	7.0	7.1
Safety/fire appliances	30.7	28.4	28.5	29.2	28.1	29.1	28.4	27.0	28.6
Stability/structure	18.6	22.8	21.9	19.0	19.0	18.0	16.5	15.8	18.8
Ship/cargo operations	13.2	13.1	12.3	13.7	12.0	12.3	12.3	12.3	12.6
Equipment/machinery	4.4	4.3	4.2	6.2	5.3	6.7	6.9	7.0	5.7
Navigation/communication	16.5	15.9	16.3	14.4	18.8	18.6	18.6	20.3	17.6
Management	2.3	3.3	4.4	5.6	4.2	4.8	5.1	5.6	4.5
% of vessels concerned by:									
Certificates	12.2	10.4	9.9	7.6	8.0	8.9	10.2	10.1	9.7
Working/living conditions	10.6	11.0	11.6	14.5	16.3	13.2	15.6	15.0	13.5
Safety/fire appliances	30.0	32.5	34.0	35.9	36.5	36.0	36.5	36.9	34.7
Stability/structure	21.7	26.6	27.6	25.6	26.4	26.5	26.0	24.8	25.6
Ship/cargo operations	19.4	21.1	20.9	22.9	21.4	23.1	22.9	23.0	21.8
Equipment/machinery	6.7	7.6	7.9	10.9	10.9	13.3	13.8	13.6	10.5
Navigation/communication	21.6	23.2	25.2	24.4	28.8	28.6	29.8	31.4	26.6
Management	4.4	6.7	8.9	11.4	10.2	10.7	12.4	12.8	9.7
Number of vessels inspected	5431	5072	5642	5180	5087	4791	5593	5275	42071

Source: own calculations, Indian Ocean MoU 2002-2009

Table 3. Portfolio analysis of deficiencies, by type of vessel

Type of vessel	Most frequently observed combination of deficiencies
Bulk carrier	(1) Safety/fire appliances (7.0%) (2) Navigation/communication (5.5%) (3) Safety/fire appliances + Stability/structure (4.9%) (4) Safety/fire appliances + Navigation/communication (4.7%)
General cargo/multi-purpose ship	(1) Safety/fire appliances (4.3%) (2) Stability/structure (4.1%) (3) Safety/fire appliances + Stability/structure (3.8%) (4) Navigation/communication (3.5%)
Oil tanker	(1) Safety/fire appliances (7.0%) (2) Stability/structure (4.7%) (3) Navigation/communication (3.9%) (4) Ship/cargo operations (3.9%)
Containership	(1) Safety/fire appliances (10.5%) (2) Navigation/communication (6.0%) (3) Safety/fire appliances+ Navigation/communication (4.8%) (4) Ship/cargo operations (3.8%)
Chemical tanker	(1) Safety/fire appliances (7.8%) (2) Navigation/communication (4.8%) (3) Ship/cargo operations (3.6%) (4) Safety/fire appliances+ Navigation/communication (3.1%)
Vehicle carrier	(1) Safety/fire appliances (10.1%) (2) Safety/fire appliances+ Navigation/communication (6.2%) (3) Navigation/communication (5.9%) (4) Ship/cargo operations (4.5%)
Woodchip carrier	(1) Safety/fire appliances (11.3%) (2) Safety/fire appliances+ Navigation/communication (5.5%) (3) Safety/fire appliances + Equipment/machinery (4.2%) (4) Navigation/communication (4.5%)
Refrigerated cargo carrier	(1) Safety/fire appliances (3.2%) (2) Safety/fire appliances + Stability/structure + Ship/cargo operations + Equipment/machinery + Navigation/communication (2.9%) (3) Safety/fire appliances + Ship/cargo operations + Navigation/communication (2.5%) (4) Working/living conditions + Safety/fire appliances + Stability/structure + Ship/cargo operations + Equipment/machinery + Navigation/communication (2.2%)
Ro-Ro cargo ship	(1) Safety/fire appliances + Stability/structure + Navigation/communication (2.8%) (2) Certificates (2.8%) (3) Safety/fire appliances (2.3%) (4) Navigation/communication (2.3%)
Gas carrier	(1) Safety/fire appliances (5.5%) (2) Navigation/communication (4.9%) (3) Safety/fire appliances + Navigation/communication (4.7%) (4) Ship/cargo operations (2.3%)
Other	(1) Safety/fire appliances (5.1%) (2) Certificates (3.6%) (3) Stability/structure (3.5%) (4) Navigation/communication (3.3%)

Source: own calculations, Indian Ocean MoU 2002-2009

Table 4. Determinants of the various deficiencies – marginal effects from Probit regression

Explanatory variables	Certificates	Working/ living conditions	Safety/fire appliances	Stability/ structure	Ship/cargo operations	Equipment /machinery	Navigation /commu-nication	Management
Age at PSC inspection								
0-4	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
5-9	-0.014***	0.008*	0.038***	0.033***	-0.014***	0.016***	-0.017***	-0.009***
10-14	-0.015***	0.025***	0.041***	0.093***	-0.030***	0.030***	-0.048***	-0.016***
15-19	-0.020***	0.039***	0.046***	0.122***	-0.044***	0.045***	-0.068***	-0.017***
20-24	-0.027***	0.047***	0.051***	0.134***	-0.049***	0.047***	-0.079***	-0.022***
25+	-0.021***	0.045***	0.037***	0.138***	-0.054***	0.046***	-0.079***	-0.025***
Flag of registry								
Panama	-0.001	-0.004*	-0.000	-0.001	0.002	-0.002	-0.001	0.006***
Liberia	-0.005	-0.005	0.013	-0.006	-0.010*	-0.002	0.010	0.003
Hong Kong China	-0.012***	0.014***	-0.001	0.003	-0.009*	0.007*	-0.006	0.004
Bahamas	0.001	-0.003	0.016*	-0.003	-0.009	0.005	-0.010	0.005
Cyprus	0.006	-0.002	0.015*	-0.004	-0.003	-0.005	-0.012*	0.004
Singapore	-0.009***	0.005	0.009	0.027***	-0.013**	0.003	-0.014**	-0.000
Russian Federation	0.005	0.046***	-0.049***	0.023*	0.031**	-0.031***	-0.023**	-0.002
Malta	0.003	-0.002	0.011	-0.004	-0.011**	-0.001	0.001	0.004
Greece	0.003	-0.028***	0.001	-0.025**	0.000	0.009	0.025**	0.015***
Others	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Type of ship								
Bulk carrier	-0.048***	0.008**	0.025***	0.049***	-0.033***	-0.002	0.003	0.013***
General cargo/multi-purpose ship	-0.029***	0.005	0.013	0.034***	-0.025***	0.001	0.010	0.014***
Oil tanker	-0.022***	0.004	0.038***	-0.013	0.014**	-0.000	-0.019**	0.020***
Containership	-0.028***	0.009	0.036***	0.038***	-0.025***	0.018***	-0.021**	0.007
Chemical tanker	-0.024***	0.002	0.060***	-0.013	0.003	0.007	-0.025***	0.019***
Vehicle carrier	-0.028***	0.033***	0.048***	-0.063***	0.014	-0.000	-0.007	0.014**
Woodchip carrier	-0.024***	0.010	0.099***	0.017	-0.023**	-0.024***	-0.031**	0.004
Refrigerated cargo carrier	-0.030***	-0.019***	0.033*	-0.016	0.047***	0.033***	-0.023*	0.017**
Ro-Ro cargo ship	-0.008	0.000	0.011	-0.022	-0.033***	0.010	0.035**	0.004
Gas carrier	-0.024***	-0.001	0.065***	0.002	-0.044***	0.032*	0.006	0.002
Others	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Recognised organization								
Nippon Kaiji Kyokai	-0.019***	0.015***	-0.002	0.007	-0.001	0.005*	0.004	-0.007***
Lloyd's Register	-0.011***	0.008**	0.006	0.001	-0.005	0.021***	-0.009	-0.005**
Det Norske Veritas	-0.012***	0.002	0.013*	0.006	-0.001	0.019***	-0.008	-0.009***
American Bureau of Shipping	0.001	0.010**	0.002	0.002	-0.007	0.008**	-0.007	-0.006**
Germanischer Lloyd	-0.009***	0.006	0.006	-0.016**	-0.004	0.015***	0.006	-0.001
Bureau Veritas	-0.008***	0.004	-0.005	0.011	0.000	0.011***	-0.004	-0.004
Russian Maritime Register	-0.016***	0.028***	0.003	0.017	-0.013*	0.027***	-0.029***	-0.012***
China Classification Society	-0.025***	0.037***	0.008	0.044***	-0.022***	0.017***	-0.037***	-0.015***
Korean Register of Shipping	-0.021***	0.004	0.015*	0.021**	-0.016***	0.012**	-0.007	-0.002
Others	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Inspecting Authority								
Australia	-0.075***	-0.024***	0.094***	-0.067***	0.043***	0.006	0.047***	0.011*
Iran	-0.019***	-0.012	0.017	-0.031**	0.069***	0.057***	-0.023*	-0.011*
India	-0.021***	-0.037***	0.050***	-0.021*	0.012	0.027***	0.066***	-0.022***
South Africa	-0.023***	-0.030***	0.063***	0.017	0.018	-0.000	0.044**	-0.029***
Others	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Estimated probability	0.041	0.068	0.284	0.181	0.124	0.051	0.171	0.039

Source: own calculations, Indian Ocean MoU 2002-2009

Note : Probit regressions also include a set of year dummies. The size of the sample is N=121319 deficiencies. Standard errors are clustered at the vessel level and significance levels are respectively 1% (***), 5% (**) and 10% (*).

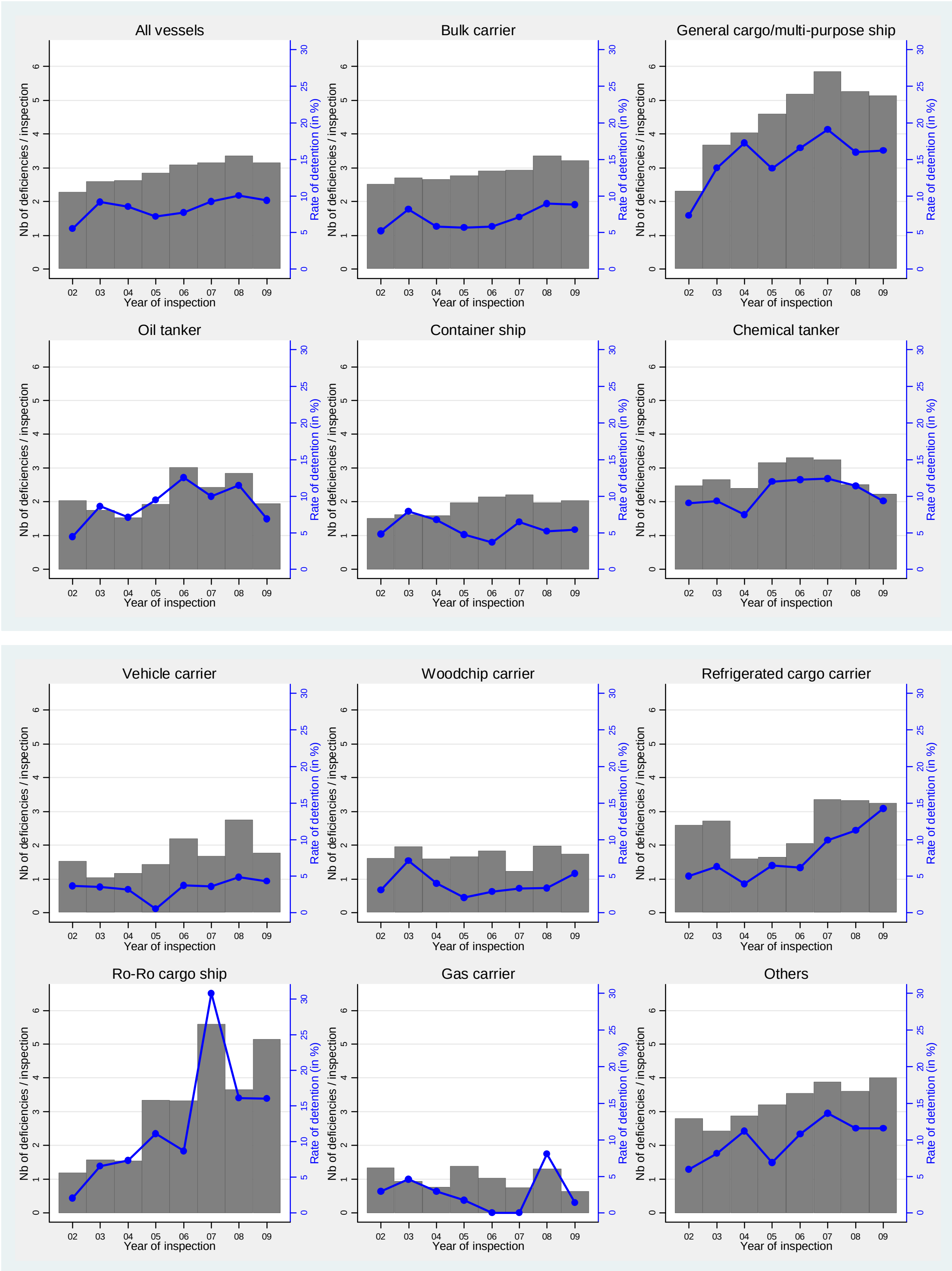
Table 5. Estimates from transition to and from deficiencies – marginal effects from Probit regression

Explanatory variables	Certifi-cates	Working/ living conditions	Safety/fire appliances	Stability/ structure	Ship/cargo operations	Equipment /machinery	Navigation /commu-nication	Mana-gement
Existence of the same deficiency								
Def t-1 (lagged value)	0.061*	0.164***	0.169***	0.157***	0.156***	0.111*	0.072**	0.061
Age at inspection								
0-4	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
5-9	0.005	0.061***	0.115***	0.118***	0.051***	0.057***	0.039***	0.022***
10-14	0.020***	0.115***	0.176***	0.224***	0.075***	0.105***	0.064***	0.021***
15-19	0.042***	0.157***	0.233***	0.307***	0.100***	0.155***	0.090***	0.048***
20-24	0.082***	0.224***	0.272***	0.358***	0.138***	0.220***	0.124***	0.040***
25+	0.130***	0.282***	0.263***	0.404***	0.181***	0.306***	0.133***	0.061***
Age at inspection * Def t-1								
5-9 * Def t-1	0.032	-0.022	0.023	-0.002	-0.018	-0.031	0.034	-0.008
10-14 * Def t-1	0.029	-0.032	0.019	0.004	-0.009	-0.041*	0.042*	0.022
15-19 * Def t-1	0.032	-0.007	-0.001	-0.000	-0.009	-0.031	0.021	-0.023
20-24 * Def t-1	0.027	-0.039*	0.009	0.005	-0.030	-0.034	0.004	-0.010
25+ * Def t-1	0.068**	-0.027	0.111***	0.064*	0.023	-0.018	0.135***	-0.010
Type of ship								
Bulk carrier	-0.023***	0.047***	0.106***	0.136***	0.031**	0.036***	0.070***	0.039***
General cargo/multi-purpose ship	0.027***	0.050***	0.061***	0.119***	0.036**	0.055***	0.057***	0.010
Oil tanker	0.003	-0.024**	-0.036*	-0.016	-0.045***	-0.001	-0.080***	-0.024**
Containership	-0.019**	-0.002	0.003	-0.003	-0.029*	0.035***	-0.028	0.000
Chemical tanker	-0.001	0.042**	0.069***	0.063**	0.033	0.058***	0.003	0.010
Vehicle carrier	-0.045***	0.004	0.003	-0.100***	-0.023	-0.016	-0.030	0.008
Woodchip carrier	-0.033***	0.014	0.101***	0.030	-0.011	-0.032**	-0.048*	-0.012
Refrigerated cargo carrier	-0.038***	-0.049**	-0.019	0.014	0.021	0.077***	-0.049	-0.029
Ro-ro cargo ship	0.022	0.014	-0.043	-0.054*	-0.026	0.002	-0.043	-0.021
Gas carrier	-0.034***	-0.072***	-0.083**	-0.076**	-0.111***	-0.012	-0.095***	-0.069***
Others	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Type of ship * Def t-1								
Bulk carrier * Def t-1	-0.023*	-0.036*	-0.076***	-0.073***	-0.059***	0.011	-0.022	-0.003
General cargo * Def t-1	-0.001	0.002	-0.034	-0.002	-0.011	0.058*	0.014	0.047
Oil tanker * Def t-1	0.025	0.029	-0.028	0.039	0.067*	0.137***	0.095**	0.065
Containership * Def t-1	-0.021	-0.008	0.016	-0.016	-0.064**	0.008	-0.021	0.046
Chemical tanker * Def t-1	0.007	-0.044	0.011	0.039	-0.037	0.040	0.026	0.020
Vehicle carrier * Def t-1	-0.014	-0.050	-0.083**	-0.000	-0.055	-0.081***	0.008	-0.089***
Woodchip carrier * Def t-1		-0.006	-0.064	-0.129***	-0.093**	-0.004	0.062	0.017
Refrigerated cargo * Def t-1	0.019	-0.058	-0.132**	-0.062	-0.013	0.027	0.106	0.042
Ro-ro cargo ship * Def t-1	0.058	0.019	-0.015	0.096	0.031	0.198**	0.143**	-0.017
Gas carrier * Def t-1		0.012	-0.069	0.044	-0.062	0.052	-0.005	0.088
Estimated probability	0.071	0.129	0.360	0.245	0.214	0.092	0.269	0.103

Source: own calculations, Indian Ocean MoU 2002-2009

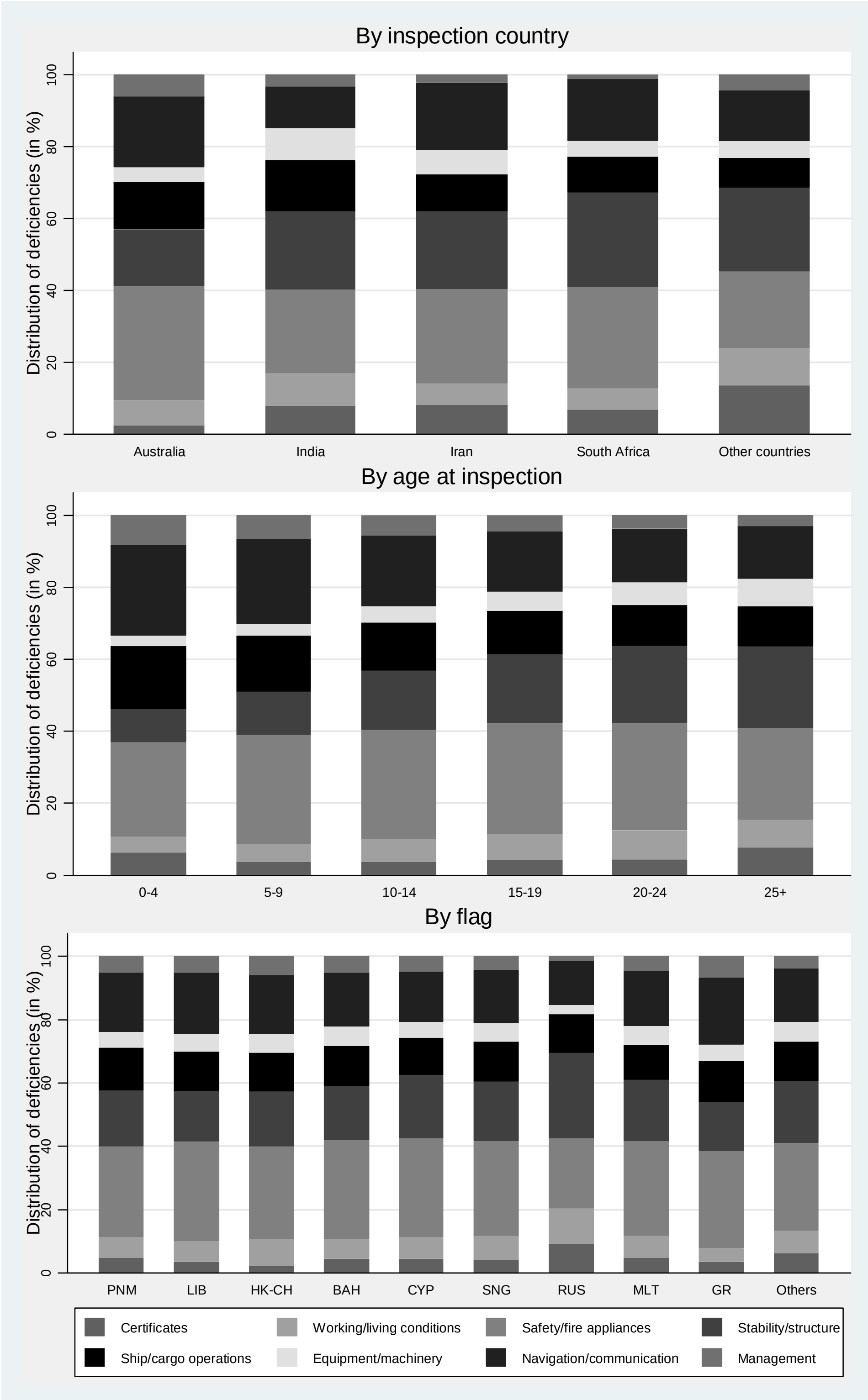
Note : Probit regressions also include a set of year dummies. The sample is N=28330 vessels subject to repeated inspections. Standard errors are clustered at the vessel level and significance levels are respectively 1% (***), 5% (**) and 10% (*).

Figure 1. Changes in number of deficiencies and detention rate over time



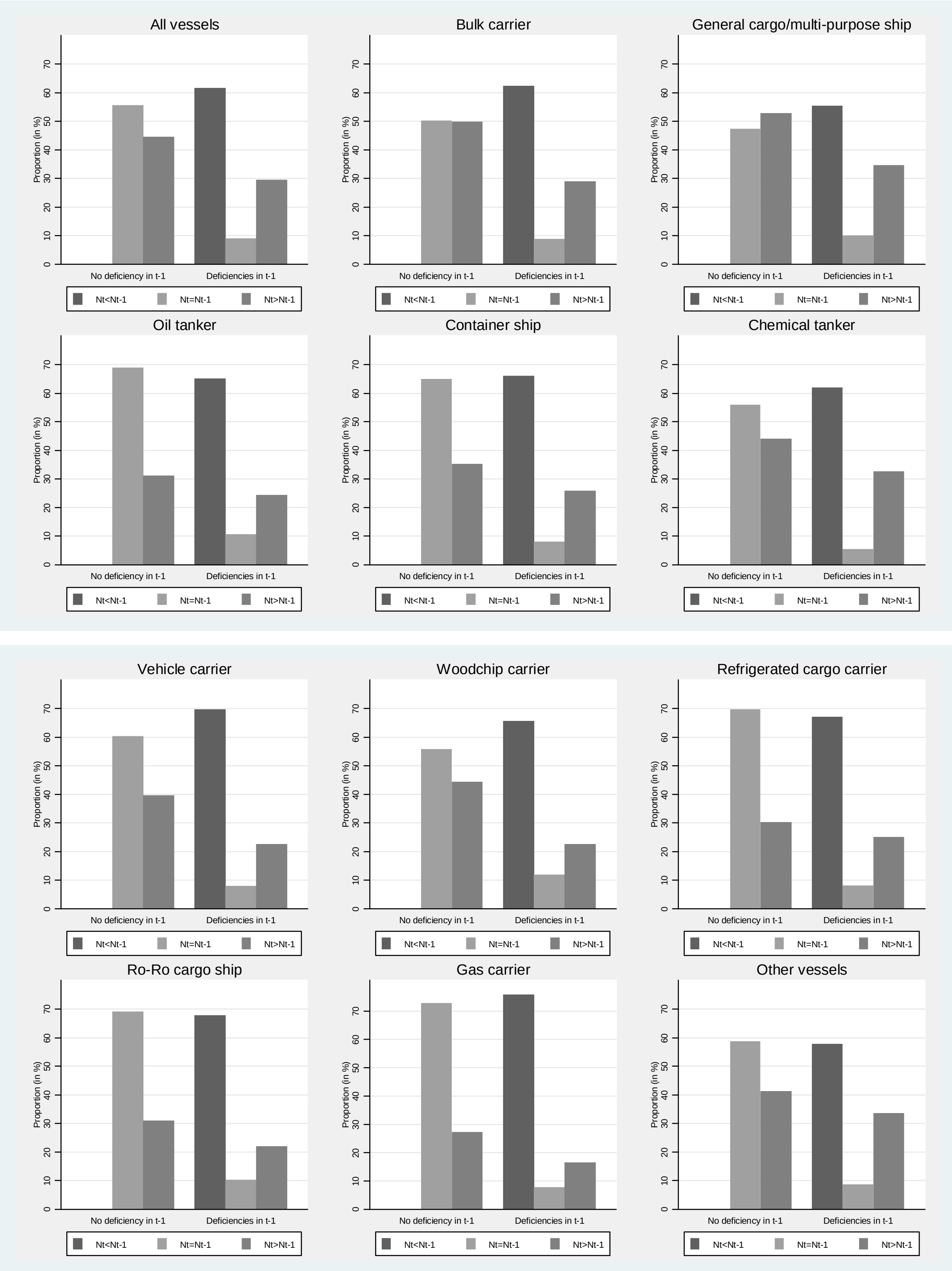
Source: own calculations, Indian Ocean MoU 2002-2009

Figure 2. The pattern of deficiencies from PSC over time



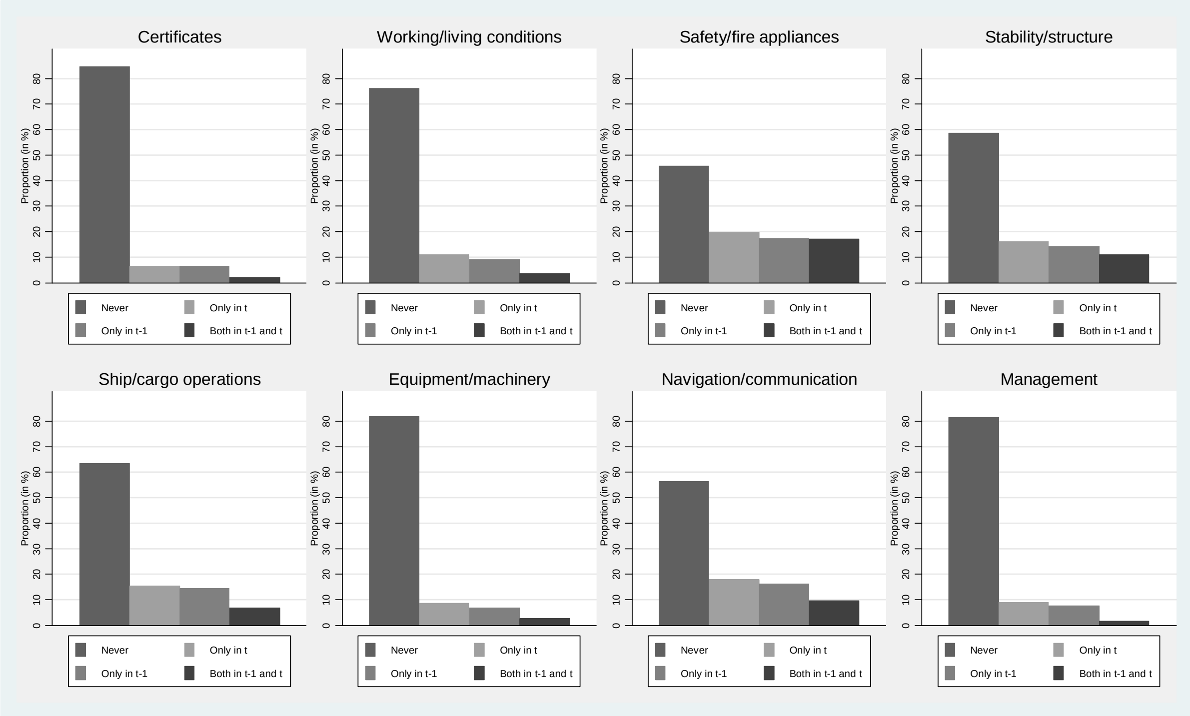
Source: own calculations, Indian Ocean MoU 2002-2009

Figure 3. Changes in number of deficiencies between two successive inspections



Source: own calculations, Indian Ocean MoU 2002-2009

Figure 4. Changes in occurrence of a given type of deficiency between two successive inspections



Source: own calculations, Indian Ocean MoU 2002-2009