Annual Conference of American Agricultural Economics Association, 2002

Long Beach, California

Ownership and Industrial Pollution Control: Evidence from China[1]

Hua Wang

Development Research Group

World Bank

and

Yanhong Jin

Department of Agricultural and Resource Economics

University of California, Berkeley

May, 2002

ABSTRACT

This study explores the differences in pollution control performances of industrial enterprises with various ownerships in China – State owned (SOE), collectively or community owned (COE), privately owned (POE), foreign directly invested (FDI) companies as well as joint ventures. A survey was conducted of approximately 1000 industrial firms in three provinces in China, which collects the detailed firm-level information in the year of 1999. Personal interviews of enterprises managers were also conducted in these samples, and subjective information was collected. Analyses have been performed on the differences in receiving and reacting to environmental regulatory enforcement, community pressure, environmental services, and internal environmental management among different ownerships. The determinants of the industrial pollution emissions in China are identified in the econometrical analyses. The results show that FDI and COE have better environmental performances, while SOEs and the POEs in China are the worst.

JEL Code: L21, Q28

Key words: Ownership, Regulation, Environmental Performance, China

[1] Corresponding address: Hua Wang, MC2626, World Bank, 1818 H St., N.W., Washington, DC 20433, USA; Email: HWANG1@worldbank.org.

I. I. Introduction

This paper explores the relationship between industrial ownership and environmental performance. 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 investments. The economic performance of SOEs deteriorated in most countries in the 1970s and 1980s as global markets fueled competitive pressures (World Bank, 1996)[2]. The poor performance and relatively decreasing impact on the national economy of SOEs have been driving governments to explore new ways for their SOEs to be re-organized, governed and operated. Three main avenues, corporation and restructuring, bankruptcy, and divestiture, have been implemented to raise efficiency and profitability of their SOEs. Particularly, with the belief of efficient resource allocation and better business performance of private sectors, privatization has been processed in most of developing countries in order to promote economic growth in the last decades (Boardman and Vining, 1989; Claessens at. 1997; World Bank, 1991, Frydman R. at. 1997).

The question then is whether this global privatization process is good for the environment. While private sectors are solely profit oriented, SOEs or COES normally take more social impacts into their decision-making processes. Therefore, the environmental performances of SOEs' and COEs could be theoretically better than the private sectors' thought SOEs and COEs possibly utilize resource inefficiently.

Beside SOEs and POEs, countries such as China have been also practicing another ownership structure, which is collectively or community owned (COE). Those enterprises are called "township and village industrial enterprises" or TVIEs in China. In additional to responding to the market, COEs have their incentive to internalize their environmental externalities to improve the social welfare of local communities. SOEs tend to internalize the environmental externality at the national level rather than community based. Obviously, the disparities in the regional development will lead to the differences in the pollution abatement of SOEs and COEs regarding their willingness to internalize the pollution externalities. One hypothesis can be that COEs in rich areas, where environmental demands may be higher, have better environmental performances than SOEs, and worse in poor areas. Given others the same such as efficiency of resource utilization, SOEs and COEs which are owned either by the nation or community, can have the better environmental performances than POEs.

[2] World Bank (1996) summarized the performance of some developing countries as follows: (1) from 1985 to 1991, SOEs in Turkey on average earned only half as much as the largest 500 private industrial enterprises in Turkey; (2) in Viet Nam, there were 12000 SOEs existing in 1990. But 2000 SOEs had ceased operation or been liquidated, another 3000 had been merged, and 20% of remaining SOEs were estimated to be losing money in 1994; (3) in Kazakhstan the gross SOE losses rose from 14.1% of GDP in 1992 to 23.7% of GDP by 1993; and (4) the loss of SOEs in Argentina reached 9% of GDP in 1989 while SOEs's share of total public debt stood at 50%.

There are few systematic studies on the relationship between the ownership structure and environmental performance. To fill this gap, this study selects three provinces in China, Jiangsu (rich), Guizhou (poor) and Tianjian (medium), to do the firm -level surveys and plant manager interviews. All major industrial firms in one county of each province were included in the sample. The firm-level surveys collected the detailed plant-level information of 1998 and 1999 such as production, material inputs, employment, discharge and emission, compliance with standards, levy and fine paid, inspections and complaints received, etc. Additional, the corresponding manger interview complies the subjective information related to plant operation, perception of environmental quality, pollution control efforts of the plant and the government, effectiveness of different policy instruments and enforcement efforts, community pressure, environmental services and markets, internal environmental management, etc.

This empirical study focus on the following five different ownerships in China – SOE, COE, POE, foreign directly invested (FDI) companies as well as joint ventures. Furthermore, since most of joint ventures have the foreign investment as a main share, FDI and joint venture are grouped together in this study. Analyses have been conducted on the differences in receiving and reacting to environmental regulatory enforcement, community pressure, and environmental services as well as in firm's internal environmental management among different ownerships. Econometrical analyses aiming to identify the determinants of industrial pollution emissions shows that FDI and COE have better environmental performances and SOEs receive highest pressures for further pollution abatement from both the government and the public.

This paper is organized as follows. Next section presents previous studies conducted in this area as well as a theoretic analysis of how ownership can affect a company's environmental performance. Section III provides background information about China industrial pollution control, the survey design and implementation, as well as the survey results. Section IV provides an econometric analysis of industrial environmental performances and Section V concludes the paper.

II. Ownership and Environmental Performance

2.1 Previous Research

Studies on the relationship between ownership structure and environment have been focused on the following areas:

2.1.1 Economic Efficiency

Private sectors may have higher efficiency in resource utilization. They may produce less pollution with same resources. In contrast to SOEs, POEs emphasize more on economic returns, which generates a higher requirement for better management. Therefore, a better environmental quality could be achieved with more private sectors (Kikeri et. at., 1992; Schmid and Rubin, 1995; Coequty and Wiles, 1998; Gentry, 1998; and Coequty, Wiles and Campbell, 1999).

2.1.2 Internalizing environmental externality

Although POEs may have higher efficiency of resource utilization, they have less incentive to internalize environmental externalities (Baumol and Oates, 1988; Pranab, 1993). In other words, the private sectors may compromise the environment to avoid the potential cost of environmental investments and expenditures (Eiser, Reicher and Podpadec, 1996). However, the SOEs and COEs have their incentives to internalize the environmental costs resulting from pollution discharge, in order to obtain higher national or local social welfare. While a country itself is heterogeneous in terms of its geographic, economic and social characteristics, the environmental damage and the internalization of pollution externality within a region are obviously different from that within a nation. Thus, we would expect SOEs and COEs internalize the pollution externalities at different levels.

2.1.3 Bargaining powers in regulatory enforcement

SOEs may have stronger bargaining powers with local environmental authorities in environmental enforcement (Wang et al, 2001). Environmental bargaining power is defined as an enterprise's capacity to negotiate 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 have very different relationships with the local environmental authorities and governments. These differences will lead to the different levels of bargaining power. For example, SOEs in China are the backbone of the national economy, which are enjoying the governmental protection and have higher bargaining power from the local environmental agencies than other types of enterprises. As a result, they are able to elicit a lower payment or less punishment; and they may have less incentive to cut down their pollution and reduce the pollution intensity. Wang et al (2001) demonstrates less bargaining powers for private companies in compare with SOEs. COEs make great contributions to the local economic development and employments. They are also equipped with relatively higher environmental bargaining powers in contrast to private enterprises in China.

2.1.4 Bargaining powers with communities

Firms with different ownerships may receive different levels of informal regulation, or community pressure, on pollution abatements. In developing countries the informal regulation is in effect no matter the formal regulation is absent or effective. Local communities have struck their own Coasian bargains with neighboring enterprises. Leverage in negotiations is provided by social pressure on workers and managers; adverse publicity; the threat of violence; resources to civil law, etc. The effect of community pressure on emissions has been confirmed in several empirical studies (Pargal and Wheeler, 1996; Wang, 2000), which found that proxies for direct community pressures (community income and education levels) have significant effects on plant level emissions. Dasgupta and Wheeler (1996) show that there is a significant correlation between the number of complaints and the pollution emission, and consequently the quality of environment. But whether a community takes environmental actions or at what level the informal regulation and community pressure are effective to pollution control, possibly depend on the impacts of a certain enterprise on the regional economy. There is a trade-off for the local residents such that they had to choose the optimal pressure level imposed on a certain enterprise taking consideration of potential economic benefits regarding their job opportunities and income expectations, and environmental and social costs of production externalities.

2.1.5 FDI with better technologies

Foreign direct investments 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 along with industrial ownership structure changes in developing countries naturally raise the question about whether "pollution heavens" hypothesis[3] 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 (Kalt, 1988; Low and Yeats, 1992; Han and Braden, 1996; Xing and Kolstad, 1996, Mani and Wheeler, 1997). But most of empirical studies cannot find significant evidence to support the hypothesis including all the paper surveyed in Dean (1992). Among which did not find a significant impact of environmental factors on trade or industrial transformation are those by Kalt (1988), Grossman and Krueger (1992), Tobey (1993) and Bouman (1996). Eskeland and Harrison (1997), Wheeler (2000) and Letchmanan and Kodama (2000) did not find any evidence for the "pollution haven" hypothesis. Rather, in developing countries, FDIs generally are equipped with advanced technologies, and therefore, the environmental performances of FDIs may be better than those domestically owned enterprises.

Thus, the direction and the level at which that ownership structures affect environmental performance depend on the magnitudes of the effects discussed above. A few empirical studies have been conducted on the relationship between the ownership structure and environmental performance (Anderson, 1995; Kikeri, Nellis and Shirley, 1992; and Talukdar and Meisner, 2001). Particularly, Talukdar and Meisner (2001), using annual data for 44 developing countries from 1987 to 1995, shows a significantly negative relationship between the degree of private sector involvement and the CO2 emission levels where the private sector involvement is valued by its investment in the total domestic investment, national GDP, or its value of output share in the national GDP. The result in tTalukdar and Meisner (2001) shows that an increased role by the private sector in an economy is more likely to help the environment of the economy.

[3] Pollution heaven hypothesis states the possibility of pollution-intensive activities re-allocated to developing countries with less stringent environmental standards.

There are some very recent empirical researches investigate the relationship between ownership and environmental performance at factory level (Wang and Wheeler, 2002). These studies show that SOEs likely pollute more than private enterprises.

2.2 A Theoretic Analysis

To analyze the differences in environmental performances of industrial firms with different ownerships, one may group firms into three categories: SOE, COE, POE, and foreign company and joint ventures. Foreign companies may be viewed as private companies because they share the same profit maximization objectives. Joint ventures may have mixed ownerships and their environmental performances may be in between.

Assume the representative of the industrial enterprises utilizes factor inputs *X* to produce output *Y*. Additionally, the production generates pollution emission *Z* which is a function of factor inputs and ownership *I*. Correspondingly, pollution emission incurs the environmental and health damage. Let $D(Z)$ and $D_k(Z)$ denote the total social damage at the nation and community *k* levels, respectively. Assume government regulates the pollution emission by collecting levies, imposing penalty such as fine, etc. Let $P(Z)$ represent the total cost on the enterprises regulated by the government.

Due to the differentiated bargaining power with the environmental authorities and local communities, firms with different ownerships actually pay different amount of penalty or levies even they generate the same volume of pollution emissions. We use $\alpha(I)$ to identify the possibility of differences in the penalty or levy actually paid by the enterprises with different ownerships. Furthermore, as we discussed above, private companies do not bear the social cost due to the pollution externality; collective enterprises have incentive to internalize the social damage up to the extent where the local communities are concerned; and the state-owned enterprises take considerations of the social damage to the whole nation. $\gamma(I)$ is then incorporated to investigate the fact that different firms may internalize pollution externalities at different level. More specifically, $\gamma(I)$ is given by

$$\gamma(\mathrm{I}) = \begin{cases} 0 & \text{if } I = 1\,(\text{POEs}); \\ \mathrm{D_k(Z) / D(Z)} & \text{if } I = 2\,(\text{COEs}); \\ 1 & \text{if } I = 3\,(SOEs). \end{cases} \tag{1}$$

where *k* represent the k^{th} community where the enterprise is owned; and the total social damage of pollution emission $D(Z)$ is given by $\mathrm{D(Z)} = \sum_k D_{\mathrm{k}}(Z)$.

Assume that an enterprise minimize its total cost subject to an output constraint. Based on the discussion above, we can divide the total cost into the following three components: (1) the total factor input cost; (2) the total penalty caused by pollution or the total cost of using environmental resources; (3) total damage to the society and the environment. The representative of industrial enterprises makes the decisions of the production and pollution abatement to minimize his cost. Specifically, the cost minimization problem is given by

$$\min_x X\, W_x + \alpha(I)P(Z) + \gamma(I)D(Z) \qquad \text{s.t. } Y(X, I) \le y \tag{2}$$

where W_x is a price vector of factor inputs X; and $Y(X,I)$ represents the production function; and $\gamma(I)$ is given by Eq. (1).

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

$$\underbrace{W_x}_{\substack{\text{marginal cost}\\ \text{of factor input}}} + \underbrace{\alpha(I)\frac{dP(z)}{dz}\frac{\partial Z(x,I)}{\partial x}}_{\substack{\text{marginal cost}\\ \text{of pollution penalty}}} + \underbrace{\frac{d(\gamma(I)D(z))}{dz}\frac{\partial Z(x,I)}{\partial x}}_{\substack{\text{marginal environmental}\\ \text{damage internalized}}} = \underbrace{\lambda\frac{\partial Y(x,I)}{\partial x}}_{\text{marginal production}} \tag{3}$$

where λ is the Lagrangian multiplier. Corresponding to the division of the total cost, the marginal cost therefore consists of three components as shown in the left side of Eq. (3) including (1) marginal cost of factor input; (2) marginal cost of pollution penalty; and (3) marginal cost of internalizing environmental damage. The optimality condition of x for a state owned enterprise is achieved when the value of marginal production equals the marginal cost that equals the summation of the market price, the marginal environmental penalty to the company and the marginal damage to the whole society. Collective enterprises possibly bear the marginal damage up to its hosting local community level; while private enterprises have no incentive to internalize the environmental damage at all.

2.2.1 Efficiency Effects

Assume that there are three types of the factor inputs based on the relationship between this input and pollution emission: (1) inputs which positively contribute to pollution emission such that $\frac{\partial Z(x,I)}{\partial x} > 0$; (2) inputs which have a negative effect on pollution emission such that $\frac{\partial Z(x,I)}{\partial x} < 0$; and (3) inputs which have no correlation with pollution emission such that $\frac{\partial Z(x,I)}{\partial x} = 0$. For example, the utilization of some raw materials possibly is the main contributor to pollution emission; labor or capital investment on pollution control leads to the reduction in pollution emission.

A higher efficiency of an input x which positively contributes to pollution emission implies a lower marginal emission because less input are used to produce the same amount of output. Therefore, the marginal cost of the input is lower. If an input negatively contributes to pollution emission, then the higher efficiency means a higher marginal pollution reduction. Therefore the marginal cost of the input is also lower. While keeping emission constant, a company with a higher efficiency would use more input to produce more output. When having same outputs or inputs, a company with a higher efficiency would produce less pollution.

2.2.2 Regulation Effects

Although enterprises with different ownerships have varied environmental performance resulting from the efficiency and the internalization effects, we assume that the gross effects of these two sources are the same for all the enterprises, i.e., the gross effect is given by *EEIE*. As a result, the marginal costs of input x for enterprise with different ownerships are given by

$$MC_1 = W_x + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,1)}{\partial x} + EEIE \quad (4\text{-}1)$$

$$MC_2 = W_x + \alpha(2)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,2)}{\partial x} + EEIE \quad (4\text{-}2)$$

$$MC_3 = W_x + \alpha(3)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,3)}{\partial x} + EEIE \quad (4\text{-}3)$$

Where Eq. (4-1), (4-2), and (4-3) shows the marginal cost of POEs, COEs, and SOEs, respectively. Assume that $\frac{\partial Z(x,i)}{\partial x}$ are the same for enterprise with different ownership structures. As a result, the differences between the marginal costs will be only from the coefficient $\alpha(I)$, $\alpha(I)$ stands for the bargaining power of enterprises with the environmental authorities, governments, and local communities. Private companies have less bargaining power such that the coefficient can be the highest, $\alpha(I)$ may be close to 1. SOEs have higher bargaining power, which leads to a lower coefficient $\alpha(I)$.

If an input *x* positively contributes to pollution emission such that $\frac{\partial Z(x)}{\partial x}>0$, the marginal cost is the highest for a private company. Fewer inputs would be used, and therefore less pollution would be emitted. On the other hand, if an input *x* helps to cut pollution emission, i.e., $\frac{\partial Z(x)}{\partial x}<0$, then its marginal cost is the lowest for a private company, therefore more pollution reduction inputs would be used. Ultimately, the environmental performance of a private company can be the best.

The situation for a state owned company is the opposite: more pollution generation inputs and less pollution reduction inputs would be used. Therefore, the environmental performance of a state owned company could be the worst, while the performance of a collectively owned company can be in between.

2.2.3 Internalization Effects

Assume the gross effects of efficiency and the strength of environmental regulation are the same for enterprises with different ownerships. Let *EEER* denote the gross effects, then EEER is given by $\alpha(i)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,i)}{\partial x}$ where i is an index of ownerships. The marginal costs of the inputs for POEs, COEs, and SOEs are given by the following equations, respectively.

$$MC_1 = W_x + EEER \quad (5\text{-}1)$$

$$MC_2 = W_x + EEER + \frac{\partial D_i(z)}{\partial z}\frac{\partial Z(x,2)}{\partial x} \quad (5\text{-}2)$$

$$MC_3 = W_x + EEER + \frac{\partial D(z)}{\partial z}\frac{\partial Z(x,3)}{\partial x} \quad (5\text{-}3)$$

Therefore, the only differences in the marginal costs of inputs are caused by the internalization of the pollution externality. If $D_i(Z)$ is an element of $D(z)$, then $0 \le \frac{dD_i(z)}{dz} \le \frac{dD(z)}{dz}$. If the utilization of an input generates pollution, the marginal cost of this input would be the highest for a state owned company. On the other hand, the cost of a pollution reduction input will be the lowest for a state-owned enterprise. Therefore, if everything else were the same except the effects of internalizing pollution externalities, a state-owned enterprise would be either use fewer amount of pollution generating inputs or employs more volume of the pollution cutting inputs. As a result, SOE can be a best environmental performer. Similarly, a collective company would be the second best, while a private company would be the worst.

It is obvious the physical damages resulting from pollution are the same for a collective company and a state owned company. But the state company may value the damage based on the national income, while the collective company may value the damage based upon the local income level. Thus, SOEs and COEs internalize the pollution externality either at the national or local levels. Their environmental performances could still be different. Assume valuations of damages are positively correlated with income. In a richer area where the income level of the community is higher than the national average level, a collective company may have a better environmental performance than a state owned company. In a poor area where the income level of the community is lower than the national average, a collective company may have a worse environmental performance than a state owned company.

2.2.4 gross effects

The marginal cost of an input is divided into three parts: the effects of efficiency, regulations and internalizing externalities as specified by Eq. (3). Furthermore, the nature of ownership also possibly affects the marginal productivity of factor input, which is illustrated by the right side term of Eq. (3). The gross effect of the nature of ownerships is determined by its effect throught these four channels: resource utilization efficiency, environmental regulations, internalization of pollution externality, and effects on input productivities. Situations would be complicated if all of those determining effects are combined. They are generally unpredictable, and the results would be of empirical issues.

III. China Survey and Statistics

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, the background information of the industrial pollution control in China is presented in the following section.

3.1. Policy Background

China's industrial growth has been extremely rapid in the past two decades. The annual growth rate has been approximately 15% in the 1990's. The industrial development has helped lift 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[4].

China has been adopting various policy measures to control industrial pollution[5], which include command-and-control approaches, administrative measures, economic instruments, as well as public information and campaign. Moreover, China also has been practicing the environmental impact assessment (EIA) policy and "three simultaneous" policy, pollution discharge standards. The goal of EIA is to forecast and evaluate likely adverse environmental effects from a proposed project. Environmental agencies at city or county level have the authorities to approve or disapprove the EIA. It is mainly used to mitigate adverse consequences of proposed project rather than influence industrial site decision. "Three simultaneous" policy 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 different environmental sensitivity, where different ambient and discharge standards are enforced. Pollution charge has been one of the most important pillars of industrial pollution regulatory system in China. This policy instrument was originally designed to promote compliance with pollution discharge standards. The Chinese

[4] For more information, see World Bank (1997 & 2001).

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 three years of experimentation, China's State Council began 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 pollution. In 1996, the system was implemented in almost all counties and cities. Four billion yuan were collected from about half a million industrial firms; and numbers are increasing each year.

There are some unique features associated with the charge system. For wastewater, this system only imposes charges on the pollutants over the standard[6], among which only the pollutant violating the standard to the greatest degree enters into the calculation of the total levy fee. In other words, fees are calculated for each pollutant in a discharge stream and the polluter only needs to pay the amount having the highest value among all the pollutants. The Chinese central government constructs a uniform fee schedule; however, the implementation in different regions is not uniform[7]. The levy collected is used to finance environmental institutional development and administration, fund environmental projects, and subsidize firms' pollution control projects. If a firm that pays levies decides to invest in pollution abatement, a maximum of 80% of the levy paid by this firm can be used to subsidize the investment project proposed by the firm. To make the levy collection effective, a schedule of penalties is also specified[8]. But penalties cannot be used to subsidize firm-level pollution control projects.

Although studies have been conducted to reform the levy system with most analysts recommending raising China's pollution charge rate, few empirical analyses have actually investigated polluters' response to the existing charges. In Wang and Wheeler (2002), province-level data on water pollution was analyzed and it shows that China's levy system had been working much better than previously thought. The results suggest that province-level pollution discharge intensities have been highly responsive to provincial levy variations.

---

[5] For more detailed discussions, see Sinkule and Ortolano (1995) and World Bank (2001).

[6] After 1993, the government started charging for wastewater discharges whether they met discharge standards or not.

[7] For a detailed discussion, see Wang and Wheeler (1996) and SEPA (1994 & 1998).

[8] The penalty schedule is usually referred as "four small parts" in Chinese.

But the existence of environmental policies does not imply that emissions will fall and environmental quality will improve. Monitoring polluters and enforcement of compliances[9] is crucial to the credible regulatory system (Magat and Viscusi, 1990; Laplante and Rilstone, 1996; and Nadeau, 1997, Dasgupta at. 2001). In china, the main policy to monitor the polluters is inspection, which are generally conducted at the national, provincial, or local city and county level. Additional to detect the pollution discharge, environmental inspections in china have another goal, to collect levy or penalties.

In additional to the formal inspection, a formal mechanism for citizen complaints allows citizens to complain about pollution via mail, phone call or visit to environmental authorities. The complaints process provides some useful monitoring information, and an important avenue for community participation in environmental policy. It also directs a major share of China's inspection resources towards areas where individuals or communities have a high propensity to complaint. Furthermore, media, whose growing environmental coverage has stimulated public awareness in recent years in China, especially in big cities. Indeed, Chinese citizens have become extremely vocal about the more visible forms of environmental damage caused by major industrial polluters. Chinese firms therefore are facing community pressure in terms of their adverse impact on environment and their pollution discharges.

3.2. Survey Design and Implementation

To study pollution control behaviors 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 municipality in Jiangsu Province, and Liupanshui municipality in Guizhou Province, were selected to conduct the survey due to their great differences in social, economic and environmental conditions (see Table 1), their significances in collective and private sectors development, and their governments' supports for conducting the research. Among these three areas, Danyang municipality is located in a relatively rich and Liupanshui municipality is the poorest area; the northern part of Tianjin is a relatively more urbanized and its 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 enterprises in the three areas were included in the sample. Plant-level information was collected from three channels: the municipal environmental protection agencies; plant-level questionnaire; and enterprise manager survey. All polluters are required to register or report their pollution related information with the local environmental authorities each year. Environmental authorities have been practiced various ways to check the accuracy of the data they received including regular inspections, surprise inspections, and material balance estimation, etc. This study designed and

[9] Monitoring the polluters and enforcement of compliance, two important components of a credible environmental regulatory system, has been attracting less research efforts (Cropper and Oates, 1992).

implemented a plant-level questionnaire to collect pollution information that is not included in the pollution registration practice. Additionally, a plant manager survey was also conducted to collect subjective information on perceptions and attitudes toward environmental quality, policy enforcement, as well as environmental services.

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 who participated in the survey conduction were trained by the principal investigator, survey experts.

The survey was conducted between April and September, 2000. Detailed information was collected from 905 industrial plants. Plant surveys were distributed by three survey coordinators in the three areas. Returned survey forms received quality checks from survey teams before they were recorded into computer for analyses. Manager surveys were conducted by well-trained interviewers. Plant managers were summoned to the designated interview sites by the local environmental authorities, but the questionnaires were finished anonymously without government officers observing the interview process.

3.3. Statistics

Table 2 shows the numbers of industrial enterprises included in the sample, by survey site, and ownership or sector, respectively. SOEs and private enterprises accounts for the largest proportions in Liupanshui Municipality. But in the northern part of Tianjin or Danyang collective enterprises accounted for approximately 60%. There were more private companies and less SOEs in Danyang than in Tianjin. Tianjin and Danyang were mainly engaged in the chemical sectors and Liupanshui had a higher proportion of mining industry. SOEs in the sample were highly concentrated in mining and chemicals; foreign companies were more engaged in textile and metal industries; and joint ventures in chemical and equipment sectors.

Table 3 presents the statistics of major economic and environmental variables. It is clear that SOEs generally have a bigger scale than other types of enterprises, while the private companies are the smallest. On the other hand, SOEs invest more in pollution abatement facilities and have higher operation expenditures than that of other type industries.

Table 4 demonstrates pollution discharge intensities and concentrations. Pollution intensity are defined as pollution discharge per unit of labor or value of output. SOEs have much higher intensity of air pollution (SO2 and TSP) than other types of enterprises. Collective enterprises have higher TSS intensity of water pollution. In terms of concentration, the water pollution discharges from the private companies are the highest.

The performance and compliance information are presented in table 5. SOEs violate the emission standards the most. Collective enterprises have the lowest violation rates.

Table 6 shows that private enterprises received environmental inspection most, even though the scales of private companies are among the smallest (Table 3). More SOEs and private enterprises received citizen complaints on pollution issues (Table 7). The levy payment rates of SOEs are lower than the collective and private companies (Table 8). More SOE managers feel that the enterprises are damaging the environment, and they also feel strong pressures from the government and the communities to further abate pollution (Table 9).

IV. Econometric Analyses

Survey statistics presented in the previous section demonstrate the differences in environmental enforcement and performances of Chinese industries with different ownerships. This section is to further investigate the determinants of environmental performances, focusing on the roles of ownership. One specific issue we would like to explore is how collective ownership generates different environmental performances in areas at different development levels.

Liupanshui is the least developed area among the three survey sites. Its GDP per capita was approximately 20% of those in Danyang and Tianjin, even though the average salaries of workers were close (see Table 1). GDP per capita was similar in Tianjin and Danyang. Tianjin was more urbanized than Danyang and the state ownership dominated more in Tianjin than in Danyang. How those collective companies, which are supposed to respond more to the community needs, are performing differently in pollution control in the three different areas is an interesting issue for analyses.

4.1 The models

This study uses the pollution intensity per unit of value of output as an indicators for environmental performance at the plant level. Based on previous studies (e.g., Pargal and Wheeler, 1996), the following sets of determinants are identified and included in the analyses:

(1) Environmental policy and external pressure

Variables in this category include pollution charge rate (levy per unit of pollution emission), number of inspections received, number of citizen complaints received, and dummy for environmental zones. Two types of environmental zones are classified: industrial zone, and living and commercial zone. The environmental standards are less restrictive if an enterprise is located in an industrial zone. Pollution charges, complaints and inspections are endogenous because they can be affected by pollution discharge performances (see Wang and Wheeler, 2002 and Wang et. al., 2001), and they are expected to have negative impacts on pollution discharges and intensities. The following two methods can be used to handle the endogeneity problem: (1) to incorporate the inspections, complaints, and pollution charge at the plant-level as independent variables and do the instrument regressions to control the endogeneity; and (2) to incorporate the town-level inspections, complaints, and pollution charges in the previous year rather than the values in the plant-level.

(2) Input prices

Prices of industrial water use, electricity, coal and wage may also affect pollution discharge and intensity. The effects of input factors depend on whether they are substitutes or complements to pollution abatement. A set of input prices for industrial water, electricity, coal and wage is compiled at the county-level, and incorporated into the model.

(3) Characteristics

The characteristics of enterprises consist of sector, vintage, scale, location, and ownership. Ownership is the focus of this analysis, which is classified by state-owned, collective, private enterprises, and foreign and joint ventures[10]. Technology level can hardly defined quantitatively and is not available from the survey. However, the possible technology effect can be expected to be controlled by the inclusion of sector dummies, vintage, and years of operations for each enterprises since it was established.

4.2 The Results

Table 10 presents the econometric estimation results. Two sets of estimation results are provided for two conventional water pollutants: total suspended solids (TSS) and chemical oxygen demand (COD). The dependent variables are pollution intensities (pollution divided by value of output), which are taken by the logarithm terms. Both TSS and COD intensities are evaluated at the level of 1999. Three policy variables are incorporated in the model: (1) environmental officials visits; (2) complaints; and (3) pollution charge.

In the first set of regressions whose results are reported by the column 2 and 3 in Table 10, the policy variables, official visits, complaints, and pollution charges are evaluated at the firm level. In this case, three policy variables are instrumented to control the endogeneity. Two-stage estimation therefore is employed. The instrument variables includes the regional factors such as income, education, pollution discharge of TSS and COD in 1998, ratio of fixed capital of each firm in the total value of fixed capital at the county level, ratio of plant's employment in the regional industrial employment, population proportion having sanitation facilities, population ratio drinking taped water, an indicator variable indicating whether a firm frequently violates the emission standard in the past; and an indicator variables identifying whether a firm conduct environmental impact assessment. Additionally, all the independent variables are included in the estimation in the first stage. The results of the Hausman test did not reject the existence of endogeneity. Furthermore, we did the test for over-identification and the results cannot reject the hypothesis that there is no over-identification problem.

In the second set of regressions, we used the policy variables at the average town-level in the previous year (1998). The values of official visits and complaints are given by the total number of visits, or complaints divided by the total number of industrial enterprises of each town in 1998. The pollution charge is given by the total levies actually paid by the enterprises divided by the total wastewater for each town in 1998. In the second set of regression,

Column 2 and 3 gives the results of the second set of regressions in which three policy variables are evaluated at the plant level. Column 4 and 5 demonstrates estimation results for the first set of regression where the policy variables are evaluated at the county level of 1998.

Basically, the estimation results are similar in these two sets. Both citizen complaints and levy significantly reduce the pollution intensities of TSS but not the intensity of COD. It is consistent with the understanding that citizens can easily perceive pollutants such as TSS rather than COD that is not easily perceivable. The complaint at the plant level has a higher elasticity (-2.78) than the town-average complaint in previous year (-1.6). Both of them demonstrate the strong existence of informal regulation in China.

The estimation results also show that the pollution charge has strong significant negative impacts on pollution intensities, which is consistent with previous empirical findings conducted in China (Wang and Wheeler, 2000 and 2002). The elasticity of the pollution charge at the plant level with respect to TSS and COD intensities are –0.63 and –0.20, respectively. The town-average level of pollution discharge of 1998 has the lower elasticities (-0.33 and –0.28 with respect to the intensity of TSS and COD, respectively).

The effects of official visits seem problematic or at least do not match with the previous studies. The results show that the visits of environmental officials to the polluting firms either have a significant positive impact on the intensities of COD and TSS or positive but not significant effects. This is counterintuitive if the visits are interpreted as the efforts of the government in enforcing the environmental laws. But if the number of visits represents a close relationship between the environmental officials and the polluters, the story could be quite different. Especially, enterprises in China usually take

[10] To further evaluate the effects of collective ownership, cross terms of collective ownership and location are can be included in the estimation equations.

advantage of official visit to bargain or arguing to cut down or waive the pollution charge. A further investigation on the natures of the official visits to the polluting companies in China seems needed.

The input price variables show that the higher the water price, the higher the pollution discharge intensities, which is true for both TSS and COD. The price of electricity has a positive correlation with TSS discharge and negative correlation with COD discharge. This is consistent with the understanding that the consumption of electricity is positively related with TSS treatment, while the treatment of COD may not consume much electricity. The price of coal is negatively correlated with TSS discharge, which could mean that the less the consumption of coal, the less the TSS discharge. The worker's wage does not have significant correlations with pollution discharge intensities.

The results also show that the nature of ownership structures does contribute to the differences in pollution intensities of TSS and COD. Keeping everything else the same, SOEs have highest discharge intensities than COEs and the FDIs and joint ventures. For example, the highest difference of TSS and COD intensities between SOEs and other types of enterprises ranges from 7% to 70%. The differences in the pollution intensities between SOEs and private enterprises are not significant, while all others are statistically significant.

Scale effects are clearly shown for the two pollutants: the bigger the firms, the lower the pollution discharge intensity. The elasticity of the scale effect is approximately –0.2. The number of operation years 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.

V. Summary

This study analyzes the ownership effects on industrial environmental performances. Economic efficiency, production and pollution abatement technology, willingness to internalize environmental externality, bargaining power with government and community in environmental enforcement have been identified as the major reasons for the difference in environmental performance of enterprises with different ownership structures. Private sectors in developing countries may have higher economic efficiencies in resource allocation. But they lack of incentives to internalize environmental externalities and are equipped with less bargaining power in environmental enforcement. State-owned and collectively owned enterprises have higher willingness to internalize environmental externalities and enjoy higher bargaining powers in environmental enforcement, but the economic efficiencies may be lower. So the overall ownership effect is an empirical issue.

The empirical study conducted in China provides consistent results with the theoretical analyses and the previous empirical studies. The results show that the state-owned enterprises have the worst environmental performances. The second worst performers are the domestic private enterprises. The best performers are those foreign companies and joint ventures, which have the lowest pollution discharge intensities. The Chinese collectively owned enterprises also have good performances in terms of pollution intensity than SOEs.

The study also finds that the pollution charge instrument is effective to cut down pollution intensity. This confirms with the previous empirical studies. Citizen complaints are found to have strong positive roles in pushing polluters to reduce pollution discharges. This shows a great potential to use community pressure approaches to promote industrial pollution control in China.

References:

Birdsall, N., and Wheeler D. (1992). In: Low, P. (Ed.), Trade Policy and Industrial Pollution in Latin America: Conceptual Issues and a Review of the Empirical Evidence.

Boardman, A.E. and A.R. Vining (1989). Ownership and Performance in Competitive Environments: a comparison of the performance of private, mixed, and state-owned enterprises. Journal of Law and Economics 32: 1-33.

Bouman, M. (1996). Do pollution Abatement Costs Induce Direct Foreign Investments? Evidence for Germany, mimeio, University of Amsterdam.

Claessens, Stijin., Simeon. Djankov and Gerhard Pohl (1997). Ownership and Corporate Governance: evidence from the Czech Republic. World Bank Policy Research Working Paper 1737, Washington D.C.: the World Bank.

Cropper, M. and Oates, W.E. (1992). Environmental Economics: a survey. Journal of Economics Literature, Vol. 30 (2), 675-740.

Dasgupta, Susmita, Laplante, Benoit, Mamingi, Nlandu, and Wang Hua (2001a). Inspections, Pollution Prices, and Environmental Performance: evidence from China. Ecological Economics Vo. 36, pp. 487-498.

Dasgupta Susmita and David Wheeler (1996). Citizen Complaints as Environmental Indicators: Evidence from China. Policy Research Working Paper, World Development Report No. ?. Washington D.C.: The World Bank.

Dasgupat Susmita, Hua Wang, and David Wheeler (1997). Surviving Success: Policy Reform and the Future of Industrial Pollution in China. Policy Research Working Paper No. 1856. Washington D.C.: The World Bank.

Dean, Judith (1992). Trade and Environment: A Survey of Literature. Policy Research Working Paper, World Development Report No. 966. Washington D.C.: The World Bank.

Eskeland, Gunnar and Ann Harrison (1997). Moving to Greener Pastures? Multinationals and the Pollution-haven Hypothesis. The World Bank Policy Research Working Paper, No. 1744. Washington D.C.: The World Bank.

Grossman, G.M., Kureger, A.B. (1992). Environmental Impact of a North American Free Trade Agreement. Discussion Paper No. 644. Center for Economic Policy Research, London.

Hartman, R.S., Huq, M. and David Wheeler (1997). Why Paper Mills Clean Up: Determinants of Pollution Abatement in Four Asian Countries. World Bank Policy Research Working Paper No. 1710. Washington D.C.: The World Bank.

Hettige, H. Huq, M., Pargal, S. and Wheeler, D. (1996). Determinants of Pollution Abatement in Developing Countries: Evidence for South and Southeast Aasi. World Development, Vol. 24 (12), pp. 1891-1904.

Letchumanan, Raman and Rumio Kodama (2000). Reconciling the conflict between the “pollution-haven” hypothesis and an emerging trajectory of international technology transfer. Research Policy, Vol. 29, pp. 59-79.

Low, P. (1992) (Ed.), International Trade and the Environment. Discussion Paper 159. Washington D.C.: The World Bank.

Lucas, R., Wheeler, D., and Hettige, H. (1992). In: Low, P. (Ed.), Economic Development, Environmental regulation and International Migration of Toxic Pollution 1960-1988.

Magat, W.A., and Viscusi, W.K. (1990). Effectiveness of the EPA’s Regulatory Reform: the case of industrial effluent standards. Journal of Law and Economics, Vol. 33, pp. 327-346.

Nadeau, L.W. (1997). EPA Effectiveness at reducing the duration of plant-level noncompliance. Journal of Environmental Economics and Management, Vol. 34 (1), pp. 54-78.

Kalt, J. (1988). The Impact of Domestic Environmental regulatory Policies on US International Competitiveness. In: Spence, A. M., Hazard, H.A. (Eds.), International Competitiveness. Harper and Row, Ballinger, Cambridge, MA.

Frydman, R., Gray, C., Hessel, M. and Rapaczynski, A. (1997). Private Ownership and Corporate Performance: some lessons from transition economies. World Bank Policy Research Paper No. ?. Washington D.C.: The World Bank.

Laplante, B. and Rilstone P. (1996). Environmental inspections and emissions of the pulp and paper industry in Quebec. Journal of Environmental Economics and Management, Vol. 31, pp. 19-36.

Pargal, S. and Wheeler, D. (1996). Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia. Journal of Political Economy, Vol. 106 (6), pp. 1314-1327.

Russell, Clifford S. (1990). Monitoring and Enforcement, in Public Policies for Environmental Protection, edited by P.R> Portney, Washingtod D.C.: Resources for the Future, pp. 243-274.

Silverman, S.L. (1990). Federal Enforcement of environemental Laws. Massachusetts law Review, 75. pp. 95-98.

Sheoli Pargal, Hemanala Hettige, Mabjula Singh, and David Wheeler (?). Formal and Informal Regulation of Industrial Pollution: Comparative Evidence from Indonesia and the US. World Bank Policy Research Paper No. ?. Washington D.C.: The World Bank.

Tobey, J.A. (1993). The impact of Domestic Environmental Policies on International Trade, in OECD (1993). Environmental Policies and Industrial Competitiveness, Paris.

Wang, Hua (2000), Pollution Charge, Community Pressure, and Abatement Cost of Industrial Pollution in China, World Bank Policy Research Working Paper #2337, Washington, D.C.

Wang, Hua, Mamingi, Nlandu, Laplante, Benoit, and Dasgupta, Susmita (2001b). Incomplete Enforcement of Pollution Regulation: bargaining power of Chinese factories. Washington D.C.: The World Bank.

Wheeler, David (2000). Racing to the Bottom? Foreign Investment and Air Quality in Developing Countries. Washington D.C.: The World Bank.

World Bank (1991). Developing the Private Sector: the World Bank's Experience and Approach.Washington D.C.: the World Bank.

Appendix

Table 1. Sample Areas

Sample area	**Liupanshui**	**Tianjin**	**Danyang**
Per Capita GDP (yuan)	2720	15932	16132
Average workers' wage (yuan)	5686	6838	6914
SO2 concentration (ug/m3)	75.9	23.3	25.2
TSP concentration (ug/m3)	134.2	158.4	231.6

Table 2: Sample Structure by Ownership and Sector

	By Ownership						**By Sector**			
Location	**SOEs**	**Collective**	**Private**	**Foreign**	**Join**	**Total No.**	**Mining**	**Chemical**	**Mental**	**Water, gas & power**
Liupanshui	99	41	122	2	12	276	104			47
Municipality	(36%)	(15%)	(44%)	(1%)	(4%)		(38%)			(17%)
Northern Tianjin	39	159	27	6	28	259		41	40	
	(15%)	(61%)	(10%)	(2%)	(11%)			(17%)	(17%)	
Danyang Municipality	21	185	82	3	16	307		68	47	
	(7%)	(60%)	(27%)	(1%)	(5%)			(22%)	(15%)	
Total	159	385	231	11	56	842	106	116		
	(19%)	(46%)	(27%)	(1%)	(7%)		(13%)	(14%)		

Table 3: Economic and Environmental Profile by Ownership (in 1999)

Category	**Variable**	**SOE**	**Collective**	**Private**	**Foreign**	**Joint**	**Total average**	**Number**
Economic variables	Output value: *10,000 yuan*	6316 (17669)	2031 (6140)	1326 (5305)	3656 (3551)	4626 (8583)	2782 (9357)	744
	Total value of assets: *10,000 Yuan*	24317 (175330)	1207 (5066)	478 (1913)	1166 (1263)	15550 (77171)	6235 (78371)	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 Operation 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

Pollution Discharges	TSS: *tons*	16849 (77545)	9542 (104287)	3433 (39601)	8075 (22839)	22405 (111720)	10108 (84051)	641
	COD: *kilograms*	165578 (794127)	8147 (33569)	7595 (45234)	1275 (3139)	13926 (39894)	41224 (369561)	635
	SO2: *tons*	274243 (2948465)	277 (2812)	34 (186)	72 (156)	14382 (87573)	55153 (1310199)	608
	TSP: *tons*	1925 (6969)	0.71 (1.15)	3.18 (8.17)	0.06 (0.10)	1.00 (1.14)	391 (3145)	69

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

Table 4: Pollution Intensity by Ownership

Variable	**Intensity of labor**				**Intensity of output**				**Emission concentration**			
Unit	**Ton/person**				**Ton/ 10,000 yuan**				**µg/l**		**µg/m3**	
Pollutant	**TSS**	**COD**	**SO2**	**TSP**	**TSS**	**COD**	**SO2**	**TSP**	**TSS**	**COD**	**SO2**	**TSP**
SOE	16.76 (129)	144.14 (97)	19.37 (88)	0.67 (76)	2.46	21.43	3.15	0.18	310.35	353.23	2097.41	440.11
Collective	34.92 (56)	119.78 (97)	1.16 (41)	0.01 (17)	2.94	8.16	0.11	0.00	177.88	281.75	1425.71	123.91
Private	15.81 (50)	115.96 (77)	0.46 (40)	0.30 (5)	1.56	11.20	0.06	0.08	955.86	426.20	2547.92	112.5
Foreign	0.00 (9)	11.24 (9)	0.35 (9)	0.00 (9)	0.00	0.12	0.03	0.00	287.50	167.75	3017.50	150.00
Joint venture	5.17 (16)	63.94 (21)	0.34 (16)	0.02 (4)	0.09	1.10	0.01	0.00	141.82	114.03	1258.29	150.00

Note: The numbers of firms by ownership are shown in the parentheses.

Table 5: Environmental performance and compliance by ownership

	violated emission concentration standards	violated emission standards frequently	exceeded emission quota	did not pay their levies on time	did not submit emission report	Discharge outlet did not meet standard	did not conduct EIA	did not comply with Three Synchronisms	No specific envi. staff
SOEs	0.64	0.22	0.80	0.47	0.42	0.45	0.61	0.63	0.62
Collecitve	0.45	0.07	0.44	0.40	0.39	0.40	0.44	0.49	0.48
Private	0.44	0.19	0.63	0.28	0.26	0.50	0.60	0.56	0.56
Foreign	0.40	0.10	0.50	0.60	0.50	0.50	0.50	0.70	0.70
Joint	0.60	0.07	0.64	0.60	0.60	0.60	0.61	0.65	0.65
Total	0.49	0.13	-0.58	0.40	0.37	0.40	0.53	0.55	0.54

Table 6: Average numbers of inspections over all the sampled firms

	SOE	Collective	Private	Foreign	Joint Venture	Total average
National Inspections	0.11	0.05	0.05	0.10	0.10	0.06
Provincial inspections	0.62	0.26	0.26	0.10	0.30	0.33
Municipal, County and Town Inspections	2.98	1.71	3.54	1.54	1.77	2.45
Regular inspections	3.35	3.62	8.16	2.18	2.93	4.76

Table 7: Citizen complaints

		SOEs	Collective	Private	Foreign	Joint Venture
Percent of firms who received complaints	Water pollution	4.40	0.78	2.60	0.00	1.79
	Air pollution	2.52	1.04	1.73	0.00	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

Table 8:Levy Payment (actual payment/required payment)

	SOEs	Collective	Private	Foreign	Joint	Total
Levy payment for wastewater discharge	0.77	0.85	0.88	0.60	102	0.86
Levy payment for air pollution	0.69	0.72	0.80	1.00	0.81	0.74
Levy payment for solid waste	0.00	0.50	1.00	1.00	N.A	N.A

Table 9: Managers' Self-evaluation of Environmental Performance and Pressure

(% of yes)

	Ownership					
Question	SOEs	Collective	private	Foreign	Joint venture	total
Damaging environment?	55	34	36	13	46	40
Meet environmental requirements?	89	89	74	80	93	85
Better than others in the same sector?	64	63	48	87	62	62
Pressure from communities?	71	59	48	60	43	42
Pressure from government?	78	33	36	47	31	31
Total number of firms	221	379	231	15	59	905

Table 10: Estimation Results of Pollution Intensities[a] of TSS and COD

Variable name and description		TSS	COD	TSS	COD
Ownership:	Collective enterprises	-1.20*** (-3.13)	-0.35 (-1.02)	-0.63*** (-2.06)	-0.04 (-0.15)
	Private enterprises	-0.60* (-1.52)	-0.15 (-0.43)	-0.15 (-0.46)	0.23 (0.71)
	Foreign companies and joint venture	-1.18*** (-2.31)	-0.20 (-0.45)	-0.91*** (-2.14)	-0.07 (-0.16)
***Policy variables*:**					
compwl[b]: number of citizen complaints about water pollution at the firm level in 1999		-2.78*** (-3.70)	0.06 (0.08)	-	-
inspl[b]: number of inspections done by envi. authorities at the firm-level in 1999		0.77*** (2.26)	1.26*** (4.12)	-	-
levypl[b]: average levy paid by each firm (actual levy paid / total waste water) in 1999		-0.63*** (-3.06)	-0.20 (-1.12)	-	-
tcompl98: county-average number of citizen complaints about water pollution in 1998		-	-	-1.69*** (-3.56)	0.25 (0.53)
tinspl98: county-average number of inspections done by envi. authorities in 1998		-	-	0.06 (0.23)	0.89*** (3.34)
levy98: county-average levy (total levy paid / total waste water) in 1998		-	-	-0.33*** (-3.78)	-0.28*** (-3.28)
***Input price*:**	**pwate,** water price	0.97*** (2.65)	0.78*** (2.41)	1.43*** (4.63)	0.99*** (3.20)
	pelec: electricity price	1.98*** (4.58)	-0.52 (-1.36)	1.51*** (4.04)	-0.76*** (-2.04)
	Pcoal: coal price	-1.63*** (-2.90)	-0.08 (-0.15)	-1.31*** (-2.99)	-0.09 (-0.22)
	Pwage: worker wage	0.29 (0.69)	-0.03 (-0.08)	0.32 (0.90)	-0.15 (-0.43)
***Scale*:**	fixed capital	-0.24*** (-3.55)	-0.24*** (-3.99)	-0.22*** (-4.08)	-0.17*** (-3.23)
Technology:	**years:** years of operation	-0.05 (-0.31)	0.22* (1.51)	-0.10 (-0.69)	0.21* (1.47)
Factor location:	**Industrial zone**	4.38*** (1.85)	2.00 (0.95)	1.89* (1.29)	0.30* (0.80)
Sector:	Mining	0.65 (1.41)	0.42 (0.30)	0.78*** (2.07)	0.30 (0.80)
	Food	2.09*** (3.81)	1.84*** (3.79)	1.68*** (3.94)	1.45*** (3.48)
	Textiles	-0.01 (-0.03)	0.51 (1.04)	-0.16 (-0.36)	0.41 (0.01)
	Leather	1.12 (0.81)	0.87 (0.71)	1.03 (0.87)	0.70 (0.59)
	Fiber	0.69 (0.57)	-1.91*** (-1.78)	0.82 (0.78)	-1.52* (-1.46)
	Paper	2.58*** (1.85)	1.30 (1.03)	3.64*** (3.50)	1.74** (1.67)

Printing	0.61 (0.73)	1.40*** (1.87)	0.04 (0.06)	1.00* (1.40)
Petroleum	-0.53 (-0.53)	1.37* (1.52)	-0.83 (-1.14)	1.04* (1.43)
Chemicals	0.35 (0.90)	0.25 (0.71)	0.24 (0.74)	0.28 (0.86)
Pharmaceuticals	1.23 (1.03)	-1.31 (-1.22)	1.70** (1.64)	-1.21 (-1.17)
Rubbers	1.27 (1.26)	-0.54 (-0.59)	0.32 (0.40)	-0.73 (-0.91)
Plastics	0.51 (0.57)	-0.56 (-0.65)	0.10 (1.25)	-0.56 (-0.70)
Non-ferrous	-0.27 (-0.38)	0.45 (0.72)	-0.21 (-0.36)	-0.07 (-0.12)
Smelting	0.35 (0.73)	-0.18 (-0.43)	0.16 (0.41)	-0.33 (-0.84)
Mental	0.76** (1.75)	0.21 (0.54)	0.42 (1.16)	0.07 (0.19)
Equipment	0.93*** (1.89)	0.41 (0.94)	0.53* (1.33)	0.08 (0.20)
Power, gas and water	3.11*** (4.11)	1.49*** (2.21)	2.27*** (3.98)	0.88* (1.51)
Number of observations	487	487	517	517
Adjusted R-square	0.35	0.11	0.52	0.14
P-value of the Hausman test	0.04	0.00		
P-value of the ver-identification test	0.00	0.00		

***, ** and * represented for 5%, 10% and 15% confidence level.

[a] pollution intensity is compiled for each firm using the following formula: pollution discharge value of output.

[b] implies that the variable is instrumented due to endogeneity problem. The instruments variables includes the town-average complaints, inspection, and levy in 1998, the town-average industrial work income; illiteracy rate; the ratio of the firm’s fixed capital of the total fixed capital in a county; the ratio of the firm’s employment of the total industrial employment in a county; population proportion drinking taped water and having sanitation facilities at the county level; an indicator variable to identify whether a firm frequently violates the emission standards in the past; an indicator variables to tell whether a firm conduct the environmental assessment.