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ANALYSIS

Inspections, pollution prices, and environmental performance: evidence from China

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Abstract

In environmental economics, monitoring and enforcement issues have attracted relatively little research effort. Moreover, the bulk of the literature on these issues has been of a theoretical nature. Few have empirically analysed the impact of monitoring and enforcement activities on the environmental performance of polluters. Moreover, all existing studies have been performed in the context of developed countries. A purpose of the current paper is to partially fill this important gap by exploring the impact of both inspections and pollution charges on the environmental performance of polluters in China. While pollution charges represent an important pillar of the Chinese environmental regulatory system, our results indicate that inspections dominate and better explain the environmental performance of industrial polluters.

Keywords: Inspections; Prices; Environmental performance

1. Introduction

Since the beginning of the 1970s, governments of developed and developing countries have enacted or amended a large number of environmental laws and regulations often directed at controlling the industrial emissions of air and water pollution. However, imposing a ceiling on a plant's emissions does not necessarily imply that emissions will fall and environmental quality improve. For the objectives of the regulation to be attained, the behaviour of the regulated community has to be monitored, and compliance with environmental standards has to be enforced.[1] While a large amount of resources is typically devoted to designing environmental regulations,

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[1] We define monitoring as the process of verifying the firm's status of environmental performance (e.g. compliance), and enforcement as the undertaking of actions (e.g. fines) to bring the firm to improve its environmental performance (e.g. comply with environmental standards).

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and negotiating environmental standards with the regulated industries, it is generally acknowledged that resources devoted to monitoring and enforcement are insufficient relative to the complexity and extent of the task (Russell, 1990; O'Connor, 1994).

While the monitoring of industrial polluters and the enforcement of compliance are both crucial components of a credible regulatory program, monitoring and enforcement issues have attracted little research effort. In a recent survey of the environmental economics literature, Cropper and Oates (1992) write: "The great bulk of the literature on the economics of environmental regulation simply assumes that polluters comply with existing directives." Moreover, most of the literature on these issues has been of a theoretical nature.[2]

On the empirical front, two broad questions have partially been addressed. A first question pertains to the impact of the regulator's behavior on the environmental performance of polluters. In particular, Magat and Viscusi (1990), Laplante and Rilstone (1996) have examined *whether* or not inspections have an impact on the emissions (biological oxygen demand (BOD) and total suspended solids (TSS)) of pulp and paper plants in the United States and Canada, respectively. Magat and Viscusi (1990) have shown that inspections reduce permanently the level of emissions of plants by approximately 20%. Laplante and Rilstone (1996) have shown that not only inspections but also the threat of inspections reduce emissions by approximately 28%. These two analyses also find that inspections induce more frequent self-reporting of emissions by the regulated plants. Hence, not only do inspections have an impact on the actual level of emissions of the plants, but they also provide regulators with a more accurate pollution profile of the plants. More recently, Nadeau (1997) has shown that inspections significantly reduce the duration of firms' violation of air pollution standards in the pulp and paper industry in the United States. These results have clear policy implications as to the importance of a credible monitoring strategy to create incentives for pollution control.

If inspections have an impact on the behavior of polluters and partly explain improvements in their environmental performance, a second question of interest thus pertains to the determinants of the regulator's monitoring strategy. Deily and Gray (1991, 1996), Dion et al. (1998) have shown that regulators are sensitive to local environmental damages in their decision to inspect specific plants and, other things being equal, that greater inspection effort is allocated towards those plants whose emissions are likely to generate a higher level of damages. If economists have greatly criticized uniform environmental standards imposed on polluters, these papers show that the presence of uniform standards does not necessarily imply uniform enforcement nor compliance with such standards. While this may be a desirable behaviour, these authors also show that the monitoring and enforcement activities of regulators are also a function of variables pertaining to local labour market conditions (such as unemployment rate, and the importance of the plant in the local labour market). Regulators thus appear to show a reluctance to enforce standards in a way that may have an impact on employment. Dion et al. (1998) thus argues that both the public interest theory of regulation and the economic theory of regulation contribute to explaining the decision of regulators to monitor the environmental performance of regulated plants.

Empirical studies on monitoring and enforcement issues have thus been of only recent interest and remain limited in numbers. Moreover, they have been performed only in the context of developed countries: we are not aware of any empirical study on the impact and determinants of monitoring and enforcement activities of an environmental agency of a developing country at the plant level.[3] The current paper is a first step toward

[2] See Downing and Watson (1974), Harford (1978), Linder and McBride (1984), Russell et al. (1986), Beavis and Dobbs (1987), Harrington (1988), Malik (1990), Russell (1990). For a recent survey of the literature on monitoring and enforcement, see Cohen (1998).

[3] Pargal and Wheeler (1996) have examined the impact of non-regulatory activities on environmental quality in Indonesia.

filling this important gap. Building upon Magat and Viscusi (1990), Laplante and Rilstone (1996), in this paper we analyse the impact of inspections and pollution charges on the environmental performance of industrial polluters in Zhenjiang, China. While inspections and pollution charges jointly determine the expected penalty faced by a firm that fails to comply with the regulatory standards, our results demonstrate that at the plant level, the variation in inspections is a better determinant of the firms' environmental performance than is the variation in pollution levies. This result may provide a key to China's future quality of environment.

In the next section, we briefly describe the institutional and regulatory context currently in place in China. In Section 3, we present the model we purport to test. In Section 4, dataset and results are presented. We briefly conclude in Section 5.

2. Context

2.1. (a) Growth and the environment in Zhenjiang, China

China's industrial growth has been extremely rapid. In the 1990s, industrial output increased by more than 15% annually. Industry now accounts for approximately 45% of China's gross domestic

Fig. 1. Zhenjiang and surroundings.

product, and has provided a source of rapidly expanding income. However, serious environmental damage has accompanied this rapid growth. A large number of China's waterways are near biological death from excessive discharge of organic pollutants. In many urban areas, atmospheric concentrations of pollutants such as suspended particulates and sulfur dioxide routinely exceed World Health Organization safety standards by very large margins (Dasgupta et al., 1997; World Bank, 1997). Chinese industry is a primary source of the environmental degradation noted in recent years. China's National Environmental Protection Agency (NEPA) estimates that industrial pollution accounts for over 70% of the nation's total emissions of pollution (National Environmental Protection Agency, 1996).

Zhenjiang, with a population of approximately 3 million people, is an industrial city located on the South Bank of the Yangtze River. It is directly under the leadership of the Jiangsu provincial government. Given its location (Fig. 1), with Nanjing lying west and Shanghai east, Zhenjiang has a key place in the economy of China and is an important hub of communication on the lower reaches of the Yangtze River. The Beijing-Shanghai Railway passes through the city. With its port, railway and airports, Zhenjiang is a major land and water communications hub in China.

Zhenjiang's industrial growth has been extremely rapid during the period of China's economic reform. Over the course of the last decade, Zhenjiang's industrial output increased at an average rate of 9% annually. The industrial sector is the most important economic sector of Zhenjiang, employing a large percentage of the total labor force. The industrial base is large and diversified. The Zhenjiang Economic Development Zone, created in October 1993, has already attracted over 170 firms, including 80 foreign investments. State-owned enterprises do not dominate Zhenjiang industry as private investments have considerably increased in the last decade. Given its importance, the rapid growth of the industrial sector has contributed significantly to improving living standards. Average wage increased from Y 1373 in 1986 to Y 3482 in 1993 (measured in constant Y of 1990). Zhenjiang's ninth Five-Year Plan

(1996–2000) calls for further development of the chemical, paper making, building material and aluminum processing industries. However, as a result of this rapid expansion, environmental quality — both air and water ambient quality — has significantly deteriorated. SO_2 concentration has more than doubled between 1993 and 1997 (from 0.022 to 0.052 mg/m^3) and ambient TSS concentration increased from 91 to 138 mg/l over the same time period.

2.2. (b) Environmental protection in China[4]

Environmental protection in China became the responsibility of the State in 1978 with Article 9 of Chapter 1 of the Chinese Constitution:

> The State ensures the rational use of natural resources and protects rare animals and plants. The appropriation or damage of natural resources by any organization or individual by whatever means is prohibited.

In accordance with the Constitution, the National People's Congress, the highest legislative authority of China, adopted in 1979 (on a trial basis) the Environmental Protection Law (EPL). The EPL was officially enacted in 1989. The purpose of the Law is clearly stated in its Article 1:

> This law is formulated for the purpose of protecting people's environment and the ecological environment, preventing and controlling pollution and other hazards, safeguarding human health and facilitating the development of socialist modernization.

The EPL provides the basic principles governing the prevention of pollution and environmental protection and imposes criminal responsibility for serious environmental pollution (Article 43):

> If a violation of [EPL] causes a serious environmental pollution accident, leading to grave consequences of heavy losses of public or private property or human injuries or deaths of persons, the persons directly responsible for such accident shall be investigated for criminal responsibility according to law.

An important pillar of China's pollution regulatory system is a pollution levy implemented nationally in 1982. Article 18 of the EPL specifies that:

> In cases where the discharge of pollutants exceeds the limit set by the state, a compensation fee shall be charged according to the quantities and concentration of the pollutants released.

Note that the levy system formally requires that a fee be paid by any enterprise only on the quantity of effluent discharge that exceeds the legal standard. Furthermore, the pollution levy is actually paid only on the pollutant that exceeds its standard by the greatest amount, and not on all the pollutants that exceed the standards. National regulations thus stipulate that a pollution levy L_{jM} be paid by a factory j emitting N pollutants where:

$$L_{jM} = \text{Max}[L_{j1},\ L_{j2},\ldots,\ L_{jN}] \tag{1}$$

where

$$L_{ji} = \rho_i \left[\frac{\eta_{ji} - \eta_i^*}{\eta_i^*}\right] W_j; \quad i = 1,\ldots,N \tag{2}$$

where L_{ji} is the estimated levy to be paid by plant j on pollutant i ($i = 1, \ldots, N$); ρ_i is the national levy rate for pollutant i; the pollution levy is further a function of the firm's industrial sector of activity; η_{ji} is the discharge concentration of pollutant i by firm j; η_i^* is the national legal discharge of pollutant i; W_j is the wastewater discharge volume by plant j.The pollution levy system in place in China is therefore not a true Pigovian charge scheme (National Environmental Protection Agency, 1992). Given its characteristics, it may also fail to provide strong incentives for pollution control.

[4] This brief overview does not intend to provide a thorough description of environmental protection in China. For a comprehensive overview of environmental legislation and institutions in China, see Mei (1995), Sinkule and Ortolano (1995).

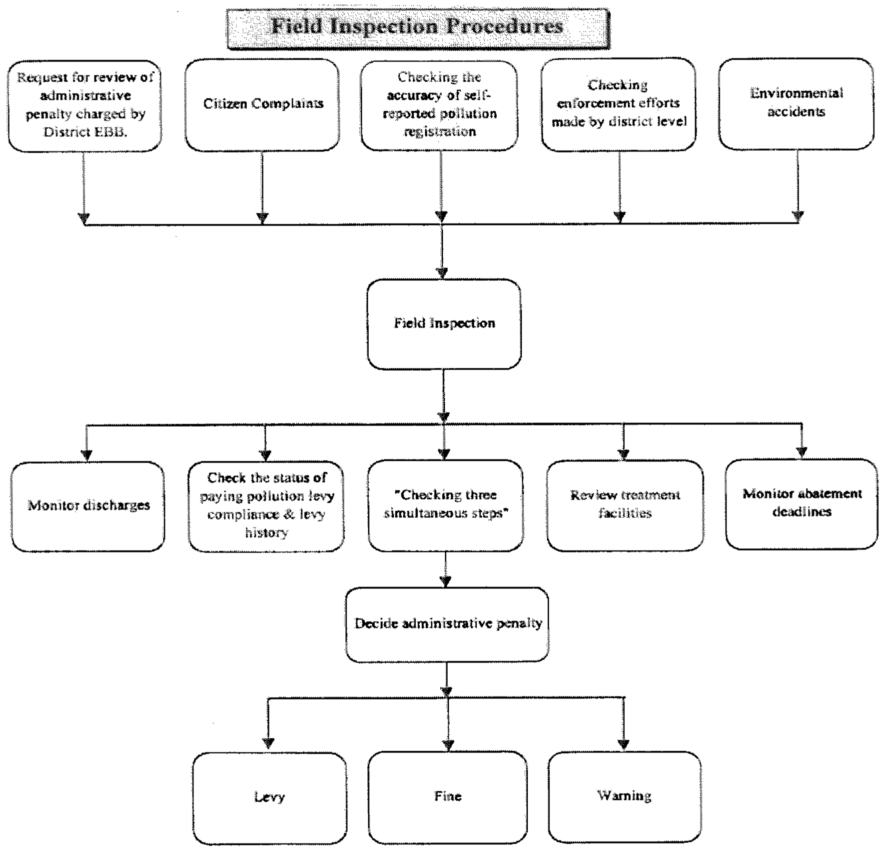

Fig. 2. Field inspection procedures

Environmental protection in China is generally decentralised. The effective implementation of environmental laws and regulations, including the implementation of the pollution levy, is in large part the responsibility of local people's governments. Article 16 of Chapter 3 of the EPL indeed states that:

> the local people's governments at various levels shall be responsible for the environmental quality of areas under their jurisdiction and shall take measures to improve the quality of the environment.

As a result, Environmental Protection Bureaus (EPB) have been created at all levels of local governments, from provinces and counties. Wang and Wheeler (1996) have shown that effective implementation of the pollution levy at the provincial level to be a function of provincial income and education: the higher the level of income and education, the higher the effective levy.

Zhenjiang Environmental Protection Bureau (ZEPB) is thus at the apex of decision-making and interagency coordination on environmental policies in Zhenjiang. At a lower level, there are environmental protection bureaus in all the various districts of the municipalities. These district-level EPBs are responsible for many activities pertaining to the actual implementation of the environmental regulations. These activities include the collection of pollution charges and non-compliance fees, the monitoring of air and water ambient quality, and the monitoring and inspection of industrial facilities. As indicated in Fig. 2, field inspections in Zhenjiang (as in all other EPB in China) follow a precise procedure. Apart from regular inspection activities, note that complaints made by citizens regarding environmental incidents may give rise to field inspections. All Chinese citizens have the right to file complaints on pollution matters, and these have to be filed and dealt with in a very precise manner. Zhenjiang EPB is entitled to bring cases to court on behalf of the public. If the polluter is found at fault, various administrative penalties or warnings may then be imposed. These may also include the need for the polluter to install treatment facilities.

3. Model

The general model we wish to test, for both air and water pollution, is similar in nature to the one developed by Magat and Viscusi (1990), Laplante and Rilstone (1996). An important difference, however, is the inclusion of the pollution levy as a determinant of environmental performance. Both the probability of inspection and effective pollution levy determine the expected penalty for noncompliance with the existing regulatory standards.

While we are generally interested in estimating the impact of ZEPB's inspections on the pollution emissions of the regulated firms, a difficulty is that inspections at any given time may themselves be a function of pollution at time t (that is, the regulator may observe pollution at time t, and then decide whether or not to inspect at time t). In other words, inspections may themselves be endogenous and correlated with the same variables which determine current pollution levels. If this is the case, least-square estimates will be biased in general. In fact, both of the above analyses have rejected the hypothesis that inspections were exogenous. As a result, Magat and Viscusi (1990) have included in their analysis a vector of only past inspections. Laplante and Rilstone (1996) on the other hand have prefered to estimate an inspection equation and to re-estimate their basic inspection model by instrumental variables using expected inspections as instruments. Interestingly, these last authors have found that the probability of an inspection in any given period is a decreasing function of past inspections — the regulator's monitoring strategy thus being akin to one of sampling without replacement. Given these results, the basic system of equations of interest in this paper is of the following nature:

$$\mathrm{INSP}_{it} = c + a_1\,\mathrm{Time} + a_2\,\mathrm{LcINSP}_{i,t-1} + a_3\,\mathrm{Lcc}_{i,t-1} + a_4\,P_{i,t-1} + d_i + v_{it} \quad (3)$$

$$P_{it} = c + X_{it}\beta + Z_i\gamma + \delta_1\,\mathrm{INSP}_{it} + \delta_2\,\mathrm{LcINSP}_{i,t-1} + \delta_3\,\mathrm{Lcc}_{i,t-1} + \delta_4\,\mathrm{Le}_{i,t-1} + \delta_5\,P_{i,t-1} + \alpha_i + u_{it} \quad (4)$$

where $i = 1, 2, 3, \ldots, N$ stands for plants; $t = 1, 2, 3, \ldots, T$ stands for time; INSP_{it} represents inspections performed at plant i at time t; $\mathrm{LcINSP}_{i,t-1}$ is cumulative inspections performed at plant i up to time $t-1$; $\mathrm{Lcc}_{i,t-1}$ is cumulative complaint targeted at plant i up to time $t-1$; Lcw and Lca will stand for water and air pollution-related complaint, respectively; P_{it} is pollution emissions produced by plant i at time t. In the current paper, water pollution is measured by discharges of total suspended solids (TSS) and chemical oxygen demand (COD). Air pollution is measured by discharges of total suspended particulates (TSP).[5] In all cases, the endogeneous variable P_{it} is measured as the level of discharges relative to their respective standards. Hence, from the point of view of the environmental regulator, the variable of interest is presumed to be the impact of its monitoring strategy on the compliance status of the regulated plants with the existing environmental standards; $P_{i,t-1}$ is the lagged pollution variable; $\mathrm{Le}_{i,t-1}$ is the one-period lagged effective levy. In the case of water, the effective levy is measured as the ratio of water levy charged to the amount of wastewater discharged. In the case of air pollution, the effective levy is measured as the ratio of air levy charged to total discharge of air pollutants; X_{it} is a matrix of time-varying variables consisting of the following variable: *Emp*

[5] While air and water ambient quality may not be solely measured by the ambient concentration of TSP and TSS–COD, respectively, limited data availability restricts us to the use of those parameters.

(number of employees); and dummy variables to indicate the nature of ownership of the plant: State (state owned enterprise) or *Coll* (collectively owned enterprise); Z_i is a matrix of dummies to indicate a plant's industrial sector of activity. For water pollution, Z_i includes textile, petrol, tobacco, food, beverage, paper and chemical; for air pollution, it includes petrol, coal, construction, paper and chemical. d_i and α_i are firm-specific effects while v_{it} and u_{it} are the usual error terms.

Eq. (3) and Eq. (4) in the current paper differ markedly from the models presented in Magat and Viscusi (1990), Laplante and Rilstone (1996). The difference pertains to the inclusion of two important variables: citizens' complaints and pollution levy. Both of these variables were absent from previous analyses.

For the purpose of estimation, we have assumed that: (1) the firm specific-effects are random; (2) the two error terms are uncorrelated and well behaved; (3) the lagged pollution variable is uncorrelated with the error term in the inspection equation and correlated with the corresponding error term in the pollution equation; (4) all the right-hand side variables in the inspection equation are doubly exogeneous — that is, uncorrelated with the firm specific effects as well as with the error term.

The system of Eq. (3) and Eq. (4) is recursive and dynamic. Since the model is recursive, we can proceed with the estimation equation by equation (see Lahiri and Schmidt, 1978). Since the pollution equation is the one of interest in the current paper, we transform Eq. (4) into the following equation in order to eliminate the individual effects:

$$\begin{aligned}\Omega^{-1/2}P_{it} = {} & \Omega^{-1/2}c + \Omega^{-1/2}X_{it}\beta + \Omega^{-1/2}Z_i\gamma \\ & + \Omega^{-1/2}\,\mathrm{INSP}_{it}\delta_1 \\ & + \Omega^{-1/2}\,\mathrm{LcINSP}_{i,t-1}\delta_2 \\ & + \Omega^{-1/2}Lcc_{i,t-1}\delta_3 + \Omega^{-1/2}\,\mathrm{Le}_{i,t-1}\delta_4 \\ & + \Omega^{-1/2}P_{i,t-1}\delta_5 + \Omega^{-1/2}e_{it} \qquad (5)\end{aligned}$$

where e_{it} is the new error term — that is the sum of the firm random specific effects (α_i) and the regular error term (u_{it}). The matrix omega is the appropriate matrix to eliminate the plants' individual effects. It is constructed as follows (see, for example, Ahn and Schmidt, 1995, p. 18):

$$\Omega^{-1/2} = Q_V + \theta P_V \qquad (6)$$

with

$$P_V = I_N \otimes l_T l'_T / T \qquad (7a)$$

$$Q_V = I_N - P_V \qquad (7b)$$

$$\theta^2 = \frac{\sigma_u^2}{\sigma_u^2 + T\sigma_u^2}. \qquad (7c)$$

For any integer m, let l_m be an $m \times l$ vector of ones. The idempotent matrix Q_v transforms the original variables into deviations from individual means and P_v transforms original variables into a vector of individual means.

4. Dataset and results

4.1. Dataset

The dataset used in the current empirical analysis covers the period 1993–1997, with most observations covering the period 1995–1997 inclusively. As indicated in Table 1, most of the firms belong to the manufacturing sector. A further breakdown indicates that the timber processing, the food processing and the petroleum processing industries represent the largest number of sectors in our dataset with 17.2, 15.6 and 10.2% of the plants.

Table 2a and b describe the characteristics of the water (Table 2a) and air (Table 2b) pollution discharges of the firms in our dataset. In brackets is the number of firms on which the entry for each characteristic has been computed. With respect to water pollution, it can be noted that the average discharges of TSS and COD fell significantly over the period covered by the dataset. Despite this reduction, the number of firms paying water levies, and therefore not complying with the standards, has remained relatively constant over the period 1995–1997. Hence, while deviation from the standards may have been reduced over time, compliance with the standards, in aggregate, appears not to have changed significantly. A similar trend can be observed in Table 2b for TSP. Note

Table 1
Number of firms, size, and ownership

	1993	1994	1995	1996	1997
Number of firms	98	97	577	556	640
Firms in manufacturing sector (%)	82	82	74	71	74
Total # of employees	80 202	78 420	204 176	201 980	217 175
Ownership (as % of firms)					
State owned	88	88	25	29	26
Collective	12	10	67	62	65
Joint-venture	0	2	7	8	8
Ownership (as % of output)					
State owned	94	92	41	46	49
Collective	6	5	48	41	37
Joint-venture	0	3	12	13	12
Size (as % of firms)					
Large	5	9	3	4	4
Medium	38	42	19	19	17
Small	51	48	76	76	78
Size (as % of output)					
Large	38	47	29	31	31
Medium	31	37	31	30	32
Small	21	16	38	39	36

Table 2
(a) Water discharge characteristics. (b) Air discharge characteristics[a]

	1993	1994	1995	1996	1997
(a)					
Average discharges (kg/year)					
TSS	250 174 (97)	229 538 (96)	88 532 (388)	71 683 (391)	47 861 (530)
COD	378 921 (97)	392 089 (96)	83 869 (507)	73 271 (528)	48 591 (626)
Average concentration (mg/l)					
TSS	–	–	127 (364)	130 (366)	99 (503)
COD	–	–	365 (381)	355 (406)	280 (507)
Proportion of firms paying levy (%)	68	68	42	43	45
(b)					
Average discharges (ton/year)					
TSP	1665 (98)	1334 (97)	243 (577)	216 (556)	136 (640)
Average concentration (mg/m^3)					
TSP	–	–	589 (343)	514 (228)	572 (211)
Proportion of firms paying levy (%)	40	30	24	25	23

[a] The numbers in brackets refer to the number of firms in the dataset that is used to calculate the level of discharges.

Table 3
Number of inspections

	1993	1994	1995	1996	1997
By national level	0	0	1	1	0
By provincial level	2	4	10	23	32
By city level (ZEPB)	1045	1089	3677	4080	5255

Table 4
Number of complaints

	1993	1994	1995	1996	1997
Water-related complaints	7	13	41	73	78
Air-related complaints	28	26	139	195	163

that the proportions of firms violating the air pollution concentration standards appear to be significantly lower than the number of firms violating the water pollution standards.

Finally, in Table 3 and Table 4, we present the aggregate number of inspections and complaints over the period of observation. Note the significant increase in the number of inspections over time. As expected, most of these inspections appear to have been performed by the environmental protection bureau at the city level. Complaints appear to concern mainly air pollution issues.

4.2. Results

Given the presence of endogeneous variables in the pollution equation (Eq. (4)), the general method of moments (GMM) is an appropriate method of estimation to obtain consistent and efficient estimates. Thus, the GMM is applied to Eq. (5). The instruments being used are $(Q_v V, P_v V, P_v Z)$[6] where the matrix V consists of X, $\text{LcINSP}_{i,t-1}$, $\text{Lcc}_{i,t-1}$, Le_{t-1}, Time and the constant term. GMM results from Eq. (5) for water pollution are presented in Table 5, and for air pollution in Table 6.

First, as Table 5 and Table 6 indicate, the number of observations used is not the same across equations as a result of missing values in some variables. Second, all equations pass the test of overidentifying restrictions; that is the instruments used are valid. Third, for both water and air pollution, the lagged dependent variable is a relatively good predictor of current pollution emissions. This variable partly reflects the fact that the installation of emissions control equipment is typically a process that requires a long time. To this extent, the lagged pollution variable could also be interpreted as a proxy for changes in the production technology. A similar result was obtained by Magat and Viscusi (1990), Laplante and Rilstone (1996): their results were, however, somewhat stronger than those obtained here. This may be explained by a rapidly changing and growing industrial sector in China. Fourth, water and air-related complaints do not appear to have a significant impact on pollution. Fifth, state and collectively owned enterprises appear to exacerbate water pollution, at least as far as COD is concerned.

Results of interest concern the impact of inspections and pollution levies. Inspections performed by the Zhenjiang EPB do have a statistically significant negative impact on both water (measured by TSS and COD discharges) and air pollution. The estimations reveal that over the period of analysis, inspections reduce water pollution by

[6] See Ahn and Schmidt (1995) for a thorough discussion on instruments.

approximately 1.18 and 0.40% for TSS and COD, respectively, and air pollution by approximately 0.34%.[7] These results are lower than those observed in the pulp and paper sector in Canada and the United States where inspections were shown to reduce water pollution by 28 and 20%, respectively. Observe, however, that the pollution levy does not have a statistically significant impact on pollution. This result differs somewhat considerably from the result obtained by Wang and Wheeler (1999). In that paper, the authors analyse the impact of the effective levy on pollution emissions in China and found the pollution levy to have a statistically significant impact on pollution

Table 5
Determinants of water pollution[a]

	TSS	COD
INSP	−0.0500*** (0.100)	−0.0850** (0.033)
LcINSP	0.0092 (0.195)	0.0176 (0.131)
Lcw	−0.2293 (0.340)	−0.0433 (0.780)
Le	0.0026 (0.419)	−0.1511 (0.236)
Lagged dependent variable	0.9964** (0.036)	0.6800* (0.000)
Emp	−0.0004 (0.211)	−0.0008** (0.020)
State	0.3800 (0.415)	1.3950*** (0.056)
Coll	0.2137 (0.712)	0.7462** (0.032)
Textile	7.4556 (0.158)	4.7110 (0.140)
Petrol	−4.0784 (0.150)	−0.7307** (0.020)
Tobacco	−1.1711*** (0.062)	−54.0391 (0.155)
Beverage	−2.0485** (0.038)	0.4573 (0.545)
Food	−0.8097 (0.112)	−0.4784 (0.264)
Paper	−0.9390 (0.252)	0.8722 (0.673)
Chemical	−0.6761 (0.351)	−1.4565* (0.002)
Test Overid. Restr.	7.0918 (0.131)	1.9825 (0.852)
# of observations	649	736

[a] Note: GMM is the method of estimation. GMM instruments are provided in the text. Variables are defined as in the text. Test Overid. Rest. tests the validity of overidentifying restrictions. Numbers in brackets are P-values. Robust standard errors are used throughout. (*), (**) and (***) mean significant at the 1, 5 and 10% level, respectively.

[7] See Appendix A for the calculation of these percentages.

Table 6
Determinants of air pollution[a]

	TSP
INSP	−0.0328** (0.022)
LcINSP	0.0032 (0.621)
Lca	0.0100 (0.843)
Le	−0.1603 (0.168)
Lagged dependent variable	0.3423** (0.040)
Emp	−0.0002 (0.499)
State	−0.1381 (0.499)
Coll	0.0177 (0.945)
Petrol	−0.4518*** (0.092)
Coal	−0.1059 (0.749)
Construction	9.0519* (0.000)
Paper	−0.7835* (0.007)
Chemical	−0.8535* (0.002)
Test Overid. Restr.	7.3977 (0.286)
# of observations	396

[a] Note: GMM is the method of estimation. GMM instruments are provided in the text. Variables are defined as in the text. Test Overid. Rest. tests the validity of overidentifying restrictions. Numbers in brackets are P-values. Robust standard errors are used throughout. (*), (**) and (***) mean significant at the 1, 5 and 10% level, respectively.

emissions. These authors were unable to include inspections in their analysis. The results obtained in the current paper indicate that main determinant of the expected penalty function are inspections and that variation in inspections dominate variations in pollution levy as determinants of environmental performance by industrial polluters in China. The difference in result pertaining to the impact of the pollution levy may also be explained by the relatively small variation in effective pollution levy in Zenjiang compared to the study by Wang and Wheeler (1999) who used plant-level data across China. Our results also demonstrate that complaints do impact significantly inspections. Given the impact of inspections on pollution, citizens' complaints therefore do have a positive and important impact on pollution control.

5. Conclusion

Monitoring and enforcement issues have been the object of a very limited number of empirical analyses at plant level. In developing countries, the difficulties of accessing data may explain this state of fact. Given the very limited number of empirical analyses of the nature conducted in this paper, we hope to have provided a better under standing of the impact of the regulator's monitoring and enforcement activities on the behavior of industrial polluters. While inspections and pollution charges jointly determine the expected penalty faced by a firm that fails to comply with the regulatory standards, our results demonstrate that at the plant level, the variation in inspections is a better determinant of the firms' environmental performance than is the variation in pollution levies. This result may provide a key to China's future quality of environment.

Whether or not these results support that additional resources be devoted to monitoring activities cannot strictly be addressed with the data currently available. Indeed, in order to do so, there would be a need to compare the costs of performing additional inspections with the net benefits of reduced pollution emissions. However, given the high level of air and water pollution currently observed in Zhenjiang, given the impact that these may have solely on health and productivity loss, it is reasonable to estimate that inspections do increase social net benefit in Zhenjiang.[8] The results, however, do suggest that informed citizens can have an important impact on pollution (via inspections). Dasgupta and Wheeler (1997) have analysed the determinants of citizens' complaints in China and found that they were an increasing function of the levels of income and education. Hence, this would suggest a greater role for the regulator to embark on information and education policies.

Further research in this field will prove to be crucial and provide key policy implications. In particular, it does appear of interest to examine more thoroughly the determinants of the monitoring activities performed by the environmental regulator as well as the impact of various enforcement actions on the environmental performance of polluters. These remain the object of continued research.

[8] Dasgupta et al. (1997) provide estimates of abatement costs and health damages associated with air pollution in China.

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Appendix A

These percentages are elasticities and have been calculated as follows:

$$e = b^* \frac{\bar{X}}{\bar{Y}}$$

where b is the coefficient of inspection in a given equation and $\bar{X}$ is the mean for the inspection variable (INSP) over all observations in a given equation. That is:

$$\bar{X} = \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} X_{it}}{N^*T}$$

with t standing for time ($t = 1, \ldots, T$ or $t = 1993, \ldots, 1997$ that is, $T = 5$), and i representing firms ($i = 1, \ldots, N$) $\bar{Y}$ is the mean of the pollution variable (TSS or COD or TSP) over all observations in a given equation. That is:

$$\bar{Y} = \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} Y_{it}}{N^*T},$$

where i and t are defined as above.

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