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Industrial Ownership and Environmental Performance: Evidence from China

HUA WANG[1,*] and YANHONG JIN[2]
[1]*Development Research Group, World Bank, 1818 H Street N.W., Washington, DC, 20433, USA;* [2]*Department of Agricultural Economics, Texas A&M University, College Station, TX 77843, Texas, USA;* **Author for correspondence*
(e-mail: hwang1@worldbank.org)

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Abstract. This study explores the differences in pollution control performance of industries with different types of ownership – State owned (SOE), collectively or community owned (COE), and privately owned (POE). A theoretic analysis is conducted and followed by an empirical assessment with Chinese data. The empirical results show that the COEs in China have better environmental performances in water pollution discharges than the SOEs and the POEs, suggesting that COEs may internalize environmental externalities.

Key words: China, environmental performance, externality, ownership, regulation

JEL Code: L21, Q28

1. Introduction

Developing countries have been witnessing reforms of state owned enterprises (SOE), a rapid growth of private sectors (POE) and a steady increase of foreign direct investment (FDI). One question associated with this global privatization process is whether the process is good for the environment. While private sectors are more profit oriented, public sectors normally take more social responsibilities into their decision-making processes. However, SOEs are normally economically less efficient than POEs. On the other hand, developing countries such as China are also practicing another ownership structure, which is of collectively or community owned(COE)[1]. While more responding to the market signals than SOEs, COEs may internalize their environmental externalities for the local communities, rather than for the whole nation as SOEs are supposed to do. This raises another question: how is the environmental performance of COEs compared with that of SOEs and POEs?

While there exist a few empirical studies comparing the environmental performance of SOEs and POEs, there have been no systematic analyses conducted on the relationship between the ownership structure and the environmental performance. To fill this gap, this study first provides a theoretical analysis of environmental performance of firms with different ownerships. The differences associated with different ownerships in internalization of environmental externality, bargaining power in regulation, as well as economic efficiency, are taken into the modeling process. Second, this study conducts an empirical analysis using detailed plant-level information of Chinese firms with different ownerships[2] in the year of 1999. The results show that COEs have better environmental performance than the SOEs and the POEs in China, implying that COEs may internalize their environmental externalities.

This paper is organized as follows. The next section presents the theoretic analysis of how ownership can affect a company's environmental performance and reviews previous studies conducted in this area. Section 3 provides background information about China's industrial pollution control, the survey design and implementation, as well as the summary statistics. Section 4 presents the empirical analysis of industrial environmental performance, and Section 5 concludes the paper.

2. Ownership and Environmental Performance

2.1. A THEORETIC ANALYSIS

To understand the differences in environmental performance of firms with different ownerships, a mathematical model can be constructed to analyze the different conditions associated with the decision-making processes on pollution discharge. A company's pollution discharge decision can be modeled by assuming that the company is to minimize the total cost subject to an output constraint. The total cost may include three components: 1. total cost of factor inputs within the company, including the pollution abatement cost; 2. total pollution discharge penalty paid to the government or society; 3. total pollution discharge damage incurred by the society. Different companies may face different total costs given a same production. For private companies, the first two components are real costs to them and they may treat the third component as zero. For collective or community companies, the social damages may be included in their objective function but may be considered only up to the extent where the local communities are concerned. However, for state owned companies, the total social damage to the whole state may be considered.

The production and pollution abatement decisions can be made by solving the following optimization problem:

$$\min_X w_X X + \alpha(I)P(Z) + \gamma(I)D(Z) \text{ s.t. } Y(X,I) \geq y$$

$$\gamma(I) = \begin{cases} 0 & \text{if } I = 1 (\text{for POE}); \\ D_i(Z)/D(Z) & \text{for} i = 1, 2 \ldots \\ & \text{if } I = 2 (\text{for COE}); \\ 1 & \text{if } I = 3 (\text{for SOE}). \end{cases}$$

$$D(Z) = \sum_i D_i(Z)$$

where I represents ownership with $I = 1$ for POE, $I = 2$ for COE and $I = 3$ for SOE[3]; X is a vector of factor inputs with a price vector of W_X; Z is pollution discharge which is a function of X and I; i.e., $Z = Z(X,I)$; $P(Z)$ is the total penalty caused by the pollution discharge as regulated by the government; $D(Z)$ is the total environmental and health damage caused by pollution discharge Z; $D_i(Z)$ is the total damage generated by pollution discharge Z upon community i where a COE belongs to; and y is the output.

$\alpha(I)$ represents the fact that firms with different types of ownership may receive different penalties even with the same pollution discharge Z; $\gamma(I)$ represents the fact that different firms may internalize pollution externalities differently. The ownership variable I is also included in the production function $Y(X,I)$, which reflects the differences in production efficiency with different ownership. $0 \leq \alpha(I) \leq 1$, and $0 \leq \gamma(I) \leq 1$.

The optimal level of input x is given by the following first-order condition:

$$\underbrace{w_x}_{\text{market price of factor input}} + \underbrace{\alpha(I)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,I)}{\partial x}}_{\text{marginal cost of pollution penalty}}$$

$$+ \underbrace{\frac{\partial(\gamma(I)D(z))}{\partial z}\frac{\partial Z(x,I)}{\partial x}}_{\text{marginal environmental damage internalized}} = \underbrace{\lambda\frac{\partial Y(x,I)}{\partial x}}_{\text{marginal production}}$$

where λ is the Lagrangian multiplier. For a state owned company, the optimality condition of x is achieved when the value of marginal production equals the total marginal price, which equals the summation of the market price, the marginal environmental penalty to the company and the marginal damage to the society. For a collective company, the marginal damage is only considered up to its hosting local community, while for a private company, the environmental damage part is not considered at all.

In the following, the first-order condition will be employed to analyze the effects of production efficiency, regulatory bargaining power and internalization of environmental externalities on the environmental performance of POEs, COEs and SOEs. During the analyses, the following assumptions have been made:

a. Others being equal, an input with a lower total marginal price will be utilized more;
b. The marginal cost of pollution penalty is positive; i.e., $\frac{\partial P(z)}{\partial z} > 0$;
c. The marginal cost of pollution damage is positive; i.e., $\frac{\partial D(z)}{\partial z} > 0$;
d. $0 \leq \alpha(I), \gamma(I) \leq 1$.

2.1.1. *Negotiation Effect*

Assume that the difference in environmental performance is only from regulation. This implies that the efficiency effects and the internationalization effects are assumed to be zero or the same for all different types of ownership. Then, when the internalization effect is zero, the marginal price of the same input for companies with different types of ownership would be as follows:

$$\text{MC1} = W_X + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \text{ for POE}$$
$$\text{MC2} = W_X + \alpha(2)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \text{ for COE}$$
$$\text{MC3} = W_X + \alpha(3)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \text{ for SOE}$$

Where 1 is denoted for POEs, 2 for COEs and 3 for SOEs. The differences between the marginal prices will be only in the coefficient $\alpha(I)$. For a private company, the coefficient would be the highest, and close to 1. A state owned company may have the lowest coefficient. Thus we have: $\alpha(1) > \alpha(2) > \alpha(3) > 0$.

For inputs with positive marginal pollution discharges, i.e., $\frac{\partial Z(x)}{\partial x} > 0$, the marginal prices of the inputs are the highest for a private company. Less inputs would be used, and therefore less pollution would be emitted by a private company. For inputs with $\frac{\partial Z(x)}{\partial x} < 0$, the marginal prices are the lowest for a private company, and therefore more pollution reduction inputs would be used. Ultimately, the environmental performance of a private company can be the best.

For a state owned company, the situation is the opposite. More pollution generation inputs and less pollution reduction inputs would be used. Therefore, the environmental performance of a state owned company would be the worst. The performance of a collectively owned company would be in between.

In summary, if only government environmental regulations are considered, the environmental performance of a POE would be better than that of a

COE, and a COE is better than a SOE. The primary reason is that the bargaining powers with government authorities are the strongest for SOEs and weakest for POEs.

2.1.2. *Internalization Effect*

Assume the strength of environmental regulation is the same for all companies, or, there is no negotiation effect, and the only difference in the marginal prices of inputs is caused by the internalization of the pollution externality. Then the marginal prices of the inputs will be as follows.

$$\mathrm{MC1} = W_X + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

$$\mathrm{MC2} = W_X + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} + \frac{\partial D_i(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

$$\mathrm{MC3} = W_X + \alpha(1)\frac{\partial P(z)}{\partial Z}\frac{\partial z(x)}{\partial x} + \frac{\partial D(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

$D_i(Z)$ is only a fraction of $D(z)$, and therefore, $\frac{\partial D_i(z)}{\partial z} \leq \frac{\partial D(z)}{\partial z}$. For a pollution generating input, i.e., $\frac{\partial Z(x)}{\partial x} > 0$, the marginal price for a state owned company will be the highest. But for a pollution reduction input, i.e., $\frac{\partial Z(x)}{\partial x} < 0$, the price would be the lowest for a SOE. Therefore, a SOE would use more pollution reducing inputs and less pollution generating inputs, and it would be the best environmental performer. A collective company would be the second best, while a private company would be the worst.

2.1.3. *Efficiency Effect*

Efficiency is not included in the model above, but a conclusion about efficiency can be fairly straight forward. For an input x positively contributing to pollution discharge, i.e., $\frac{\partial Z(x)}{\partial x} > 0$, a higher efficiency means a lower marginal discharge of such an input. For an input negatively contributing to pollution discharge, i.e., $\frac{\partial Z(x)}{\partial x} < 0$, the higher efficiency means a higher marginal pollution reduction. Therefore a higher efficiency means a less pollution generation and a higher pollution reduction, and finally better environmental performance. If POEs have higher efficiencies than COEs and SOEs, the environmental performance of POEs would be the best. COEs could be better than SOEs as COEs may be more market oriented and have higher efficiency.

2.2. PREVIOUS RESEARCH

Part of the theoretical analyses above has been confirmed by previous research, even though the overall differences in environmental performance of firms with different types of ownership may be an empirical issue. Kikeri et al.(1992) and Schmid and Rubin (1995) analyzed that private sectors might have higher efficiency in resource utilization and they might produce less pollution with the same resources. Therefore, a better environmental quality could be achieved with greater private sector participation, if only considering efficiency. However, although POEs may have higher efficiency in resource utilization, they may not seek to internalize environmental externalities (Baumol and Oates, 1988). In other words, the private sector may compromise the environment to avoid the potential cost of environmental investments and expenditures (Eiser, Reicher and Podpadec, 1996).

Wang et al. (2003) discussed about the environmental bargaining power of companies with the local or national environmental agencies pertaining to the enforcement of pollution control regulations such as pollution charges, fines, etc. Due to the difference of ownership structures, enterprises may have significantly differentiated impacts on the local or national economy and politics, or they may have different relationships with the local environmental authorities and governments. These differences can lead to the different levels of bargaining power. For example, SOEs in China have strong connections with the governments and some managers of SOEs have higher political status than the local environmental authorities. As a result, SOEs are able to elicit a lower pollution payment or punishment, and they have less incentive to decrease their pollution and reduce the pollution intensity. Similarly, COEs in China are strongly connected with the local governments, and they are also equipped with relatively higher environmental bargaining powers in contrast to the private enterprises. Wang et al. (2003) have empirically demonstrated the lower bargaining power of POEs as compared with SOEs and COEs. Pargal and Wheeler (1996) and Wang (2000) show that firms with different ownership may receive different levels of informal regulation, or community pressure, on pollution abatement. Informal regulation may always exist whether or not any formal regulation is present or effective in developing countries. In this view, local communities may have struck their own Coasian bargains with neighboring plants. Leverage in negotiations is provided by social pressure on workers and managers, adverse publicity, threat of violence, resources to civil law, etc.

FDI in developing countries may, or may not, generate more pollution. The increase of foreign direct investment and an emergence of foreign companies and other joint ventures in developing countries naturally raise the question about whether the "pollution havens" hypothesis[4] holds. If it holds, then more severe industrial pollution and environment degradation will be a result of an increase of direct foreign investment and plant re-allocations (Kale, 1988; Dean 1992; Low and Yeats, 1992; Xing and Kolstad, 1998; Copeland and Taylor, 2003). However, most of the empirical studies do not find significant evidence to support the hypothesis, and the results may suggest just the opposite: free trade will shift pollution-intensive goods production from poor countries with lax regulation to rich countries with tight regulation, thereby lowering world pollution (Copeland and Taylor, 2003).

The direction and the level that ownership structure can affect environmental performance depend on the magnitudes of the effects summarized above. A few empirical studies have tested the overall effects (Anderson, 1995; Talukdar et al. 2001; Wang and Wheeler, 2003, 2005). Particularly, Talukdar et al. (2001), using annual data for 44 developing countries from 1987 to 1995, show a significantly negative relationship between the degree of private sector involvement in terms of its investment in the total domestic investment, national GDP, or its value of output share in the national GDP, and CO2 emission levels. A conclusion drawn from this study is that an increased role by the private sector in an economy is more likely to help the environment of the economy. Wang and Wheeler (2003, 2005) show similar relationships between water pollution discharge intensity and industrial ownership by using a panel dataset of Chinese provinces and a cross section dataset of 3000 Chinese factories in 1993. The results confirm that SOEs are more likely to pollute than other types of enterprises in China. However, there has been no research comparing the environmental performance of COEs with that of SOEs and POEs. This paper presents the first attempt in this endeavor.

2.3. TESTABLE HYPOTHESES

While previous studies have demonstrated the existence of differences in efficiency and regulatory bargaining power associated with different types of ownership, which may lead to different environmental performance, no studies so far have been conducted on the existence of internalization of environmental externalities by SOEs or COEs.

Without considering the possible internalization of environmental externalities by SOEs and COEs, the environmental performance of POEs should always be superior to that of SOEs and COEs, because both the efficiency effect and the regulation effect are positive with POEs' environmental performance, when all other factors such as technology, scale, sector, etc. are the same. Only the existence of internalization effect may make the environmental performance of SOEs and COEs better than that of POEs. If this is correct, then a finding that the performance of SOEs or COEs to be better than that of POEs could mean the existence of internalization effect.

On the other hand, COEs are supposed to have higher efficiency and less regulatory bargaining power, and therefore better environmental performance than SOEs, when the internalization effect is not taken into consideration. If an empirical study demonstrates that SOEs have better environmental performance than COEs, it may support the hypothesis that SOEs internalize their environmental externalities more than COEs, as discussed in the theoretical analysis.

The empirical study on China presented below does show that the environmental performance of COEs is better than that of POEs, which could imply that those community owned enterprises do consider the possible pollution damages they generate to society in their decision-making process.

3. Chinese Practices

To investigate the ownership effects on environmental performance, an enterprise level survey has been conducted in China. Before presenting the survey and the survey statistics, in the following we first provide some background information about the industrial pollution control in China.

3.1. POLICY BACKGROUND

China's industrial growth has been extremely rapid in the past two decades. The annual growth rate has been about 15% in the 1990's. This has lifted tens of millions of people out of poverty. However, serious environmental deterioration has accompanied this rapid growth. Many cities in China have been among the worst polluted urban areas in the world[5].

China has been adopting various policy measures to control industrial pollution[6], which include command-and-control approaches, administrative measures, economic instruments, as well as public information and campaigning. New sources are subject to environmental impact assessment policy and "three simultaneousness" policy, which requires pollution abatement facilities be designed, installed and operated simultaneously with industrial production process technologies. Pollution discharge standards have been designed and implemented for different industries, different pollutants and different areas. Air, water and land have been classified into different zones according to environmental sensitivities, where different ambient and discharge standards are enforced.

The pollution charge has been one of the most important pillars of the industrial pollution regulatory system in China. This policy instrument was originally designed to promote compliance with pollution discharge standards. The Chinese environmental protection law 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." In 1982, after 3 years of experimentation, China's State Council began a nationwide implementation of pollution charges. Since then billions of yuan (US$1 = 8.2 yuan) have been collected each year from hundreds of thousands of industrial polluters for air pollution, water pollution, solid waste, and noise. In 2004, the system was implemented in all counties and cities. Five billion yuan were collected from more than half a million industrial firms; and numbers are increasing each year. Although studies have been conducted to reform the levy system with most analysts recommending an increase in China's pollution charge rate, few empirical analyses have actually investigated the polluters' response to the existing charges. Wang and Wheeler (2003, 2005) analyzed the province-level and plant-level data on water pollution and found that China's levy system had been working much better than previously thought. The results suggest that pollution discharge intensities have been highly responsive to levy variations.

3.2. SURVEY DESIGN AND IMPLEMENTATION

To study the pollution control behavior of Chinese industries and to investigate the ownership effects on environmental performance, we conducted a plant-level survey in China in the year of 2000. Three areas (Northern Tianjin, Danyang, and Liupanshui) were selected to conduct the survey. These three areas were selected because of their differences in social, economic and environmental conditions and their significances in collective and private sector development. Danyang municipality is located in a relatively rich, southeast province, Jiangsu province, while Liupanshui municipality is a part of a poor southwest province, Guizhou province. The northern part of Tianjin was also selected for this study, which is a relatively more urbanized, rich area, where the environmental situation is more serious than other two areas because of its dense population, even though the absolute quality is in between.

All major industrial polluters in each area were included in the sample. Plant-level information was collected from two channels. One is the municipal environmental protection agencies. All polluters in China are required to register each year their pollution related information with the local environmental authorities. Various ways, including surprise inspections and material balance estimation, etc., have been practiced by the local authorities to check the accuracy of their data. A questionnaire was also designed and implemented to collect information for those variables which were not included in the pollution registration practice. Personnel responsible for a plant's environmental management was required to submit the information, and returned surveys received quality checks from the survey teams before they were recorded into computer for analyses. The survey was conducted between April and September, 2000[7].

3.3. STATISTICS

Table I shows the number of industrial enterprises included in the sample by ownership. COEs accounted for 46% of the total sample, SOEs for 19% and POEs for 27%. About 7% of the sample is joint ventures and 1% foreign directly owned companies, or FDIs. Table II presents the statistics of major economic and environmental variables. It is clear that the SOEs are generally bigger than other types of companies, while the private companies are the smallest in terms of scale, While there were much higher investments in pollution abatement facilities with SOEs, operation expenditures with collective enterprises were much higher than other types of industries.

Pollution discharge intensities are given in Table III. SOEs and COEs had similar highest TSS (or total suspended solids) intensity, followed by the private companies. Pollution intensities of the joint ventures and the foreign companies were much lower than the pure domestic companies. Table IV shows that private companies received environmental inspections the most, even though the scales of private companies were among the smallest. More SOEs and private companies received citizen complaints on pollution issues. The levy payment ratios of SOEs are lower than that of the collective and private companies.

4. Econometric Analyses

The survey statistics presented in last section demonstrate the differences in environmental enforcement and performance of Chinese industries with different types of ownership. In this section, we further investigate the determinants of environmental performance, focusing on the roles of ownership.

4.1. THE MODEL

Following the modeling procedure developed by Wang and Wheeler (2003, 2005), the estimation model for this study is specified as,

$$\begin{aligned}\log \mathrm{TSSI}_i = {} & \alpha_0 + \sum_{m=1}^{M} \alpha_{1m} o_{m_i} + \sum_{n=1}^{N} \alpha_{2n} S_{n_i} \\ & + \alpha_L \mathrm{Locat}_i + \alpha_V \log \mathrm{Vin}_i + \alpha_S \log \mathrm{Scale}_i \\ & + \sum_{k=1}^{K} \alpha_{3k} \log p_{k_i} + \sum_{j=1}^{J} \alpha_{4k} \log r_{ji} + \varepsilon_i \end{aligned} \quad (4.1)$$

where TSSI = TSS intensity (TSS discharge/value of output);

o_{m_i} = Ownership dummy of company i, with a total of $M + 1$ ownerships;

Table I. Sample Structure

Ownership	SOE	COE	POE	Foreign	Joint	Total
Observations (%)	159 (19%)	385 (46%)	231 (27%)	11 (1%)	56 (7%)	842 (100%)

s_{n_i} = Sector dummy of company i, with a total of $N + 1$ sectors;
p_{k_i} = Price of an input, with a total of K inputs;
r_{ji} = Strength of environmental regulation, with a total of J regulations;
Locat_i = Location dummy, 1 = industrial zone; 0 = otherwise;
Vin_i = Vintage – years in operation;
Scale_i = Scale of a company – fixed capital;
ε_i = A stochastic error term.

In (4.1), the performance indicator selected for this analysis is discharge intensity of total suspended solids (TSSI), which is defined as TSS discharge divided by total value of output. The regulatory variables include the pollution charge rate, inspections, citizen complaints, as well as a dummy variable for location, as environmental standards are less restrictive if an enterprise is located in an industrial zone. Average charge rates (charge per unit of water pollution discharge), average complaint rates (complaints per company) and average inspection ratios (inspections per company) in the year before (i.e., 1998)[8] at the town level (the lowest government unit in China) are used in the econometric models, and they are expected to have negative impacts on pollution discharges.

The prices of water, electricity, labor and coal can also affect pollution discharge, as they affect a company's total cost. Depending on whether or not they are substitutes or complements to pollution abatement, they may affect the pollution discharge positively or negatively. The uses of water, electricity and labor are directly contributing to TSS removal, so the prices of them could have positive impacts on TSS discharge. The use of coal contributes to TSS generation rather than treatment and, therefore, the price of coal is expected to have a negative impact on TSS discharge.

The characteristics of a company include ownership, sector, vintage, scale as well as location. Ownership is the focus of this analysis, which includes SOEs, COEs, POEs, foreign as well as joint ventures, The level of technology is not available for this analysis. However, the possible technology effect can be expected to be controlled by the inclusion of sector dummies, vintage and scale. Water pollution intensive sectors such as mining, food and paper, etc., should have positive signs in the model. While vintage may have a positive sign, as younger companies are expected to be cleaner, the scale effect should be negative, because of the effect of "economy of scale." Companies located in industrial zones may have higher pollution discharge intensities, as the environmental standards are lower for industrial zones.

Table II. Economic and environmental profiles (in 1999)

Category	Variable	SOE	COE	POE	Foreign	Joint venture	Total average	*N*
Economic variables	Total value of output: (10 million yuan)	6.3 (17.7)	2.0 (6.1)	1.3 (5.3)	3.6 (3.6)	4.6 (8.6)	2.8 (9.4)	744
	Total value of assets: (10 million Yuan)	24 (175)	1.0 (5.1)	0.5 (1.9)	1.2 (1.3)	15.6 (77.2)	6.2 (78.4)	790
	Employment: (Persons)	986 (2191)	151 (331)	118 (357)	326 (516)	256 (363)	307 (1049)	821
Environmental variables	Fixed environmental assets: (10,000 Yuan)	686 (3706)	77 (458)	21 (112)	10 (15)	297 (1334)	194 (1735)	630
	Environmental investment: (10,000 Yuan)	324 (1231)	51 (492)	4 (10)	0 (0)	8 (18)	77 (602)	439
	Environmental Operational costs: (10,000 Yuan)	34 (122)	16 (173)	3 (21)	2 (2)	10 (26)	16 (130)	486
	Waste water treatment facility: (set)	1.52 (0.86)	1.09 (0.44)	1.17 (0.89)	0.75 (0.50)	1.07 (0.39)	1.22 (0.70)	204
	TSS discharge: (10000 tons)	16.8 (77.5)	9.5 (104.3)	3.4 (39.6)	8.1 (22.8)	22.4 (111.7)	10.1 (84.1)	641

Note: Data are averages by category. Standard variances are shown in the parentheses.

Table III. Water pollution intensity (ton/1000 yuan)

Pollutant	TSS
SOE	2.5
COE	2.9
POE	1.6
Foreign	0.0
Joint venture	0.1

Log transformations are made to all continuous variables in the model. It can help control the potential heterogeneities associated with cross section data, and the coefficients of the variables can directly provide elasticity estimations.

4.2. THE RESULTS

Table V presents the econometric results for TSS discharge intensity[9], as specified in Equation (4.1). The results are generally consistent with the expectations as discussed above.

Ownership does contribute to the difference in TSS intensity. While the difference between SOEs and POEs is not significant, all other differences are statistically significant. Overall, SOEs have the highest discharge intensities,

Table IV. Inspections, citizen complaints and levy payments by ownership

		SOE	COE	POE	Foreign	Joint venture
Average numbers of inspections						
National inspections		0.11	0.05	0.05	0.10	0.10
Provincial inspections		0.62	0.26	0.26	0.10	0.30
Municipal, county and town visits		2.98	1.71	3.54	1.54	1.77
Regular visits		3.35	3.62	8.16	2.18	2.93
Citizen complaints						
Percent of firms who received complaints	Water pollution	4.40	0.78	2.60	0	1.79
	Air pollution	2.52	1.04	1.73	0	1.79
Average number of complaints	Water pollution	0.39	0.01	0.16	0	0.13
	Air pollution	0.09	0.03	0.02	0	0.09
Levy payment (actual payment/required payment)						
For wastewater discharge		0.77	0.85	0.88	0.60	1.00
For air pollution		0.69	0.72	0.80	1.00	0.81
For solid waste		0.00	0.50	1.00	1.00	N.A

Table V. Estimation result of pollution intensity equation[a]

Variable name and description	TSSI
Ownership	
COE	− 0.63*** (− 2.06)
POE	− 0.15 (− 0.46)
Foreign and joint venture	− 0.91*** (− 2.14)
Policy variables	
Complaint (town average in 1998, complaints per company)	− 1.69*** (− 3.56)
Inspection (town average in 1998, official visits per company)	0.06 (0.23)
Levy (town average in 1998, levy collected per unit of wastewater discharge)	− 0.33*** (− 3.78)
Input price	
Water price	1.43*** (4.63)
Electricity price	1.51*** (4.04)
Coal price	− 1.31*** (− 2.99)
Worker wage	0.32 (0.90)
Scale	
Fixed capital	− 0.22*** (− 4.08)
Vintage	
Years of operation	− 0.10 (− 0.69)
Location	
Industrial zone (1 = yes; 0 = otherwise)	1.89* (1.29)
Sector	
Mining	0.78*** (2.07)
Food	1.68*** (3.94)
Textiles	− 0.16 (− 0.36)
Leather	1.03 (0.87)
Fiber	0.82 (0.78)
Paper	3.64*** (3.50)
Printing	0.04 (0.06)
Petroleum	− 0.83 (− 1.14)
Chemicals	0.24 (0.74)
Pharmaceuticals	1.70** (1.64)
Rubbers	0.32 (0.40)
Plastics	0.10 (1.25)
Non-ferrous	− 0.21 (− 0.36)
Smelting	0.16 (0.41)
Mental	0.42 (1.16)
Equipment	0.53* (1.33)

Table V. continued

Variable name and description	TSSI
Power, gas and water	2.27*** (3.98)
Number of observations	517
Adjusted R^2	0.52

***, ** and *represented for 5%, 10% and 15% confidence level.
[a]Pollution intensity is defined as pollution discharge/value of output.

followed by POEs, COEs and the FDIs and joint ventures[10]. This confirms with the previous research findings that the environmental performance of SOEs is poorer than others, and therefore there should be no significant concerns over the potential negative environmental impact of privatization. As a matter of fact, if a reform of SOEs involves of foreign capitals, the environmental impact of the ownership reform could be positive, as the variable for FDIs and joint ventures in the model has a significant, negative sign over TSS discharge intensity. The empirical result about FDIs is also consistent with the previous research findings; FDIs and joint ventures have the best environmental performance in China. The Chinese private companies behaved much poorer than the foreign companies in environmental protection. This difference may be mostly due to the difference in operation efficiency, if the technology effect has been well controlled in the modeling process. Another reason may be that foreign companies may consider to meet international environmental standards, which are much more restrictive than the Chinese ones.

According to the modeling result, COEs have significantly better environmental performance than the POEs. As discussed in the theoretical analysis section, without the internalization effect, the performance of COEs should be worse than that of POEs. Therefore, this empirical result could imply the existence of the internalization effect; i.e., the collectively owned enterprises in China may take the potential negative environmental externalities into consideration even when there is no environmental regulation. SOEs have worse environmental performance than COEs. This is consistent with the argument that SOEs are less efficient in operation and have more bargaining power in environmental enforcement, but does not support the hypothesis that SOEs may take more environmental externalities into consideration than COEs.

Beside ownership, other variables are also contributing to the difference in TSS discharge intensity. The citizen complaint variable, an indicator of informal regulation, defined as complaints on water pollution received in 1998 in a town divided by the total number of polluting firms in the town, shows a strong negative impact on TSS intensity. The elasticity is about 1.7, which demonstrates the strong existence of informal regulation in China. The pollution charge variable also shows a significant, negative impact on pollution intensity, which is consistent with previous empirical findings conducted in China (Wang and Wheeler, 2003, 2005). The elasticity of the pollution charge with respect to TSS intensity is 0.33. However, the inspections, or the number of visits of government officials to the polluting firms, have no significant impact on TSS discharge intensity[11].

The price variables also show results as expected. Both water price and electricity price are positively correlated with TSS discharge intensity. The treatment of TSS needs water and electricity[12]. The higher the water price, the less the water use, the less the TSS treatment, and therefore, the higher the TSS discharge intensity. The higher the electricity price, the less the use of electricity, the less the TSS treatment, and therefore the higher the TSS discharge intensity. The elasticity of TSS discharge intensity is 1.4 with respect to water price and 1.5 with respect to electricity price. The price of coal is negatively correlated with TSS discharge. Coal is used in a production process, rather than in a treatment process, which may generate TSS. The higher the coal price, the less the coal use, the less the TSS generation and discharge. The elasticity is negative 1.3. The worker's wage does not have a significant correlation with TSS discharge intensity. The use of labor in TSS treatment may not be elastic.

The scale effect is clearly shown for TSS discharge intensity: the bigger the firms, the lower the pollution discharge intensity. The elasticity is negative 0.22. The number of years in operation does not show a significant effect. Plants located in industrial zones have higher pollution discharge intensities, which is consistent with the fact that pollution discharge standards in the industrial zones are less restrictive. TSS pollution intensive sectors are also picked up, which include mining, power, food, paper, and pharmaceuticals, etc.

5. Summary

This paper provides a systematic analysis of the ownership effects on environmental performance. The theoretical analysis has identified three major aspects of determinants of environmental performance associated with different ownerships, which include economic efficiency, willingness to internalize environmental externality, and bargaining power with government as well as with local community in regulatory enforcement. The efficiency effect and the internalization effect on environmental performance should be positive, while the negotiation effect should be negative. The private sectors may have higher economic efficiencies in resource utilization, fewer incentives to internalize environmental externalities and less bargaining power in environmental enforcement than the collective sectors, which, similarly, may have higher economic efficiencies in resource utilization, fewer incentives to internalize environmental externalities and less bargaining power in environmental enforcement than the SOEs.

Previous studies have demonstrated empirically the efficiency effect and the negotiation effect, but no studies were conducted on the internalization effect. This study fills the gap with an empirical analysis based on a plant-level dataset collected in China. The Chinese collectively owned enterprises are found to have a significantly better performance in pollution discharge intensity than the domestic private sector. If the efficiency with the private sector is not lower than the collective sector and the regulatory bargaining power with the private sector is not higher than the collective sector in China, which are generally believed to be true, this empirical result could imply the existence of internalization of environmental externality by the collectively or community owned enterprises, according to the theoretical analysis.

Other interesting empirical results are also found about the industrial environmental performance in China. The SOEs are found to have the worst environmental performance, while the domestic private enterprises are the second worst in water pollution abatement. The best performers are the foreign companies which have the lowest water pollution discharge intensities, and the second best are the companies of collectively owned.

The empirical results also show that the pollution charge instrument is effective in terms of providing incentives for pollution reduction. This confirms with previous empirical studies. Citizen complaints are found to have a strong positive role in pushing polluters to reduce pollution discharges. This demonstrates a great potential to use community pressure approaches to industrial pollution control in China.

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Notes

1. Those enterprises are called “township and village industrial enterprises” or TVIEs in China.
2. See Table I for ownership structure of the Chinese firms in our sample.
3. One may group firms into three categories: SOE, COE and POE. Foreign companies may be viewed as private companies because they share the same profit maximization objectives.
4. The pollution haven hypothesis states the possibility of pollution-intensive activities reallocating to developing countries with less stringent environmental standards.

5. For more information, see World Bank (2001).
6. For more detailed discussions, see Sinkule and Ortolano (1995) and World Bank (2001).
7. The data collection work was supported by the World Bank and China State Environmental Protection Administration (SEPA). Local environmental protection authorities in the three survey areas participated in the survey design and implementation processes. The survey teams were comprised of researchers from SEPA's Policy Research Center, Nanjing University, Beijing Normal University, as well as Guizhou Provincial Institute of Environmental Protection. The team members participated in the survey design and questionnaire pretests, were trained by the principal investigator, a survey expert, and conducted the survey.
8. Data in the year of 1998 are used in order to control potential endogenities.
9. Data for another conventional water pollutant–chemical oxygen demand (COD) are also available to the authors. However, the authors have no confidence in the quality of the data and the modeling results for COD are also not significant. Therefore, the results presented in this paper may or may not hold for COD.
10. SOE is a default variable in the model. Signs for all other ownerships are negative. Joint ventures mostly have foreign capitals and share similar modern operation procedures as FDIs in China. And the sample sizes for FDI and joint venture are also relatively small. So in the analysis, FDIs and joint ventures are grouped together into one category.
11. However, a significant impact of inspection and an insignificant impact of pollution charge were found by Dasgupta et al. (2001) with a panel data of major polluters from one city in China. This study finds a significant impact of pollution charge and an insignificant impact of inspection. The difference may be due to the different datasets used in the two studies. The dataset used by this study is from three provinces (cities) covering all sizes of polluters in each region, while the effective pollution charge rate varies from one city to another.
12. The uses of water, electricity and labor in a production process do not directly contribute to TSS generation, but the use of coal does.

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