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ORIGINAL ARTICLE

Timing of environmental inspections: survival of the compliant

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Abstract Environmental inspection agencies have limited resources. A natural response to this shortage of resources is targeting and this targeting policy leads to higher compliance than random inspections. This paper uses individual inspection data on the inspection policy of the environmental agency for the textile industry in Flanders (Belgium). We distinguish between three types of inspections and use a survival model to show that the environmental agency inspects firms in a non-random way. Even though the agency solves most environmental problems, it can increase compliance by using the deterrence effect of more stringent inspections and sanctions.

Keywords Environmental regulation · Monitoring and enforcement · Survival analysis · Textile industry

JEL Classifications K42 Illegal behavior and the enforcement of law · Q53 Water pollution · C41 Survival analysis

1 Introduction

Environmental inspection agencies have limited resources. On a regular basis we find pleas for more funds and more staff in the media. Within their given budget it is impossible for the environmental agency to inspect all firms frequently. A natural response to this shortage of resources is targeting. The agency will inspect those firms it suspects of being non-compliant with the environmental rules or

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those firms that are major polluters. This targeting policy leads to higher compliance with regulations than random inspections of firms. In this paper we address two empirical questions: (1) does the Flemish environmental inspection agency (AMI) use targeting? and (2) which factors influence this targeting policy?

One of the first to address this targeting approach of environmental inspections was Harrington (1988). He shows how an enforcement agency can enhance deterrence by dividing regulated firms into two groups according to their past compliance record. The firms are divided into what Harrington labels 'good' firms and 'bad' firms. The environmental agency devotes most of its resources to inspect the firms in the target group or 'bad' group. Therefore, bad firms face high inspection probabilities and high expected fines. By complying they can return to the good firm category. By contrast, good firms can afford to violate the rules because they are infrequently monitored and face low expected penalties. As Friesen (2003) puts it, "the 'stick' of stricter enforcement and the 'carrot' for compliance combine to make stronger incentives to comply than a simple random auditing framework". Subsequent papers have considered the robustness of Harrington's results under asymmetric information (Raymond, 1999), the social optimality implications (Harford, 1991; Harford & Harrington, 1991), and alternative explanations for high compliance rates such as self-reporting (Livernois & McKenna, 1999) and regulatory dealing (Heyes & Rickman, 1999). The optimal targeting scheme in Harrington's theoretical framework is derived by Friesen (2003) and she finds that firms should be moved at random[1] into the target group. Escape from the target group occurs only when an inspection reveals that the firm is in compliance.

Several empirical papers have estimated the link between past compliance and expected inspections and have looked for evidence of targeting. Harrington's initial model has been translated as targeting that occurs based on the compliance status in the last quarter(s) (Stafford, 2002), on the predicted compliance status of the firm (Gray & Deily, 1996; or Laplante & Rilstone, 1996) or on warnings issued (Eckert, 2004).

For example, Gray and Deily (1996) use data on individual steel plants to study the relationship between regulator's enforcement of air pollution regulations and firms' compliance decisions in the United States. They find that compliance behavior influenced enforcement decisions. Steel plants, which anticipated being in compliance, faced less enforcement, measured either by total enforcement actions or by inspections. Moreover, regulators directed less pressure toward plants expected to close and toward plants in attainment areas, while exerting more pressure on plants producing large absolute amounts of pollution, irrespective of their compliance status.

Helland (1998) also provides empirical evidence on the role of targeting in regulatory compliance. He finds that targeting produces more cooperation, in the form of self-reporting, although it does not deter violations. What targeting

[1] By randomly selecting firms for the target group the agency can save on inspections in the non-target group. The incentives for compliance are unaffected because an appropriate adjustment is made to the transition structure between the groups (Friesen, 2003).

does, is to encourage pulp and paper firms in the US to report violations they detect and take steps to correct them. However, the author concludes that, due to interest-group politics, "targeting does little to speed up compliance and is hindered by political factors".

The use of inspections and warnings to enforce environmental regulations is examined by Eckert (2004). The author finds evidence that past warnings increase the probability of an inspection more than do past findings of non-compliance. Also the probability of an inspection decreases the probability of a violation. Moreover, the paper shows that warnings are used to group Canadian petroleum storage sites according to their compliance history. Warnings can be used as a targeting device, and can, therefore, deter future violations through the threat of stronger enforcement.

In this paper we analyze individual inspection data to establish whether AMI uses a targeting approach. We focus on the length of time that firms in the textile industry in Flanders (Belgium) have to wait before they are inspected by the environmental inspection agency. Given that a firm has not been inspected for t periods, what is the probability that it will be inspected in the next interval of time? If the agency adopts a targeting approach, we can expect the probability that a targeted firm is inspected in the next period to be higher than for a non-targeted firm. We use a survival model[2] to determine whether firms are inspected in a non-random way, and to investigate which aspects influence the probability of inspection.

By using survival analysis, we avoid one shortcoming of the methods applied in previous studies, i.e. we do not waste a lot of interesting information about the individual inspections. After all, in 25% of the observed quarters more than one inspection occurs.[3] The previous empirical papers all use quarterly and, therefore, aggregated data. Typically, a 0/1 variable indicates whether a firm was inspected during that quarter or not. The inspections data are also treated as belonging to one category and not divided into several subcategories. This is not in line with the procedures followed by the Flemish environmental inspection agency, whose monitoring efforts are divided between several categories. As mentioned in its yearly reports, the Flemish inspection agency distinguishes routine and reactive inspections as well as project-related inspections.[4]

[2] Survival analysis (Cox & Oakes, 1984) was previously used by Nadeau (1997) to model the EPA's effectiveness at reducing the duration of plant-level non-compliance. The results of this paper indicate that the EPA is effective at reducing the non-compliance period of pulp and paper plants. Moreover, Nadeau also shows that the EPA follows separate enforcement strategies based on compliance status; i.e. the EPA uses a targeting approach. However, inspections were estimated as a Poisson process based on quarterly data.

[3] This high inspection frequency is not a general feature of Flemish environmental inspection but is specific for our dataset. As a large industrial sector, the textile industry contributes significantly to water pollution in Flanders.

[4] Also the United States Environmental Protection Agency (US EPA) conducts several types of audits. For example, as stated in Heyes (2002), it conducts 'compliance evaluation inspections' (CEIs) and 'compliance sampling inspections' (CSIs) to enforce industrial effluent standards. CEIs involve a cursory inspection on a single day. A bad result in a CEI triggers a CSI, which involves 30–50 days of detailed sampling and analysis of discharge.

It, therefore, makes little sense to add the three types of inspections into one category and treat all inspections alike. The Flemish environmental inspection agency (AMI) clearly reports that the inspection decision is influenced by different factors for each category. Routine inspections for water ((AMI, 2003), p. 100) are determined by the waste load that is discharged, the receiving medium of the discharge, the presence of hazardous pollutants, the available budget, and personnel. Reactive inspections are answers to complaints, calamities, questions from the public prosecutor, parliamentary questions, evaluation of temporary licenses, and some other things. Finally, project-related inspections are chosen by the headquarters in Brussels and are part of specific monitoring and enforcement campaigns, which are both well defined in time and in content. They focus on sectors, on problem companies or on a specific pollutant or medium.

These differences between inspection types appear clearly in our results when we look at the timing of the site visits. Therefore, we estimate the factors that influence each inspection decision separately. These estimations confirm the different treatment of the three categories. However, our results do not fully coincide with the rules stated by AMI.

Regarding the characteristics of the three types of inspections, our paper shows the following. First, routine inspections of textile firms do depend on previous inspections, on the firm's capacity and on the firm's compliance history. Larger firms are more frequently inspected. Firms that were in violation during the previous inspection but did not receive a notice of violation (NOV), are also more likely to be inspected. Firms that were in violation three inspections ago, however, were less likely to be routinely inspected. Second, reactive inspections depend on previous inspections and on previous compliance behavior. Firms that received a NOV two check-ups ago are more likely to receive a follow-up inspection. Surprisingly, firms that were given a NOV during the previous inspection are less likely to be inspected. As we explain later, this is probably due to the procedural aspects associated with a NOV. Third, project related inspections depend on previous inspections.

As articulated by the Flemish environmental inspection agency (AMI), our results show that AMI uses a targeting approach to select firms for site visits. However, the aspects that are important in the targeting policy are not exactly the same as the inspection strategy mentioned by the agency itself.

2 The institutional setting

Next we provide some background information on the Flemish environmental institutions. We focus on the Flemish environmental inspection agency (AMI) and the Flemish environmental agency (VMM).

First, the Flemish[5] environmental inspection agency ('Afdeling Milieu-Inspectie') formulates its main objective as *'inspecting and sanctioning polluters in order to improve environmental quality'*. The agency has several means at its

[5] Belgium as a federal state consists of three regions: Flanders, Wallonia and Brussels Capital.

disposal to fulfill this goal. These include, as was previously mentioned, three types of monitoring activities of interest for us: routine inspections, reactive inspections and regulatory projects.

Moreover, the environmental agency can also use enforcement instruments to protect the environment. It can issue advices, warnings or notices of violations.[6] An advice is given to recommend the firm to make sure that the present situation of compliance with regulations continues in the future.[7] A warning, on the other hand, is provided to instruct the firm to end the present situation of non-compliance and abide with all appropriate laws, decrees, and permits. A NOV[8] formally documents a violation. This document can be used as evidence in a court of law and a copy is send to the Public Prosecutor. Moreover, the agency can also use administrative sanctions, such as making a motivated proposal to the administration in power to suspend or withdraw the firm's environmental permit.

Second, the Flemish environmental agency ('Vlaamse Milieumaatschappij') prepares and adjusts environmental policy making through research and measurements. It reports on the quality of the environment in general and controls the quality of surface waters in particular. The Flemish environmental agency also collects taxes on wastewater and on the extraction of groundwater. The environmental inspection agency AMI is responsible to check if firms do not tamper with the measurements, which are necessary to calculate these taxes and are performed by VMM.

To sum up: the Flemish environmental agency is an important actor in implementing the Flemish environmental policy. It complements the actions of AMI by collecting effluent charges and taking measurements. Moreover, VMM can be an important source of data for the inspection agency. Although in reality, the interaction between the two institutions is fairly limited.

3 Econometric methodology

We investigate whether targeting is part of the Flemish environmental inspection policy and we analyze which characteristics make it more likely that a particular firm is inspected. We use survival analysis to make inferences about the length of time between two environmental inspections. In a survival model we estimate the probability of remaining in a particular state for t periods. In this paper we are looking at the probability that a firm is inspected by

[6] The use and definitions of these enforcement instruments can be found in art. 30 of the Environmental Permit Decree and art. 64 of Vlarem I.

[7] In practise this instrument is also used for minor administrative violations (such as the presence of a fire safety report) and to enforce previously issued warnings. In our sample, 19 of 20 advices follow a violation.

[8] Internal regulations of AMI state that the civil servants do not always have to issue a NOV when violations are discovered. They have the power to evaluate the situation and use their professional competences to decide on the level of precaution and care displayed by the firm. However, a warning will always be sent to the firm if a violation was detected.

the environmental agency at time t, given that it has not been inspected for t periods. This method allows us to make assumptions about how factors, such as past compliance behavior, affect the probability of being inspected. If the firm's past compliance behavior significantly increases the audit probability, we can say that the agency uses targeting to select firms for an environmental audit.

Let the spell length, or the time between two inspections, be represented by the random variable T. Suppose that T has a continuous distribution $f(t)$ and cumulative $F(t)$, where t is a realization of T.

The probability that the spell is of length t or larger is given by the survival function

$$S(t) = 1 - F(t) = \text{prob}(T \geq t).$$

Next we consider the hazard rate

$$\lambda(t) = \frac{f(t)}{S(t)}.$$

Roughly, the hazard rate is the rate at which spells are completed after duration t, given that they last at least until t. In our model the hazard rate represents the probability that a firm is inspected after not being inspected for t periods.

We follow Cox's (1972) approach to the proportional hazard model to analyze the effect of covariates on the hazard rate. The model specifies that

$$\lambda(t_i) = \mathrm{e}^{-\beta' x_i} \lambda_0(t_i).$$

The function λ_0 is the 'baseline' hazard, which represents individual heterogeneity. In principle, the hazard rate is a parameter or a function for each observation that must be estimated. Let x be a set of regressors[9] that explain the length of time until inspection. Cox's partial likelihood estimator provides a semi-parametric method of estimating the coefficients β without requiring estimation of λ_0. For a more detailed exposition on proportional hazard models see Cox and Oakes (1984), Hosmer and Lemeshow (1999) or Greene (2000).

We estimate a recurrent event model since an environmental inspection can take place multiple times in the course of the follow-up of a firm. A potential problem occurs since the inspection agency and the firms can be viewed as making decisions about enforcement and compliance simultaneously. If not accounted for, this may bias the results of the estimations. We assume that the firms only review their compliance status after an inspection has taken place. In

[9] Regressors or covariates are naturally introduced as conditioning variables in the hazard. This poses no problem even when the covariates are endogenously time-varying, as long as the hazard at t is conditioned only on variables that are known at t. The situation where some of the explanatory variables depend on time, implies that the hazard ratio is no longer constant over time. The model is no longer a proportional hazard model and is referred to as a Cox regression model. In this contribution no time-varying covariates are used.

the interval between inspections, this compliance status is assumed to stay constant. Moreover, since we work with individual data, simultaneity is less of an issue than with aggregated data. For this reason, we can estimate the inspection function separately from the compliance function.

4 Data

First we describe the dataset we use for the empirical analysis and illustrate some interesting findings. Next we provide some descriptive statistics.

4.1 Description of the dataset

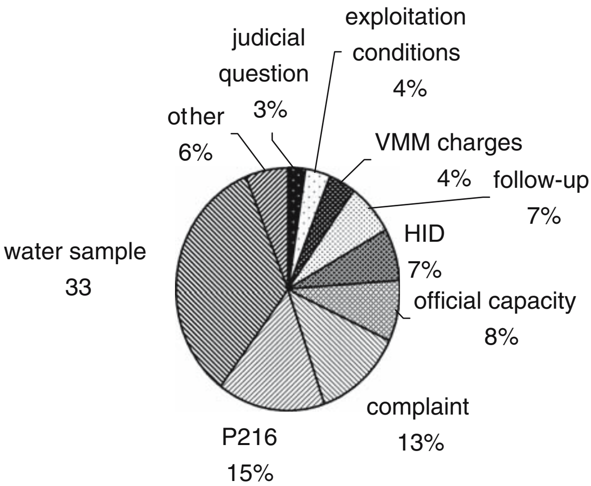
During the summer of 2003, we collected data gathered by the Flemish environmental inspection agency (AMI). Within the framework of internal project P216, AMI performed a complete environmental audit of 41 textile improvement and carpet production companies. Historically, most of the Flemish textile industry has always been located in East and West Flanders. The firms included in our sample are situated in West Flanders (21), East Flanders (18), and Limburg (2). The database contains information about 1800 inspections completed by the environmental inspection agency between 1991 and 2003. Per inspection we gathered data on its characteristics (type, cause, and timing) and on its results (violations and enforcement actions).

Two third of the inspections were water related. Water pollution is indeed the main environmental problem for textile companies. We also look at the cause of the inspection (see Fig. 1) as stated on the administrative inspection report. Most site visits were aimed at taking routine water samples. Also during the project P216 'Integrated audit of textile improvement companies', several inspections were performed. The project started in 2001 and ended in 2003. These project related inspections, which often included water samples, account for 15% of all inspections included in the database. AMI often receives complaints about firms included in the sample and, as a consequence, 13% of the inspections were triggered by complaints. Furthermore the administration inspected firms to follow-up on advices and warnings (7%) and to check special conditions in the firms' exploitation licenses (4%). The inspection agency also performed check-ups (4%) of VMM measurements, which were performed to calculate the effluent charges. Finally, some inspections (7%) were performed following a request of the headquarters in Brussels (HID) and 'in their official capacity'[10] (8%).

These different types of inspections do not all require the same amount of resources. In Appendix A, we summarize the average duration of an audit per type. These averages include the time needed to get to the site and back to the office as well as the actual time spent on the firms' premises. Inspections

[10] Since all inspections are actually performed in their official capacity, AMI has stopped using this terminology. The same applies for the 'HID' inspections.

Fig. 1 Causes of inspections



performed to follow-up on VMM measurements and to take routine water samples take just under an hour of the inspectors' time on average. The duration of inspections executed as part of the P216 project, on the other hand, is twice as long. These inspections are more thorough and systematic. Overall, an inspection took on average 77 min.

Next, we consider the number of inspections performed per year (see Fig. 2). The peak in 2002 is clearly due to the project P216. The smaller number of inspections before 1995 is no reflection of reality. For several firms, the files were no longer complete. Moreover, in those days the agency did not yet keep its records in an electronic format. Finally, we may not forget that the environmental inspection agency (AMI) was only founded in 1991[11] and it took at least 2 years to get the administration fully functioning.

We now look at the compliance status of the firms during the inspections (Fig. 2). We found that over the years at least 25% (1992) and at most 66% (1999) of the firms were compliant. Over the complete database, we found that 47% of the firms were found to be compliant during an inspection. The violations that were detected include: missing documents such as maintenance reports or fire safety reports, incomplete or missing exploitation licenses, violations of emission standards for one or more water pollutants, air pollution (gases, smoke or bad smell), oil spills, and inaccessibility of measuring points.

We also investigated the enforcement actions taken after or during an inspection, which found a firm in violation. In spite of the many violations, we did not encounter any administrative sanctions. AMI, for instance, did not send any motivated proposals to the administration in power to suspend or withdraw

[11] Before 1991 only one administration was responsible for both issuing permits and enforcement. Most of its resources, however, were used to deal with permit requests or with modifying them and not with monitoring and enforcement.

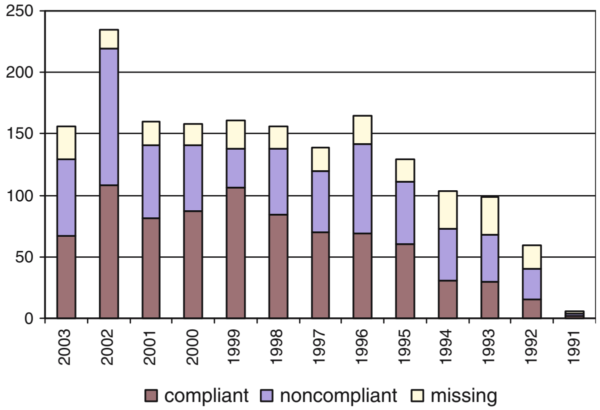


Fig. 2 Number of inspections per year and compliance status

the firm's environmental permit. These instruments are, however, legally at the disposal of the environmental agency.

After detecting a violation the inspection agency took some type of enforcement action in 20–30% of the cases. This does not mean that the agency only reacts to 20% or 30% of total violations. After all, it might take several visits—during which the firm is in violation—to formally prove the violations. For example:

Visit 1: water sample 1 is taken
Visit 2: results of sample 1 are discussed: one or more parameters indicate a violation of less than 100% of the emission standard and therefore a second water sample[12] is taken
Visit 3: results of sample 2 are discussed: violation of one or more parameters is confirmed ⇒ NOV and warning are issued

It is also plausible that after the NOV accompanied by a warning has been issued, the firm's violation will continue for quite some time. After all, it often takes time to comply. Requesting a new or extended license can take months. Building a new water purification station can even take years. Throughout this period, the agency is likely to pay some follow-up visits. During these visits they find the firm in violation (which they already knew) and take no further action (because they already did).

In Table 1 we analyze what happens after an inspection that found a firm in violation and focus, more specifically, on the monetary penalties imposed. As mentioned above, in the majority (72%) of the cases no enforcement action was taken. We concentrate on the notices of violations that are issued, since a copy of those is always sent to the Public Prosecutor in order to start legal prosecution. These violations can potentially lead to monetary penalties.[13]

12 The requirements under which such a second sample is necessary can be found in art.4.2.6.1 of Vlarem II.

13 Rousseau and Billiet (2005) study criminal fines for environmental violations in Flanders in more detail.

Table 1 Enforcement action for non-compliant firms in Flemish textile industry

Non-compliant during inspection	Enforcement action taken		Information on follow-up[14]		Legal consequence		Average monetary penalty
709	NOV	140	Info	69	Court of appeal	2	7165 Euro
					First instance	15	2869 Euro
					Settlement	16	260 Euro
					Dismissal	36	0
			No info	71			
	Warning	38					0
	Advice	21					0
	No action	510					0

In our sample, only 25% of the cases (17 out of 69) are actually brought to trial. In 23% of the cases (16 out of 69) a settlement is negotiated and the remaining cases (52%) are dismissed without further consequences. Looking at the average monetary penalty, we see that the average settlement amount is 260 Euro, the average fine at the first instance is 2869 Euro and the average fine at the Court of Appeal is 7165 Euro.

The monetary penalty for violating environmental regulations in Flanders is apparently limited. There must be other motivations for firms to comply with environmental policies. First, firms also have to pay taxes; an effluent fee that depends on the concentrations of pollutants in their wastewater. Second, textile firms have sizeable incentives to recycle their wastewater and to minimize water use during production. These incentives are generated by the tightening of the Flemish groundwater policy. Firms are only allowed to pump up limited amounts (specified in their permit) of groundwater and they have to pay an annual groundwater tax, which is also collected by VMM, for the water they use. Finally, it is possible that firms are complying in order to avoid bad publicity or because the firm culture is an ethical and environment-friendly one.

4.2 Descriptive statistics

First, we define the different variables needed in order to estimate the probability that a firm receives a site visit. Next, we divide our sample into three types of inspections and look at the composition of the three sub samples. Finally, we examine the direction of the effects we can expect on theoretical grounds.

4.2.1 Definitions

In Table 2 the different variables used in the estimations are defined.

[14] We process here the information received by AMI on the follow-up on NOVs by the Prosecutor's office.

Table 2 Definition of the variables

Variable	Description
DURATION	Days between two inspections
INSPYEAR	Number of inspections in previous year
COMPLAINT	= 1 if a complaint was issued against firm
P216	= 1 if inspection was performed for project P216
COMP1/2/3/4	= 1 if firm was compliant 1/2/3/4 inspections ago
VIOL1/2/3/4	= 1 if firm was in violation 1/2/3/4 inspections ago and no enforcement action was taken
WARNING1	= 1 if agency issued a warning one inspection ago
NOV1/2/3/4	= 1 if agency issued NOV 1/2/3/4 inspections ago
ADVICE1	= 1 if agency gave an advice one inspection ago
IMPROVE	= 1 for independent textile improvement firms
CAPACITY	Firm's capacity for pre-treatment and dyeing in ton/day
SEWER	= 1 for discharge in sewer system
RETURN	Net return on firm's total assets
AMIPERS	Number of people working at the regional inspection agency

Table 3 Description of sample

	Reactive	Routine	Project	Total[17]
Number of observations	332	859	192	1685
Mean DURATION (in days)	60.7	103.6	66.9	93.4
Median DURATION (in days)	35.5	74.0	34.0	57.0

4.2.2 Descriptive statistics

We divide our sample into three types: reactive, routine, and project related inspections. For each category, we estimate the probability that a particular firm is inspected, if it has not been inspected[15] for t previous periods. This allows us to identify the variables used by AMI to select firms for audits.

Table 3 gives the mean and median of the variable DURATION for each of the three categories. Overall, the average time between two inspections is 93 days or 3 months, while the median is only 57 days or slightly less than two months. A Kruskal–Wallis test of the hypothesis that the median time between inspections is identical for the three groups of inspections can be rejected.[16]

15 The type of the previous inspection does not matter.

16 The Kruskal–Wallis test (K–W test) for differences in medians is, for example, explained in Berenson, Levine, and Krehbiel (2002). The K–W test requires that all observations are independent. This independence assumption might be violated for our sample. The number of observation for each group were 331 (reactive), 789 (routine) and 192 (project). The level of significance of the test was smaller than 1%.

17 Since we do not know the type of inspection for all our observations, the sum of the observations belonging to the three different categories does not equal the total number of observations.

In Table 4 we represent the composition of the three samples. AMI states that complaints were the main reason for almost 60% of the reactive inspections. We also see that over 60% of routine inspections consist of water samples. Not surprisingly given the biased nature of our sample, the project related inspections are dominated by project P216 'The integrated audit of textile improvement firms'.

4.2.3 Expected signs

In order to examine which firm characteristics might influence the inspection decision, we investigate each of the variables in Table 5 and look at their potential as a targeting variable. We start by discussing four variables in general since their expected signs do not depend on the type of inspection. First, the variable INPSYEAR will probably pick up firm characteristics that are not included in the analysis but that influence the likelihood of being examined by AMI. Examples of these unobservable plant characteristics are the social norms of the managers, the environmental awareness of the plant's neighbors, and the skills of the workers. We can expect a positive coefficient for this variable. Also, however, if the plant was inspected often before (INPSYEAR), this could be

Table 4 Composition of the different samples (in %)

Reactive		Routine		Project	
Complaint	57.9	Water samples	60.8	P216	78.1
Follow-up	31.7	Official capacity	14.1	Other	21.9
Prosecutor's office	9.8	Headquarters	11.7		
Other	0.6	VMM charges	5.6		
		Exploitation conditions	4.4		
		Acoustic measurements	1.3		
		Air samples	1.1		
		Other	1.0		
Total	100	Total	100	Total	100

Table 5 Expected signs

	Reactive	Routine	Project
INSPYEAR	+	+	+
COMPLAINT	?	n/a	n/a
P216	n/a	n/a	+
COMP1/2/3/4	n/a	n/a	–
VIOL1/2/3/4	?	+	n/a
WARNING1	+	+	n/a
NOV1/2/3/4	+	+	n/a
ADVICE1	+	+	n/a
IMPROVE	–	–	–
CAPACITY	?	?	?
SEWER	–	–	–
RETURN	–	–	n/a
AMIPERS	+	+	n/a

n/a = not applicable

because it is known to be a bad performer. A significant and positive coefficient for the variable INSPYEAR might be proof of targeting.

Second, the firms in our sample belong to two subsectors of the textile industry, textile improvement and carpet production, and we expect to see a difference between the two firm types. The average composition of the wastewater discharged by the two sectors (see Appendix B) shows that, overall, carpet production tends to be dirtier than textile improvement. The environmental agency could, therefore, focus on the dirtier firms, since they can be expected to have higher marginal benefits for the environmental agency.[18] Increasing compliance at those firms will have a higher impact on the environmental quality. Hence, we can expect a negative sign for the variable IMPROVE that relates to the less dirty firms.

The size of the firm is also an important factor and is measured by the variable CAPACITY. Larger firms potentially produce more pollution and are a likely target for the inspection agency. However, they might be more complex and thus more costly to inspect. Usually, larger firms are also better informed and have more resources to spend on abatement. The influence of firm size on inspection frequency is, therefore, ambiguous.

Finally, it will also be important whether the firms discharge in the sewer system or in surface waters (directly or indirectly).[19] Since the effluent disposed in sewers is carried to water treatment plants for additional treatment, the environmental agency can find it beneficial to target firms that discharge in surface waters instead. The impact on environmental quality is possibly greater. As a result, we expect a negative sign for the variable SEWER.

We now discuss each category separately since we do not estimate exactly the same variables for each type of inspection (see Table 5).

Reactive inspections are answers to complaints, questions from the public prosecutor, parliamentary questions, and evaluations of temporary licenses. It is possible that the inspection agency reacts differently, i.e. slower or faster, to complaints than to other causes of reactive inspections. Internal regulations of the Flemish inspection agency state that complaints must be followed by a site visit within 3 months. Since the average time between the previous inspection and a reactive inspection is 60 days or 2 months, we cannot predict the sign of the variable COMPLAINT.

Reactive inspections triggered by questions from the public prosecutor on NOVs or by follow-up requirements, imply that the firm must have been in violation previously. We expect a positive sign for WARNING1, NOV1/2/3/4 and ADVICE1. We cannot, however, predict the coefficient of variables VIOL1/2/3/4 since no enforcement action was taken as a response to these violations.

18 In this model, the environmental inspection agency does not take the compliance costs of firms into account. Its goal is not an efficient allocation of the abatement costs but minimising environmental damages (see objective functions mentioned in yearly reports).

19 In our sample half of the firms discharge in surface waters while the other half discharge in the sewer system.

We also look at the influence of the financial situation of the firm through the variable RETURN. Firms with more financial resources presumably spend more on information gathering and emission abatement. This implies a negative coefficient for RETURN. We also assume that there will be more reactive inspections if there is more staff available in the environmental inspection agency. As a result, we expect a positive sign for the variable AMIPERS.

Routine inspections for water are, according to the yearly report of ((AMI, 2003), p. 100), determined by the waste load that is discharged, the receiving medium of the discharge (sewers vs. surface waters), the presence of hazardous pollutants in the wastewater and the available budget and personnel. For our estimation, this implies a positive sign for the variable AMIPERS and a negative sign for SEWER.

The history of a firm's compliance is also a matter of concern to the environmental agency. The agency can perceive the benefits of targeting firms with a poor compliance history to outweigh the associated increase in costs. As mentioned in the introduction, empirical evidence[20] has already shown that environmental inspection agencies (in US and Canada) often target firms based on their compliance history. The firm's compliance history can possibly influence the routine inspections and we can expect a positive sign for VIOL1/2/3/4, WARNING1, NOV1/2 and ADVICE1. Analogously to the reactive inspections, we expect a negative coefficient for the financial variable RETURN.

Finally, project related inspections are chosen by the headquarters in Brussels and focus on one firm, sector or technology. For example, the project P216 'Integrated audit of textile improvement companies', realized in 2002, allowed us to collect our data. During the course of such a project the firms under consideration are inspected more frequently and more thoroughly (see Appendix A). Since P216 implied a thorough scanning of the textile firms, we can expect more frequent inspections in this project than for other projects in our sample, which have more specific objectives (e.g. removal of PCB transformers). We expect, therefore, a positive sign for the variable P216. We anticipate a negative coefficient for the variable COMP1/2/3/4. It is, after all, plausible that firms with more past violations are more likely to be selected to participate in a project.

5 Results

In order to find evidence on targeting and how it is done, we estimate the probability that a textile firm is inspected after not having been inspected for t periods (i.e. the hazard rate). Because of the limited data in the beginning of our time period (see Sect. 4.1), we exclude the inspections performed in 1991 and 1992 from our sample.

First we present the estimation results we obtained. Next we discuss the difference in timing between the different types of inspections.

[20] See, for example, Gray and Deily (1996), Nadeau (1997), Helland (1998) and Eckert (2004).

Table 6 Estimation of probability of inspection

	Reactive		Routine		Project	
	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
INSPYEAR	**0.086*****	0.0000	**0.192*****	0.0000	**0.096*****	0.0000
P216					−0.034	0.8664
COMP1					−0.028	0.8948
COMP2					−0.081	0.7166
COMP3					0.259	0.2614
COMP4					−0.109	0.6347
VIOL1	0.009	0.9528	**0.291*****	0.0079		
VIOL2	**0.347****	0.0308	0.004	0.9749		
VIOL3	−0.082	0.6034	**−0.321*****	0.0062		
VIOL4	0.195	0.2041	0.036	0.7219		
WARNING1	0.678	0.1721	−1.355	0.1754		
NOV1	**−0.496***	0.0545	−0.138	0.4783		
NOV2	**0.708*****	0.0059	−0.042	0.8204		
NOV3	0.212	0.4720				
NOV4	−0.433	0.1004				
ADVICE1	−0.557	0.3872	0.176	0.5757		
COMPLAINT	**0.467*****	0.0059				
IMPROVE	0.040	0.7875	0.129	0.1888	−0.023	0.8992
CAPACITY	−0.003	0.3832	**0.006*****	**0.0009**	0.004	0.4154
SEWER	−0.226	0.1153	0.026	0.7746	0.069	0.7201
RETURN	0.018	0.1274	0.001	0.8884		
AMIPERS			0.003	0.8440		
	Number of observations = 214		Number of observations = 540		Number of observations = 148	
	Log likelihood function = −1047		Log likelihood function = −2760		Log likelihood function = −585	
	Restricted log lik. = −1087		Restricted log lik. = −2864		Restricted log lik. = −597	

***, **, * = significant at 1%, 5%, 10% level

The results in Table 6 show that the Flemish environmental inspection agency uses targeting and that its targeting behavior differs for the three samples. Hence, we examine the three types of inspections separately.

First, reactive inspections depend on previous inspections, on previous compliance behavior and on received complaints. The variable INPSYEAR probably picks up some unobservable firm characteristics, such as management practices or specific characteristics of the firm's location, that were not included in the analysis but that influence the likelihood of being examined by AMI. If firms, which are often inspected during the past year, are labeled as bad environmental performers, the positive sign of INSPYEAR could be an indication of targeting. The relative instantaneous probability that a firm with one (two)inspection(s) in the previous year will be inspected is $e^{0.086} = 1.089$ ($e^{2(0.086)} = 1.187$) times higher than the inspection probability for a similar firm without any previous inspections. Thus at each moment in time, the hazard rate for firms with one (two) previous inspection(s) is 8.9% (18.7%) higher than the hazard rate for firms without previous checkups.

Surprisingly, we find that firms, which received a NOV during the previous check-up (NOV1), are less likely to receive a follow-up reactive inspection. Their inspection probability decreases with 39% with respect to similar firms, which did not receive a NOV during the previous inspection. However, a closer look at the procedure that starts with a NOV clarifies the matter. A NOV is always accompanied by a warning. In this warning the agency states the precise nature of the violation and determines a time period during which the firm has to return to compliance. Typically firms get a certain amount of time (three, six, twelve or even more months) to rectify the situation depending on the complexity of the corrective measures needed. Within this time frame the environmental agency will not inspect firms to follow up on the violation.[21] The violation is, after all, already detected and legal prosecution has been initiated. As mentioned in Table 3 the average time between a previous inspection and a reactive inspection is 60 days. This explains why we obtain a negative relationship between the probability of being inspected and the fact that firms have received a NOV at their previous inspection. However, we do see that firms, which received a NOV two inspections ago, have a 103% greater probability of being inspected than firms who did not receive such a notice.

Firms, which were in violation two periods ago but did not receive a related enforcement action (VIOL2), are more likely to receive a reactive visit. The inspection probability increases with 41%. It is, after all, plausible that, only after a second visit, the violation was properly documented and a NOV was issued. After this action the follow-up of this problem belongs to the reactive inspections.

If a complaint was issued, the firm has a higher probability of receiving a reactive inspection. The timing between the previous inspection and a reactive inspection following a complaint is smaller than the time between the previous inspection and a reactive inspection not following a complaint.

Several of our variables turned out insignificant. The firm's previous violations without any enforcement action (VIOL1/3/4), the firm's financial status (RETURN), the sector (IMPROVE), the medium into which the firm discharges (SEWER) and the size of the firm (CAPACITY) do not appear to influence the occurrence of reactive inspections.

Second, routine inspections of textile firms depend on previous inspections, on the firm's capacity and on the firm's compliance history (Table 6). Larger firms, with a larger pre-treatment and dyeing capacity, are more frequently inspected. Each ton of daily capacity extra increases the instantaneous hazard rate, i.e. the inspection probability at each moment, with 0.6%. Firms that were in violation during the previous inspection but did not receive a notice of violation (VIOL1) are also more likely to be inspected. The coefficient of VIOL3 is negative. After all, it takes two site visits to clarify the detected situation. If a violation is formally proven, the follow-up will fall under the reactive inspections

[21] Other inspections are, however, still possible.

and fewer routine inspections will be performed. This reasoning is analogous to the one applied to the coefficient of VIOL2 for reactive inspections.

Notice that the probability of a routine inspection does not depend on the medium in which the firm discharges its wastewater. The coefficient for the variable SEWER is not significant. The yearly reports of AMI, however, state that routine inspections take into account whether the firm discharges in surface water or in the sewer system. We also do not find a positive influence of the size of the agency's staff (AMIPERS) on the probability of a routine inspection. Again, we cannot corroborate the statement in AMI's yearly report that routine inspections depend on personnel available. The reason for this result might be that the inspection agency gives priority to inspecting textile firms. After all, the results published by VMM (VMM, 2003) show that the textile industry is an important contributor to surface water pollution in Flanders. The textile industry is the third largest contributor for discharges of chemical oxygen demand (COD), total phosphorus and total nitrogen, after the food and chemical industry. For total chrome it is even the largest industrial discharger in Flanders.

Finally, the fact that the firm received a NOV during the previous inspection (NOV1/2), the financial position of the firm (RETURN) and the sector (IMPROVE) do not seem to influence the probability that the plant will be routinely inspected.

Third, project related inspections[22] depend only on previous inspections. Since we look only at one sector and since projects are usually defined by headquarters in Brussels, this result could be expected. The factors that influence the set-up and selection of projects cannot be determined by our sample. This is due to the sample selection bias introduced in our sample by only using firms that were audited during project P216.

Finally, we discuss the variables the Flemish environmental inspection agency uses to target its inspections. With respect to the reactive inspections we cannot talk about targeting since these site visits are by definition reactions to questions, previous enforcement actions or complaints. In a way, however, one could say that AMI targets firms for which it receives complaints since these firms are always inspected within 3 months. Due to insufficient data, we cannot discuss targeting for project related audits. However, we can talk about targeting if we look at routine inspections. Firms with a higher capacity or firms, who were in violation during the previous inspection without having received any enforcement action, are more likely to be routinely inspected. This is in line with previous empirical studies.

6 Conclusions

The inspection agency has an important role to play in determining the effectiveness of environmental regulations. Using a limited budget, the agency might want to bring as many firms into compliance as possible or it might want to

[22] We do not include the variables AMIPERS and RETURN since they were highly correlated.

reduce emissions as much as possible. Theory shows that selecting firms based on past behavior or firm characteristics can greatly increase overall compliance relative to randomly inspecting firms. This monitoring policy is called targeting. Our empirical exercise shows that the Flemish environmental inspection agency (AMI) indeed uses targeting to select the textile firms it will routinely inspect. This selection is based on past compliance behavior and on the firm's capacity.

The Flemish inspection strategy is very effective when it comes to problem solving but it does not fully exploit the deterrence potential of targeting (see also (Billiet & Rousseau, 2005)). Firms are inspected more frequently as long as the environmental problem persists. Once it is solved, however, firms receive only routine inspections, which do not depend on previous notices of violation. Harrington (1988) assumes that firms' escape probability from the 'bad' group (with higher inspection frequency) is smaller than one, even if they were found to be compliant at the latest inspection. Apparently, the policy applied in Flanders implies that this probability is equal to one. Higher deterrence could be achieved by lowering the probability of returning to the 'good' group. The environmental inspection agency is able to solve most violations given enough time. However, it would be possible to use the deterrence effect of targeting—of inspecting and sanctioning offenders more stringently—and to obtain more compliance in the industry.

We analyze individual inspection data and focus on three different inspection types. Obviously, reactive, routine and project-related inspections are treated differently by the inspection agency. The estimation results for each category are quite different. We can, therefore, conclude that previous studies where different types of inspections are treated identically disregard a lot of interesting information. Moreover, aggregating the inspection data makes the interpretation of the results difficult.

If we look at the result for the routine inspections, we see that it does not coincide completely with the officially stated inspection policy of the Flemish environmental inspection agency. They point out in their yearly reports that routine inspections for water are determined, among others, by the receiving medium of the discharge and the available personnel. We, however, could not find any evidence of these reported relationships. Therefore, if AMI really finds it important to inspect firms discharging in surface water more often than firms discharging in sewers connected to a water purification station, it could consider improving this part of its inspecting practice.

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Appendix

Appendix A: Average duration of the inspections

Reason for inspection	Average duration in minutes
VMM charges	51.37
Water sample	54.21
HID	55.32
Complaint	64.54
Official capacity	69.21
Follow-up	79.59
Judicial question	84.34
Other	88.44
Exploitation condition	114.66
P216	121.93
Total	76.54

Appendix B: Average composition of the effluent emitted by carpet production and textile improvement sectors (without treatment)

Parameter	Unit	Carpet production	Textile improvement
Daily load	m^3	458	513
BOD	mg/l	744	478
COD	mg/l	2310	1475
SS	mg/l	163	193
Arsenic	μg/l	0	2
Silver	μg/l	6	9
Chromium	μg/l	349	136
Zinc	μg/l	3488	593
Copper	μg/l	57	117
Cadmium	μg/l	3	2
Lead	μg/l	33	34
Nickel	μg/l	178	20
Total nitrogen	mg/l	57	32
Total phosphorus	mg/l	10	6

Source: Jacobs, Bettens, Grijse, and Dijkmans (1998)

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