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Effects of inspections on plants' regulatory and environmental performance

- evidence from Norwegian manufacturing industries

Abstract:
The present paper investigates effects of regulatory inspections on compliance and emissions of energy intensive manufacturing plants in Norway. The regression analysis shows that increased probability of inspection reduces the probability of violation. This is in line with previous studies, and may appear as an encouraging evaluation of the practiced regulatory enforcement policy. However, the direct environmental impact of the enforcement policy is more dubious: Regression analyses reveal a positive relationship between the probability of an inspection and emissions. It appears puzzeling that increased probability of inspection can yield both reduced probability of violation and higher emissions. The possibility that such a puzzle evolves from incentives inherent in the practiced regulatory policy is discussed.

Keywords: Environmental regulations; regulatory enforcement; inspections; emissions

JEL classification: K42, Q28, L51, K32

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Introduction

Passing anti-pollution laws is only the first step in securing compliance with direct environmental regulations. The existence of effective monitoring and enforcement policies is crucial to reach required environmental standards. Inspections are an important feature of most countries' monitoring and enforcement policies. According to Becker's (1968) theory of rational crime, a firm only complies if the (marginal) costs of complying are lower than the expected (marginal) penalty of violating. In the simplest framework, both compliance costs, and the penalty for a violation (i.e. the penalty and the probability of inspection and detection) are constant. Hence, firms continue violating after an inspection and detection, and pay the levied penalties. Thus, an inspection has no effect on the compliance status of a firm. However, in a more realistic setting the regulator may change the expected inspection probability according to certain criteria. An increase in expected inspection probability will then (ceteris paribus) raise the expected penalty and thereby reduce violations. The present study investigates empirically whether increased inspection probability improves plants' regulatory and environmental performance.

Although the number of theoretical studies of monitoring and enforcement of environmental regulations is growing (see Cohen 2000 for a review), empirical contributions are scarce. I am only aware of five papers that include effects of the *inspection probability* on compliance status (Eckert 2004, Grey and Deily 1996) or emissions relative to the emission cap (Laplante and Rilstone 1996, Earnhart 2004, 2004a).[1] Eckert (2004) finds a positive relationship between expected inspections and compliance. She considers compliance with the petroleum storage regulations in a province in Canada. Grey and Deily (1996) investigate compliance and enforcement of environmental regulations in the U.S. steel industry, and obtain similar results. Laplante and Rilstone (1996) observe plants in the Pulp and paper industry in Quebec. They find a negative relationship between the probability of inspection and water emissions relative to the cap. Finally, Earnhart (2004, 2004a) examines discharges (relative to the cap) from municipal wastewater facilities in the state of Kansas. The effects of inspections on emissions are less clear in his studies.

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[1] In addition to these papers, there are some that consider related aspects of enforcement policies. Magat and Viscusi (1990) regress water emissions (BOD) and compliance status for U.S. pulp and paper plants on whether the plant was inspected in previous period(s) or not. They find that inspections reduce emissions and increase compliance rates. Nadeau (1997) investigates how effective the US Environmental Protection Agency (EPA) is in reducing the time that plants spend out of compliance. The result shows that EPA's monitoring activity significantly reduces the periods of non-compliance. Dasgupta et al. (2001) explore the effects of inspections on emissions of polluters in China. Their setting differs from the one of the present study and the ones analyzed in the papers mentioned in the main text, since it is not illegal to exceed the "emission caps" in China (Dasgupta et al. 2001, p. 490). Helland (1998) investigates the role of targeting in regulatory compliance.

To my knowledge, the present study is the first empirical analysis of the effects of enforcement activities on regulatory *and* environmental performance. The regulatory performance of a firm does not relate to emissions only, but also to extensive qualitative and institutional requirements set in the emission permit. For example, it is an almost universal requirement that internal routines and audition systems for environmental surveillance must be properly implemented. Such regulatory focus on institutional aspects is not a peculiarity of the Norwegian regulatory system (Nyborg and Telle 2004, Russel 1990). It is important to note that any violation of the conditions of the emission permit, including qualitative institutional requirements, is a violation of environmental regulations. Hence, it is an interesting question whether this kind of regulatory policies can result in improved regulatory performance despite e.g. worsened environmental performance (higher emissions).

I am not aware of any previous quantitative studies considering effects of enforcement activities on regulatory or environmental performance using data from Europe. Moreover, the previous studies focus on water emissions; none of them contain effects of enforcement on emissions that are extensively regulated in international treaties, like greenhouse gases or acids. It could be that inspections are more effective in reducing emissions of pollutants with impacts locally than pollutants with more regional or global impacts. It could also be that inspections reduce emissions of pollutants that are easily abated with end-of-pipe technology; like various forms of water pollutants, but not for emissions that are very costly or impossible to abate (like greenhouse gases). The present paper focuses on emissions to air.

The present study applies a panel data set covering annual emissions and inspections of more than 100 polluting Norwegian manufacturing plants from 1989 to 2001. This makes it possible to use econometric methods that control for unobserved plant specific characteristics. Formal tests show that such characteristics should be included in the econometric model. None of the previous studies on compliance status account for such unobserved characteristics. This shortcoming of previous studies may provide one explanation why some of the results of the present study diverge from results of previous ones.

The next section includes a brief introduction to the monitoring and enforcement activities of the Norwegian Pollution Control Authority (NPCA), and presents a description of the data. Section 3 contains the econometric models and results from the regression analyses. First, I estimate the probability that a plant will be inspected. Second, the relationship between inspection probability and regulatory or environmental performance is estimated. Regulatory performance is determined by the NPCA's post inspection evaluation of the compliance status of the plant; while environmental performance is measured by the plant's emissions of greenhouse gases, acids, particles, or nmvoc-equivalents. Section 4 contains a concluding discussion of the findings.

Context[2] and data

In Norway any emission that harms or may harm the environment is prohibited. However, the Norwegian Pollution Control Authority (NPCA) may grant emission permits. A permit may specify maximum emission levels per unit of time, spill water, or production. However, the permits also contain a variety of qualitative requirements concerning institutional aspects within the plant; and when inspecting plants, the NPCA focuses on routines and general maintenance of equipment rather than actual emissions. The emphasis on such qualitative aspects often makes it impossible to decide the compliance status of a plant solely on emission information. Moreover, the heterogeneity of the quantitative regulations makes data on the allowed emission caps unavailable for quantitative analysis.

The NPCA monitors the regulatory performance of operations. The inspection frequency of the NPCA follows a scheme that dictates the regular inspection frequency of a plant. This scheme depends on the *risk class* of the plant: When a plant is granted a permit, the NPCA puts the plant in one of four risk classes, with risk class one embracing plants whose operation is considered potentially highly environmentally dangerous. The potentially least dangerous plants are placed in risk class four, etc. The NPCA deviates from the inspection frequency dictated by the scheme for several reasons. First, after an inspection, the inspection officer makes an evaluation of the need for future inspections based on an overall judgment of the performance of the inspected plant. Normally, when non-minor violations are observed or suspected, the inspection officer recommends inspections more frequent than the scheme. Second, information from the plant, the police or the public may also result in more than regular inspections.

After an inspection, the NPCA routineously notifies the inspected plant of detected violations. The standard wording in these letters of notification depends on the observed regulatory performance. If serious violations are observed, then the wording of the notification of violation letter (NoV) underlines the seriousness of the observation, emphasizes the plant's obligation to take necessary actions to become compliant, and reminds it of possible penalties.[3]

To analyze what determines the inspection frequency of plants, and the effect of expected inspections on environmental performance, I use a plant level panel data set with annual observations from 1989 to 2001. The dataset includes plants holding emission permits. Hence, the sample is not representative for Norwegian manufacturing plants: The (potentially) most polluting plants and industries are over-

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[2] See Nyborg and Telle (2004) for a more careful description of the practice of the NPCA.

[3] Also, this practice may be interpreted as one of issuing warnings since cooperative plants that respond adequately to these letters are virtually never prosecuted (Nyborg and Telle 2004). Hence, the results of the present paper can illuminate effects of warnings on compliance; and issue apparently studied explicitly in only two papers - empirically by Eckert (2004) and theoretically by Nyborg and Telle (2004a).

represented. More than 80 percent of the plants in the sample belong to the following four sub-industries: Pulp and paper, Chemicals, Non-metallic minerals, or Basic metals.

The NPCA keeps record of all its inspections, including various aspects like date and the officer's evaluation. A dummy variable for Notification of Violation is set to one if serious violations are detected or if non-minor violations are detected or suspected, and the dummy variable for inspection is set to one if the plant was inspected during the year. Data on the compliance status of plants is inherently difficult to obtain. In the present study I rely on the NPCA's evaluation after an inspection. This evaluation contains a separate category for detected serious violation(s). I apply this category as the measure of the plant's compliance status.

Statistics Norway and the NPCA publish emission data for the manufacturing industries in Norway; see e.g. Flugsrud et al. (2000). From this inventory, I have received plant specific emissions of greenhouse gases, acids, particles and nmvoc-equivalents (ozone precursors). These emission data initially originate from plants' self reports. However, the quality of the reported data is carefully investigated e.g. by comparing the figures with data on energy or input consumption originating from another source (see next paragraph). When inconsistencies are observed, officers at the NPCA or the plant are normally consulted, and the figure most consistent with the energy or input data may be chosen. This procedure secures that the plants' incentive to under-report emissions is unlikely to seriously bias the data.

Survey data on manufacturing plants are available from Statistics Norway. This extensive database includes a variety of annual plant specific data, like return on sales, production (in 1992-prices), and employment.

Table 1 provides summary statistics for the variables used in the analyses.

Table 1: Variables and summary statistics

Variables	N	Mean	Std. Dev.	Min.	Max.
Dummy Variables:					
Inspection ($I_{i,t}$)	1708	0.51	0.50	0.00	1.00
More than one inspection ($MI_{i,t}$)	1708	0.06	0.23	0.00	1.00
Risk class 1(i)	1708	0.48	0.50	0.00	1.00
Risk class 2 (i)	1708	0.21	0.41	0.00	1.00
Risk class 3 (i)	1708	0.30	0.46	0.00	1.00
Notification of Violation ($NoV_{i,t}$)	1708	0.05	0.22	0.00	1.00
Violation (i,t)	862	0.04	0.18	0.00	1.00
Emissions relative to production of (log):					
Greenhouse gases (i,t)	931	-2.91	2.85	-13.67	0.98
Acids (i,t)	838	-11.34	1.97	-17.37	-7.79
Nmvoc-equivalents (i,t)	939	-8.32	2.15	-14.77	-4.58
Particles (i,t)	1100	-9.43	2.08	-15.84	-4.52
Employees (log) (i,t)	1436	5.05	1.20	0.69	-7.55
Return on Sales ($ROS_{i,t}$)	1443	0.11	0.16	-1.99	0.83

Models and results

Theoretical basis for the econometric models

Following the ideas of Becker (1968) a firm will comply with environmental regulations if it is profitable to do so.[4] Let C denote compliance costs, F the fine for violators and q the probability of inspection and detection. Then a (risk neutral) firm, *i*, will violate as long as $C_i > q_i F$. Assuming that q is a constant, an inspection in period t will have no influence on the future compliance status of the firm. However, if q in period t is a function of variables like whether there was an inspection or not in period t-1, or whether violations have been detected or suspected in the past, then an inspection in period t can influence on the future compliance status of the firm. Moreover, if q is increasing in violations, an inspection in the present period that reveals violations will increase the inspection probability and thereby also the expected fine. Then the compliance costs of some firms may turn lower than the expected fine, making it profitable to become compliant. Hence, an increase in a firm's expected inspection probability can improve performance.

This idea resembles the one modeled by Harrington (1988). Here the regulator lets i.a. the inspection frequency depend on the compliance history of the firm. If a firm is detected violating, it is moved to a

[4] See e.g. Heyes (1998) for an introduction to some applications of Becker's (1968) ideas in the economics of environmental regulations.

group of firms whose inspection frequency is higher. Next, if the firm remains in compliance, it will be moved to a group whose firms are inspected less frequently. Under this policy, Harrington (1988) shows that the regulator can improve enforcement without increasing costs. Basically, the reason is that some firms (with intermediate compliance costs), which would not comply under a static model, will find it profitable to comply under this history dependent enforcement policy. Hence, this model first provides a reason for the regulator to let inspection frequency depend on the compliance history of the firm. Such a policy partly resembles the one applied by the NPCA. Second, it provides a rationale for a hypothesis saying that expected inspection probability influences on firms' compliance with environmental regulations. The next two subsections present estimates of how the expected inspection probability depends on firm characteristics and compliance history. Then the estimated effect of expected inspection probability on regulatory and environmental performance is presented.

Expected probability of inspection

As mentioned, the NPCA has an inspection frequency scheme depending mainly on the risk class of the plant. In addition, the previous performance of the plant also influences on the probability of inspection. Moreover, other (control) variables are included when the probability of inspection is estimated:

$$\Pr(I_{i,t}=1) = a + \sum_{j=1}^{J} b_j * I_{i,t-j} + X_{i,t} * d + u_{i,t} \qquad (1)$$

where the binary response variable $I_{i,t}$ equals one if plant *i* was inspected in year *t*. X is a vector of other variables, and u is the error term.

Since the NPCA follows an inspection scheme, whether the plant was inspected or not in the previous periods is expected to influence on the probability of an inspection in the present period. In general, a plant that was inspected last period would, according to this scheme, regularly not be inspected in the successive period. However, if the plant was not inspected during several previous periods, this will normally increase the probability of an inspection. This provides reason to include lags of $I_{i,t}$ in the regression.

X is a vector of other variables. First, as the inspection frequency scheme of the NPCA depends on the risk class of the plant, I include a dummy variable for risk class. Second, if the overall performance of the plant was poor in the last inspection, the plant routinely receives a letter containing notification of violations (NoV). As described, such plants should expect to be inspected more frequent than regular. Third, a time trend is included to account for e.g. increased overall monitoring activity, and fourth, the number of employees as a way of controlling for the size of the plant. I also include a dummy variable indicating whether the plant was inspected more than once in period t-1 ($MI_{i,t-1}$).[5] I pool the data and apply maximum likelihood based on the logit model to estimate (1), see e.g. Greene (2000). This approach is similar to the ones applied by e.g. Eckert (2004) or Gray and Deily (1996).[6]

The results of the maximum likelihood estimation on (1) are presented in Table 2.[7]

In accordance with the inspection scheme of the NPCA, the probability of an inspection is significantly lower for plants in risk class 2 and 3 than for plants in risk class 1. Further, if the plant was inspected one period ago, the probability of inspection this period decreases significantly. However, if inspected two, three or four periods ago, the probability of inspection rises. Again as expected, if the plant received a NoV after the last inspection, this increases the probability of inspection in the subsequent year. The probability of an inspection increases with the size of the plant even after controlling for risk class. Overall, these results are as one should expect from the discussed enforcement policy of the NPCA.

[5] The economic performance of the plant is an issue that can be taken into account when conditions in the emission permit are set, but to my knowledge this is not an issue in the NPCA's decision on inspection frequency. Nevertheless, I ran the regression reported in Table 2 including return on sales (ROS). ROS had no significant effect on the probability of inspection.

[6] It would have been preferable not to pool the data, i.e. to apply a panel data model. However, as discussed by Arellano and Honore (2001), very little is known about estimation of nonlinear panel data models that include lagged dependent variables.

[7] The likelihood ratio statistic reveals that a hypothesis that all slope coefficients are zero can be rejected; indicating that the included explanatory variables possess explanatory power. I also ran this regression 1) including industry dummies, 2) including ROS, 3) including one more lag of the inspection variable (this additional lag was not statistically significant at any conventional level), 4) including one less lag of the inspection variable, and 5) including separate dummies for control class 2 and 3. The main qualitative results remained unchanged in all these cases. Moreover, a probit or a OLS regression on (1) did not change the main qualitative results. Throughout the paper regressions are performed using Stata8.

Table 2: Maximum likelihood estimation (logit) of the probability of an inspection

Variables	Coefficient	Std. Err.	z	p>|z|
$I_{i,t-1}$	-0.93	0.17	-5.51	0.00
$I_{i,t-2}$	0.31	0.15	2.04	0.04
$I_{i,t-3}$	0.76	0.16	4.90	0.00
$I_{i,t-4}$	0.92	0.16	5.90	0.00
$MI_{i,t-1}$	0.60	0.38	1.60	0.11
$NoV_{i,t-1}$	0.79	0.35	2.27	0.02
Risk class $2/3_i$	-0.96	0.18	-5.29	0.00
Log $employees_{i,t}$	0.26	0.07	3.52	0.00
Log time $trend_t$	-0.53	0.11	-5.02	0.00
Intercept	-0.57	0.45	-1.26	0.21
Number of obs (i,t)	1116 (118,10)			
Log likelihood	-619			
Likelihood ratio chi^2	305 (p<0.00)			

Effect on performance of inspection probability

Next, I test for effects of inspection probability on two sets of variables; (i) the compliance status of the plant, and (ii) the emissions of the plant. As mentioned in the introduction, the NPCA's focus on qualitative institutional requirements may open for the possibility that regulatory performance can improve despite worsened environmental performance. I apply the following econometric model:

$$P_{i,t} = a' + b' * Pr(I=1)_{i,t} + X'_{i,t} * d' + v'_i + u'_{i,t} \qquad (2)$$

where $P_{i,t}$ is one of the two sets of dependent variables indicating regulatory or environmental performance for plant *i* in year *t*. The probability of an inspection estimated in the previous subsection ($Pr(I)_{i,t}$) is the explanatory variable of main interest in (2). X' is a vector of other variables, including dummy for risk class, number of employees, and a time trend.[8] I also include a variable indicating the economic performance of the plant (ROS), since it could be that plants with bad economic performance put low priorities on environmental issues[9]. v'_i is a random effect that controls for unobserved plant specific time invariant characteristics, like plant location and industry, or time invariant elements of plant technology, vintage, management, employee motivation and education, etc. u'_{it} is the error

[8] Data on the size or development of fines is not available. Hence, I implicitly assume that the fine is fixed or that its development is captured by the included time trend.

[9] Griffin and Mahon (1997) or King and Lenox (2001) are examples of papers that provide evidence of a positive association between environmental and economic performance of firms.

term. Again, the procedure resembles the ones taken by Eckert (2004) and Gray and Deily (1996).[10] Contrary to these studies, however, the present study controls for unobserved plant specific effects (v'_i).

Compliance status

According to the theoretical reasoning above, a higher inspection probability would raise plants' violation costs. Hence, plants will increase their effort to comply, and therefore one should expect a negative relationship between the inspection probability and violation; i.e. b in (2) is negative when violation is the dependent variable.

Eckert (2004) uses the subset of inspected sites when estimating the effect of predicted probability of inspection on the probability of violation. Gray and Deily (1996) also estimate this relationship, but although it is not quite clear, it seems like their compliance variable is based on some kind of self-reported data. Magat and Viscusi (1990) base their estimation of the effect of inspections on the probability of violation in plants' self-reports. Since plants may have incentives to underreport violations in self-reports, I follow Eckert (2004) and use data from inspections on detected serious violations as an indicator of compliance status.

I apply maximum likelihood based on the logit model with random effects to estimate (2) (see e.g. Baltagi 2001, Arellano and Honore 2001 or Hsiao 1992). The results of this regression on (2) are reported in Table 3.[11] The probability of violation increases with plant size (employees) and over time. The latter result could be due to changes in the practice of the NPCA rather than poorer regulatory performance. The probability of violation is lower for plants in control class two and three than control class one; and good economic performance seems to raise compliance.

The association between the probability of an inspection and violations detected in an inspection is, as expected, negative. It is also statistically significant. This result indicates that the enforcement policy of the NPCA improves compliance, which is interesting and important to establish. However, compliance may not *necessarily* result in improved environmental performance; like reduced emissions. Indeed, it may be more interesting to investigate whether inspections lead to emission reductions. Hence,

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[10] Such two-step estimation yields consistent estimators under standard conditions (see e.g. Greene 2000 or Murphy and Topel 1985).

[11] The Wald statistic reveals that a hypothesis that all slope coefficients are zero can be rejected; indicating that the included explanatory variables possess explanatory power. The Breusch-Pagan statistic reveals that a hypothesis of no random effects can be rejected. I also ran this regression including industry dummies, and excluding ROS; and I ran a probit and a GLS regression on (2). This did not change the main qualitative results. Moreover, a generalized 2SLS regression (cf. Baltagi 2001, Ch. 7), where the probability of inspection is instrumented for using (1), did not change the main qualitative results.

the relationship between the probability of inspection and emissions is investigated in the next subsection.

Table 3: Maximum likelihood estimation (logit with random effects) of the probability of violation

Variables	Coefficient	Std. Err.	z	p>|z|
Log Pr(I) $_{i,t}$	-2.89	0.99	-2.93	0.00
Risk class 2/3$_i$	-4.73	1.68	-2.82	0.00
Log employees$_{i,t}$	1.10	0.45	2.44	0.02
ROS$_{i,t}$	-2.24	1.17	-1.91	0.06
Log time trend$_t$	0.77	0.42	1.83	0.07
Intercept	-11.41	2.99	-3.82	0.00
Number of obs (i,t)	591 (115,10)			
Log likelihood	-83.2			
Wald chi^2	17.9 (p<0.00)			

Emissions

Here I investigate the effect of the inspection probability on emissions per unit of production. Again according to the ideas of Becker, every plant will emit until the marginal benefit of higher emissions is lower than the marginal costs of such emissions. Given some assumptions about the penalty function (and risk attitude), this implies that plants will emit in excess of emission caps. The fact that most plants are violating environmental regulations (Nyborg and Telle 2004) may be taken to indicate that the regulations are binding. Hence, increased probability of an inspection should reduce emissions. Interestingly, however, the following results on the association between emissions and probability of inspections do not adhere to this prediction.

The dependent variable is now continuous and (2) can be estimated using generalized least squares (see e.g. Greene 2000 Ch. 14, or Earnhart 2004). The results are reported in Table 4.[12] Emissions decline with the size of the plant (employees), and are lower for plants in control classes two and three than control class one. The time trend reveals that emissions have declined over the period for all pollutants. It is not clear that emissions decline with improved economic performance.

[12] For acids, the Hausman test reveals that the individual effects are correlated with the other regressors in the model. However, in all regressions in Table 4 the main qualitative results remained unchanged under a fixed effects specification. The same held if industry dummies were included in the regressions. Moreover, a generalized 2SLS regression (cf. Baltagi 2001, Ch. 7), where the probability of inspection is instrumented for using (1), did not change the main qualitative results.

The estimated coefficients on the probability of an inspection (b) are all positive: When the probability of an inspection increases, the plants actually emit more. For greenhouse gases the effect is even statistically significant. This is not as expected, and different from several similar studies elsewhere.

Before I discuss possible explanations of these results in the final section, I will briefly argue that endogeniety is unlikely to be a serious problem. If the probability of an inspection increases with emissions, the estimates reported in Table 4 would be inconsistent. Routinely, however, the risk class of the firm (and not emissions) dictates the NPCA's inspection frequency. Emissions from the firm are important when deciding what risk class to put the firm in, but this decision is taken when the firm gets its emission permit, and will not change solely due to annual variations in the emissions. The inspection frequency may, however, change due to variations in a firm's previous regulatory performance. In evaluating this performance, the NPCA seems to focus more on routines and general maintenance of equipment than on emissions (Nyborg and Telle 2004). Nevertheless, the inclusion in (1) of lagged values of the NPCA's overall evaluation of the plant in the previous inspection (NoV) and whether the plant was inspected more than once in the last period (MI), should therefore be sufficient to avoid serious problems caused by endogeniety.[13]

Table 4: GLS estimation (with random effects) of emissions (standard error in parenthesis)

Variables	Greenhouse gases	Acids	Nmvoc-equivalents	Particles
Log Pr(I) $_{i,t}$	0.20*** (0.07)	0.12 (0.09)	0.13 (0.08)	0.11 (0.08)
Risk class 2/3$_i$	-3.24*** (0.60)	-1.27** (0.46)	-1.89*** (0.45)	-0.90* (0.39)
Log employees$_{i,t}$	-0.43*** (0.12)	-0.35*** (0.12)	-0.54*** (0.13)	-0.51*** (0.12)
ROS$_{i,t}$	-0.05 (0.17)	-0.21 (0.19)	-0.26 (0.20)	0.41† (0.23)
Log time trend$_t$	-0.09** (0.03)	-0.99*** (0.03)	-0.06 (0.04)	-0.32*** (0.04)
Intercept	0.57 (0.76)	-9.01*** (0.72)	-4.76*** (0.77)	-6.02*** (0.71)
Number of obs (i,t)	786 (81,10)	697 (72,10)	792 (81,10)	919 (100,10)
Wald test statistic (no explanatory power)	64***	29***	38***	117***
Breusch-Pagan test statistic (no random effects)	3124***	2136***	2596***	2855***
Hausman test statistic (uncorrelated)	4.0	14**	-	2.6

***, **, *, and † indicates 0.005, 0.01, 0.05, and 0.1 level of significance, respectively.

[13] To investigate this empirically I included one lag of the emissions in the regression on (1). The estimated coefficients on the lagged emissions were not statistically significant at any conventional level, neither individually nor jointly.

Concluding discussion

The empirical analysis reveals that the probability of inspection increases in accordance with the articulated policy of the NPCA. For example, previously detected poor performance increases inspection probability. Moreover and interestingly, an increase in the estimated probability of an inspection increases the probability of plants' compliance. This is in line with the results of previous studies. Hence, the results suggest that the inspection and enforcement policy of the NPCA is successful in reducing violations of environmental regulations.

However, to conclude that the NPCA's inspection policy is environmentally beneficial may be preliminary. The present analyses indicate a discouraging relationship between the probability of inspection and emissions: When the expected probability of an inspection increases, emissions are unchanged or even increase. This result seems to be at odds with related analyses elsewhere. Laplante and Rilstone (1996) find a negative relationship between water emissions and expected inspections. Magat and Viscusi (1990) regress water emissions for U.S. pulp and paper plants on whether the plant was inspected in previous period(s) or not. They find that inspections reduce emissions. Dasgupta et al. (2001) explore the effects of (an instrument for) inspections on emissions of polluters in China. Although not quite convincing, their results also indicate a negative relationship between emissions and expected inspections. The divergence in the results of the present paper and these previous studies could be due to several reasons. First, although enforcement policies in Norway and these other countries have some common elements, they are far from identical.[14] Comparing the incentives of enforcement policies and the performance of such policies across nations is an interesting and important task for further scrutiny. Second, unlike all previous studies on compliance status and most previous studies on emissions (relative to cap), I account for unobserved plant specific effects. Formal tests show that such effects should be included in the models. Incorrect exclusion of such unobserved effects would yield biased estimators. Third, opposed to the previous studies in the USA and Candada, I investigate emissions to air (not to water). Could it be that inspections influence differently on emissions with mostly national or international impacts (like many air emissions) than on emissions causing more local or geographically restricted environmental problems (like the water emissions investigated in the mentioned studies)? If environmental impacts of water emissions are easily observable, it is unlikely that excessive emissions would not be detected. Fourth, firms have incentives to under-report emissions when self-reporting. Previous studies generally rely on self reported

[14] At first glance the system in the USA and Norway have some elements in common, compare Russell (1990) and Nyborg and Telle (2004). I am not aware of any description of the Canadian system, while the Chinese system seems very different (Dasgupta et al. 2001, Section 2).

emissions, while the emission data applied in the present paper is carefully adjusted for possible errors.

The present paper is the first to include both measures of regulatory and environmental performance when investigating effects of inspection probability. This reveales an interesting and apparently puzzeling result: Increased expected probability of inspection seems to simultaneously yield (a) unchanged or higher emissions and (b) improved regulatory performance.

First, this result may evolve if plants invest in "uninspectability" (see Heyes 1994 or Kambhu 1989): If it is possible for a plant to reduce the probability that a violation is detected during an inspection, then the plant will have incentives to increase masking effort as the probability of an inspection increases. Hence, violations *detected* during an inspection may decline (cf. result b). However, the high quality of the applied emission data reduces the possibility that masking (underreporting) of emissions influences my results (cf. result a). In a model where firms can invest in "uninspectability", Heyes (1994) shows that more thorough (and less frequent) inspections can improve plants' performance.

Second, as mentioned, the granted permits and the inspections performed by the NPCA focus on qualitative aspects of the environmental performance of the plant. Hence, it is not unlikely that the regulatory performance of the plant can improve despite unchanged emissions. When the NPCA emphasizes the quality of the plant's internal routines, its general maintenance of equipment, and its internal surveillance systems, it may provide incentives for the plants to put more effort in improving performance in these areas rather than in reducing emissions. During and after inspections the plants may learn that the NPCA does not react to increased emissions (of some pollutants), or that the sanctions for such excess emissions are less stringent than previously believed. Such perverse effects of regulatory activity are also known from other fields. E.g. Slemrod et al. (2001) find that taxpayers with high incomes reduce reported tax liability when they are informed that the probability of audit increases.

Finally, it is worth noting that the present study does not warrant clear normative assessments on a regulatory policy that focuses on qualitative institutional aspects rather than actual emissions. Compliance with institutional requirements may not immediately improve the environment, but it may reduce the probability than an environmentally harmful situation occurs. Further theoretical and empirical research is necessary before clear policy evaluations or recommendations can be made regarding this aspect of regulatory enforcement practices.

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