WPS-2337

POLICY RESEARCH WORKING PAPER 2337

Pollution Charges, Community Pressure, and Abatement Cost of Industrial Pollution in China

Hua Wang

Community pressure may be as strong an incentive for industrial firms to control pollution in China as pollution levies are.

The World Bank
Development Research Group
Infrastructure and Environment
May 2000

Summary findings

Wang evaluates the strength of the effect that community pressure and pollution charges have on industrial pollution control in China and estimates the marginal cost of pollution abatement. He examines a well-documented set of plant-level data, combined with community-level data, to assess the impact of pollution charges and community pressure on industrial behavior in China.

He constructs and estimates an industrial organic water pollution discharge model for plants that violate standards for pollution discharge, pay pollution charges, and are constantly under community pressure to further abate pollution.

He creates a model and estimates implicit prices for pollution discharges from community pressure, which are determined jointly by the explicit price, the pollution levy. He finds that the implicit discharge price is at least as high as the explicit price. In other words, community pressure not only exists but may be as strong an incentive as the pollution charge is for industrial firms to control pollution in China.

Wang's modeling approach also provides a way to estimate the marginal cost of pollution abatement. The empirical results show that the current marginal cost of abatement is about twice the effective charge rate in China.

This paper — a product of Infrastructure and Environment, Development Research Group — is part of a larger effort in the group to study environmental regulation in developing countries. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Yasmin D'Souza, room MC2-622, telephone 202-473-1449, fax 202-522-3230, email address ydsouza@worldbank.org. Policy Research Working Papers are also posted on the Web at www.worldbank.org/research/workingpapers. The author may be contacted at hwang1@worldbank.org. May 2000. (27 pages)

Produced by the Policy Research Dissemination Center

Pollution Charges, Community Pressure, and Abatement Cost of Industrial Pollution in China[1]

Hua Wang

Development Research Group

World Bank

---

[1] My sincere thanks to Dr. Jostein Nygard and other World Bank colleagues for their comments on an earlier draft of this paper, and to Ms. Ping Yun for her excellent research assistance. Thanks also go to China State Environmental Protection Administration (SEPA) and Chinese Research Academy of Environmental Sciences (CRAES) for providing data necessary for this research exercise. Usual disclaimer applies. Corresponding address: Dr. Hua Wang, MC2-626, 1818 H St., N. W., Washington, DC 20433, USA. Email: HWANG1@worldbank.org.

Pollution Charges, Community Pressure, and Abatement Cost of Industrial Pollution in China

I. Introduction

This paper reports an empirical analysis of industrial water pollution discharge in China. A well documented plant-level data set is examined and combined with a community-level data set, which allows for a careful assessment of the impact of pollution charge instrument and community pressure on industrial behavior in China. An industrial organic water pollution discharge model is constructed and estimated for those plants which violate pollution discharge standards and pay pollution charges and are constantly under pressure for further pollution abatement from the communities. The impacts of pollution charge and community pressure are estimated and compared with each other. Also reported in this paper are the demand function approach to marginal abatement cost estimation and the empirical results of Chinese industries.

In literature, two recent empirical studies demonstrated the existence of informal regulation, or community pressure, of industrial pollution. Using Indonesian data of plant-level organic water pollution, Pargal and Wheeler (1996) tested and supported the informal regulation hypothesis that communities are often able to negotiate with or otherwise informally pressure polluting plants in the vicinity to clean up when formal regulatory mechanisms are absent or ineffective. With data on industries in the United States, Pargal et al. (1997) provided support for the idea that community-based pressure on plants to abate pollution exists even in the presence of formal regulation. Under formal regulation, the government acts as an agent for the community. Frequently employed regulatory instruments include both command-and-control instruments such as effluent discharge standards and market-based instruments such as emissions charges. When formal regulations are absent or weak, many communities have struck bargains for pollution abatement with local factories. As pointed in Pargal et al. (1997), this community-based informal regulation may take many different forms including demands for compensation by community groups, social ostracism of the firm's employees, the threat of physical violence, boycotting the firm's products, and monitoring and publicizing the firm's emissions. They may rely on the leverage provided by recourse to civil law or pressure through politicians and local administrators, or religious leaders. When formal regulatory standards and institutions exist, informal regulation can still play a significant role in providing incentives for polluters to abate pollution. One tactic a community can use is simply reporting the violation of legal standards. Another channel for informal regulation is to pressure regulators to tighten local monitoring and enforcement.

While the existence of informal regulation has been empirically demonstrated, an important issue remains of how strong the informal regulation is. While one can expect that informal regulation may play an important role in pollution control where formal policy doesn't exist, the importance of informal regulation could be lower in a relative sense where formal regulation is functioning. Studies on the strength of community pressure, both in an absolute sense and in a relative sense with respect to formal government pollution regulations, can help both for better understanding polluters' behavior as well as for designing pollution control programs for communities and governments.

This paper provides an empirical estimation of community pressure on pollution discharges in China where formal regulation on industrial pollution exists. The pressure is estimated as an implicit price it provides for pollution discharges. This implicit price is jointly estimated by a discharge demand function with an explicit price that the current Chinese pollution charge system imposes for pollution discharges. In the estimation, the implicit price is instrumented with variables including community economic status and pollution discharge situation. The estimated implicit price is compared with the explicit price the government regulation provides. Estimation results show that informal regulation on those firms which are violating effluent concentration standards is at least as strong as the pollution charge instrument which is imposed on the violators in China.

With the same pollution discharge model, this study also provides an assessment of the impact of China's pollution charge on industrial organic water pollution discharge. China's pollution charge system has been widely implemented for about 20 years. Almost all of China's counties and cities have implemented the levy system, and approximately 500,000 factories have been charged for their emissions. Despite certain weaknesses in the pollution levy system, it remains by far the largest application of a market-based regulatory instrument in the developing world. And in sheer magnitude, the current Chinese system may be without peer in the world. However, this system was not systematically evaluated until recently. With plant-level and province-level data, Wang and Wheeler (1996 &1999) did econometric analyses of levy system enforcement and plants' responses to the variance in the effective levy rate. These analyses have shown that the local enforcement of the levy system has been driven by local socio-economic and environmental status and that industrial firms do respond to the levy rate changes. Due to data limitations, however, levy price indices constructed in these studies did not match very well with the levy formula employed in practice, nor well fit with economic theory in terms of the consistency of the demand variable and the price. This prevented the econometric analyses from being a rigorous quantitative estimation of the price elasticity of pollution discharge.

This study employs a data set with detailed information on levy collection. A discharge function of organic water pollution - chemical oxygen demand (COD) can be constructed and estimated with a marginal levy price of COD which matches both the economic theory and the levy practice in China. An implicit price index for pollution discharge is also constructed and instrumented in this estimation, which should be able to provide a more accurate estimation of the price elasticity of COD discharge. Analyses conducted in this study show that the pollution charge is only one part in the marginal penalty of pollution discharge in China. The levy price is about half of the total discharge price which equals the marginal penalty. For a firm minimizing the total cost, the marginal abatement cost should be equal to the total discharge price, which is about twice of the levy price in China.

The estimation of the pollution discharge demand function in this study also provides a unique estimation of marginal pollution abatement cost. Two empirical models have been previously employed in estimating marginal pollution abatement cost. The total factor productivity approach estimates a total cost function which combines both production cost and pollution control cost. The marginal cost of pollution abatement can be derived by taking the derivatives of the total cost with respect to a specific pollutant. This marginal cost estimation takes into consideration of pollution reduction both in the production process and the end-of-pipe treatment. However this method has been rarely used because of heavy data requirements. Another method that has been used is the end-of-pipe treatment approach which estimates an end-of-pipe treatment cost function. A marginal abatement cost can be estimated by taking derivatives of the abatement cost with respect to a pollutant. This approach only considers the pollution abatement option with the end-of-pipe treatment.

The demand function approach to marginal abatement cost estimation, employed in this study, requires information on prices of pollution discharges. Just as the total factor productivity approach, this approach can provide a correct estimation of industrial firms' pollution abatement costs which takes into consideration both the production process and the end-of-pipe treatment. To author's knowledge, this is the first empirical estimation of pollution abatement cost with a pollution discharge function.

This paper is organized as follows. The next section provides further background information about the pollution control practices of those Chinese industries which have to pay a uniquely designed fee for pollution discharge and are also under constant pressure of other formal and informal pollution control measures as well. Section III presents the model for pollution discharge where firm characteristics, input prices, community pressure and formal regulation are identified as the major determinants. Data and variable descriptions are presented in section IV, and section V provides estimation results. Section VI concludes the paper.

II. Institutional Background

Chinese industry has been fast growing in the past two decades with an average annual increase rate about 15%. While about 50% of the total value of output comes from those industries established originally by farmers, which are mostly privately owned, a significant portion of the industry, especially those large firms, are state-owned enterprises (SOEs). Those state-owned enterprises face imperfect market competition. The prices of the outputs are partly regulated by the government even though recent reforms have brought more autonomy to the SOEs. While plant managers' incomes are more and more correlated with the economic performances of the plants and it is in most plant managers' interests to maximize profits, firms are facing constraints additional to those set by the market in their practices of minimizing the total costs. One example is the target of minimum values of output set by the government for some plants.

There are a set of pollution control policy instruments applied to Chinese industries[2]. The central government set up the general requirement of regulation according to the environmental laws, and it has been the local governments' responsibility to enforce and improve the regulations set by the central government. There are command-and-control approaches such as the requirement of environmental impact assessments for new construction projects and the requirement of design, construction and operation of pollution treatment facilities simultaneously with the construction or expansion of industrial production facilities. After the production processes are in place, the emission

---

[2] For a detailed review of China's pollution control system, see Sinkule and Ortolano (1995).

standards and effluent concentration standards apply. However, while the command-and-control approaches are implemented, it is not illegal to violate those requirements. It is not until recently that a firm or its manager can be prosecuted for violating environmental standards. If not polluting extensively, firms may not be seriously penalized, even when violating abatement deadlines that are sometimes issued by local environmental authorities.

To provide incentives for industrial firms to control pollution, the environmental regulators have relied heavily on a market-based approach since the early 1980's. For more than a decade, hundreds of thousands of firms have had to pay a fee if their discharges did not meet the discharge standards[3]. 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 three years experimentation, China's State Council began nationwide implementation of pollution charges. Since then billions of Renminbi (RMB) have been collected each year from hundreds of thousands of industrial polluters for air pollution, water pollution, solid waste, and noise. In 1996, the system was implemented in almost all counties and cities. A total of 4 billion RMB's ($1 = 8RMB) were collected from about half a million industrial firms. 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[4], among which, only the pollutant which violates the standard the most 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 whichever amount has the highest value among all the pollutants. The Chinese central government

---

[3] Most small industries in the remote rural areas have effectively escaped the levy due to the weak enforcement capacity of local environmental protection agencies.

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

constructs a uniform fee schedule, however the implementation in different regions is not uniform[5]. The levy collected is used to finance environmental institutional development, administration and environmental projects and to subsidize firms' pollution control projects. If a firm, who pays levies to the levy fund, decides to invest in pollution abatement, a maximum of 80% of the levy paid by the 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[6]. Penalties can not 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 (SEPA, 1998), few empirical analyses have actually investigated polluters' response to the existing charges. In Wang and Wheeler (1996), province-level data on water pollution was analyzed and it was determined that China's levy system had been working much better than previously thought. Provincial variations in the enforcement of the levy appear to reflect the local valuation of environmental damage and community capacity to enforce local norms. The results suggest that province-level pollution discharge intensities have been highly responsive to provincial levy variations. With a joint plant-level and city-level data set, Wang and Wheeler (1999) have shown that pollution intensities of Chinese industries have been significantly responsive to the levy system, and that citizens' complaints on pollution can significantly affect the implementation of air pollution levy system.

While under formal regulation, Chinese industries are also constantly under pressure from local communities for further pollution control. Cases are not scarce in China where citizens or citizen groups fight with plants which are seriously polluting local watersheds or airsheds by directly using violence or lawsuit. Chinese environmental authorities are also responding to a citizen complaint program with which any citizen can write, call or visit the local office of environmental authorities for any environmental issues. Responding to those complaints, environmental authorities

---

[5] For a detailed discussion, see Wang and Wheeler (1996 and 1999) and SEPA (1998).

investigate the issues mostly by doing field inspections. Issues are for the most part settled with polluters' correcting the problems. Each year hundreds of thousands of complaints are received. Studies have shown that these complaints have significantly increased the numbers of inspections (Dasgupta et al. 2000) and increased the effective rate of pollution charge (Wang and Wheeler, 1999), and have contributed to pollution reduction especially for air (Dasgupta and Wheeler, 1996).

III. Model

Models estimated in this study can be derived directly from the general assumption that firms are minimizing the total cost[7]. Assuming that C is the total cost of inputs that a firm spends on the production process and the pollution treatment facilities. C is then a function of x, the total amount of a certain residual or pollutant such as chemical oxygen demand (COD). The firm discharges x to the environment and gets a penalty of F due to this discharge. F is also a function of x.

A firm minimizes the sum of total input costs (C) and total penalty (F) of pollution discharge (x):

(1) minimize $C(x) + F(x)$.

To solve for the optimization problem, the first order condition is:

(2) $\partial C/\partial x + \partial F/\partial x = 0$.

The first term in the first order condition (2) is the cost reduction of an extra unit of pollution discharge. Therefore, the marginal abatement cost (MAC) of x is,

(3) $MAC = - \partial C/\partial x$.

---

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

[7] As discussed in last section, most Chinese industries face additional constraints while minimizing the total cost. But for some firms during a certain period of time, the management objective might not be to minimize the total cost. For these firms, the models developed in the following are invalid.

The second term in the first order condition (2) is the marginal penalty of pollution discharge, which can also be defined as pollution discharge price P:

(4) $P = \partial F / \partial x$

When F is a linear function of x, P is a constant. The first order condition (2) prescribes that a firm abates its pollution up to a point where the marginal abatement cost equals the marginal penalty of pollution discharge. From (2), one can solve for a pollution discharge demand function given discharge price P:

(5) $x = f(P)$.

While the total penalty (F) of a pollution discharge x may include both a financial penalty, such as paying a discharge fee, and other damages to the firm, such as reputation damages with law suits, citizen complaints / demonstrations, and risk of being shut-down, etc., the pollution discharge price P also has two parts: one corresponding to the explicit financial charges (P1) and another corresponding to implicit damages to the firm (P2).

The marginal abatement cost function can be derived from equations from (2) to (5), as,

(6) $MAC = f^{-1}(x)$.

Therefore, a marginal abatement cost function (MAC) can be obtained by first estimating a pollution discharge demand function ($x = f(P)$) and then taking an inverse of the demand function.

In this study, a COD discharge demand function will be empirically estimated for Chinese industries which have to pay a price for COD discharges and are constantly under strong pressure from local communities for further pollution reduction. To estimate equation (5) for COD, four sets of variables or determinants need to be identified:

a) plant characteristics (f), which includes sector, output, ownership (for efficiency), vintage (for technology), etc.;

b) market prices (m), which includes manufacturing wage, materials price, capital price, energy price, stock price of the plant, etc.;

c) community characteristics (c), such as income, education, environmental quality, population, etc.;

d) pollution regulation (r), including pollution charges, inspection, etc.;

Assume a simple functional form of COD discharge as follows:

(7) $x = \alpha P^{\beta}$

where α is a parameter which is determined by plant characteristics (f) such as total value of output, sector, ownership, etc., and market prices (m). That is,

(8) $\alpha = \alpha(f, m)$.

β is a parameter to be estimated, which is the price elasticity of pollution discharge. P is an aggregate price for the discharge of pollution COD. Price P is a function of variables for pollution regulation and community characteristics, i.e.,

(9) $P = P(r, c)$.

With further assumptions on the functional form of P, such as,

(10) $P = \gamma\, r^{\delta 1} c^{\delta 2}$,

the relative contribution of different sets of variables to the variance of pollution discharge can be estimated by substituting (10) into (7).

In the Chinese case, which will be presented in the following, the formal regulation is a charge on pollution discharge, from which an explicit price, the effective charge rate or levy price, P1 can be observed. Equation (10) becomes,

(11) $P = \gamma\, P_1 c^{\delta 2}$.

The implicit pollution discharge price generated by community pressure, or non-levy price, P2, can then be estimated by subtracting P1 from P; i.e.,

(12) $P2=P-P1$.

In estimation, γ in equation (11) can be identified with an appropriate assumption such as the minimum implicit price P2 is zero in a society. In this case, estimated P2 would be a lower bound of the community pressure on pollution discharge.

IV. Data and Variables

A plant-level dataset of 1500 industrial firms in 1994, which was randomly selected from a nation-wide random sample, was provided by China State Environmental Protection Administration for conducting analyses of economics of industrial pollution control in China. All plants were under close monitoring by state and local environmental authorities, and information about pollution and production was well documented. Among the 1500 firms, effective levy prices can be estimated for about 200 firms which discharged COD at a level above the COD discharge standards and paid discharge levies for the part of COD discharge above standards. City-level data about average wage, water pollution discharge concentration and population density in 1994 were collected from China urban statistical yearbooks.

Table 1 lists the major variables used in the model. The dependent variable is the total COD discharge of a plant. Plant characteristics include sector, state ownership, and value of output. For sectors, paper, chemical, food, and textile are water pollution intensive sectors. Their impacts on COD discharge are expected to be positive. State-owned plants are expected to be less efficient, so the impact on COD discharge is expected to be positive. Value of output measures the scale of a plant. COD discharge is expected to grow with output, and the effect on COD discharge is expected to be positive. However, the elasticity of pollution with respect to value of output is expected to be significantly less than one because of the scale economies.

For market input prices, the city-level average wage was available and can approximate for the manufacturing wage. As an input price, wage should have a positive impact on COD discharge. However, wage is also a measure of wealth. Empirical studies on informal regulation have shown that wealth is positively correlated with the strength of informal regulation of pollution, and therefore wage can also have a negative effect on COD discharge. So, there is not a prior expectation of the sign of the variable wage. There is also a possibility that the wage is an endogenous variable because high income people may move away from pollution intensive areas. However, it is not expected to be a problem because population mobility was extremely low in China in 1994.

Input price information is also reflected in the model by a dummy variable "coast." In the coastal areas of China, materials price, capital price, energy price as well as manufacturing wage are all higher than in non-coastal areas. However, income, education and population density are also higher in the coastal areas, which are most important determinants of strength of informal regulation according to previous empirical studies (Pargal and Wheeler, 1996; Wang and Wheeler, 1996). Therefore the possible effect of the variable "coast" is ambiguous and it is an empirical issue.

Two more community variables in table 1 are population density and average water pollution discharge concentration. Both of the variables are expected to have negative effects on COD discharge. The higher the population density, the stronger the informal regulation of pollution. The worse the overall water pollution, the higher the demand of water pollution control, and therefore informal water pollution regulations should be stronger.

The explicit COD discharge price is defined as the total levy paid for the above-standard COD discharge divided by the total COD discharged at a concentration level above the standard. It is an observed marginal economic penalty of COD discharge. The impact of the levy price on total COD discharge is expected to be negative. There is a possibility that the levy price is endogenous in the COD model because there are cases observed in China where final levy collection is negotiated with the plants. However, this problem is not expected to be serious in this study because the selected plants were under close monitoring by state environmental authorities and it was not very likely for them to be able to bargain with environmental authorities to reduce levy payments.

V. Results

5.1 Discharge Function Estimation

An econometric model is estimated with the data described above. Table 2 lists estimates of coefficients[8]. As expected, plant characteristics play a significant role in determining the COD discharge. The elasticity of COD discharge with respect to value of output is about 0.63. The state owned enterprises discharge more COD. Water pollution intensive sectors such as paper, textile, food and chemical industries have significant, positive coefficients.

The COD levy price has a highly significant, negative impact on COD discharge. The elasticity is close to -1. Dummy variable "coast" is found to be significant and negative in the COD discharge equation. Due to multicollinearity between these community variables, other variables do not show significance. However, when these community variables are included in the model individually, they are all significantly negative, except variable log(wage). Since the primary purpose of this analysis is to estimate relative importance of community pressure with respect to formal pollution regulation, the insignificant community variables are included in the final analysis to enhance the robustness of the estimation.

---

[8] Stata Robust procedure was used to correct the possible White heterogeneity associated with cross-section data.

5.2 Levy and Non-levy Price

The empirical model estimated in table 2 is based on the models previously presented in section III. Specifically, the price function of (10) is specified in this study as,

(10)' $P = \gamma\, P1 * Q^{\delta 1} D^{\delta 2} W^{\delta 3} e^{\delta 4 * coast}$

Where P1 is the levy price; Q is the city-level COD discharge average concentration; D is population density; W is city-level average wage; and coast is a dummy variable of 1 for plants locating in coastal areas and 0 for locating in non-coastal areas. δ1, δ2, δ3, and δ4 are all positive parameters.

The parameter α in model (7) is specified as,

(8)' $\alpha = \alpha_0 * Y^{\theta 1} W^{\theta 2} e^{\theta 3 Coast + \theta 4\, State + \sum \omega\, Sector}$.

where variables W and coast reflect input prices for production and pollution abatement. θ1, θ2 and θ3 should be positive. The econometric model estimated in this study is as,

(13) $\ln(x) = \ln(\alpha) + \beta \ln(P)$

$= (\ln(\alpha_0) + \beta \ln(\gamma)) + \theta 1 \ln(Y) + \theta 4\, State + \sum \omega\, Sector + \beta \ln(P1)$

$+ (\beta\, \delta 1) \ln(Q) + (\beta\, \delta 2) \ln(D) + (\beta\, \delta 3 + \theta 4) \ln(W) + (\beta\, \delta 4 + \theta 3)\, coast + error,$

where β should be negative.

Because of the dual roles of variable W and coast for input prices and community pressure, parameters associated with these two variables cannot be fully identified without further restrictions on the parameters. Because the purpose of this estimation is to assess how significant community pressure is on pollution control relative to the formal pollution regulation, an estimation of the lower bound of community pressure is sufficient for this exercise.

In order to get a lower bound of the estimation for community pressure, following restrictions are further imposed:

a. $\theta 3 = \theta 4 = 0$;

b. $\gamma = 1/\min(Q^{\delta 1} D^{\delta 2} W^{\delta 3} e^{\delta 4 * coast})$.

Restriction (a) underestimates $\delta 3$ and $\delta 4$, while restriction (b) imposes that the minimum of community pressure on pollution abatement be zero. With restrictions (a) and (b), all parameters in the model can be identified.

While assuming the minimum implicit price generated from market and community pressure on COD discharge in the sample is zero, γ is estimated to be about 2.7. The total COD discharge price P is then estimated for each plant. Subtracting levy price P1 from the total price P, the non-levy price P2 is then estimated. Table 3 provides the mean and the median estimation of levy, non-levy and total prices, as well as the ratio of P2 to P1.

The estimation results in table 3 reveal that the non-levy price is almost equal to the levy price in general. The levy price in the coastal areas is not significantly higher than in the interior regions, while the non-levy price in the coastal areas is 2-3 times of the non-levy price in the non-coastal areas. Therefore the total price is higher in the coastal areas. In coastal areas, non-levy price is higher than the levy price. No significant difference is found in the total prices between the state sector and non-state sector. However, in the non-state sector, the non-levy price is higher than the levy price. While no significant difference can be found between the levy price and the non-levy price with different industrial sectors and different scales of plants, paper industries are found to face the lowest total marginal penalty of COD discharge and large plants are paying less for one more unit of COD discharge.

No other formal regulation variable other than pollution levy is included in the model. For those plants in the sample which were paying fees for their violations of the COD discharge standards, it is not very likely that other formal policy instruments practiced in China would have systematic impacts on the variance of COD discharge. Nevertheless, missing these instruments in the model could cause an overestimation of the levy price if they are positively correlated with the levy price.

5.3 Marginal Abatement Cost

The scale parameter α in the discharge function (7) can be estimated as a function of value of output, state and sector when parameter γ is identified in the model (13) while restriction (a) is imposed. Then marginal COD abatement cost can be estimated with the functional form,

(14) $MAC = (X/\alpha)^{1/\beta}$.

With restriction (a), MAC is underestimated. Table 4 lists MAC estimates for plants with different scales, and different sectors and at different levels of percent COD reduction from current discharge levels. A plant at a medium level of output and COD discharge is selected from each plant category to do the simulation.

In table 4, the paper industry can be found to be an outlier, with highest COD discharges but lowest abatement costs at the current discharge level. While the marginal abatement cost with paper industries can be higher than other sectors when they are at same levels of COD discharges, currently it is clearly a correct strategy for China to focus more on paper industries in order to address the organic water pollution problem.

VI. Conclusion and Discussion

This paper analyzes the relative strength of informal regulation when formal regulation is present. Using Chinese data on plant-level organic water pollution from those industrial plants violating discharging standards, the author estimated a pollution discharge demand model which includes variables for both formal and informal regulation. The sample selected includes those plants which discharge water pollution at a concentration level above the discharge standards set by environmental authorities and which pay the government fees for those above-standard discharges. An effective discharge price, the levy price, is then constructed and estimated for the model. Community variables such as average wage, pollution status, population density, etc., which are associated with informal regulation, are included in the model as well. The estimation results show that both formal regulation and community variables are significant determinants of the water pollution discharge behavior. The relative strength of informal regulation is the estimated with respect to formal regulation.

A conservative estimation of the strength of informal regulation show that it is at least as strong as formal regulation. The marginal financial penalty of pollution discharge estimated in this study is more or less reflecting the strength of formal regulation. However, the estimated non-levy price is a lower bound estimation of the implicit price generated from community pressure on pollution discharge. There are two reasons for it to be a lower bound. First, the market input price effect is embedded in the non-levy price estimation. Because the input price effect on pollution discharge is positive, the negative effect of non-levy price on pollution discharge should be smaller than the negative effect caused by the community pressure. Secondly, the minimum non-levy price is assumed to be zero while it should be positive given the fact that the pollution control effort is far from being satisfied by the citizens in China.

In the literature, there are only few econometric studies on determinants of pollution discharge at the plant level. Econometric estimation of pollution discharge demand with a well constructed discharge price is even more scarce. With a well documented plant-level data set from China, this is the first such study. Not only are the effects of a pollution charge system examined quite rigorously, possible impacts of community variables are also jointly assessed. The study shows that the Chinese pollution levy system has been quite effective in providing incentives at least for those industries which are violating water pollution discharge standards to control pollution.

The strong impacts of community variables on an industry's discharge performance in China, found in this study, may not stop functioning even when plants are in compliance with discharge standards. As long as a community is dissatisfied with its pollution situation, the pressure from the community would be expected to continue. This pressure can be either directly imposed on polluting plants, or indirectly via government pollution control authorities through "formal" channels such as the citizen pollution complaint program, found to affect regulators' efforts in monitoring and enforcement of regulatory programs such as the pollution charge system (see Wang & Wheeler 1996 & 1999 and Dasgupta et al. 2000). A cost-effective strategy for promoting pollution regulation in China can be to provide pollution information services to communities, given the status of economic development in the communities.

The marginal cost estimation shows that the paper industries have highest COD discharges but lowest abatement costs at the current discharge level. While the marginal abatement cost with paper industries can be higher than other sectors when they are at the same levels of COD discharges, currently it is clearly a cost-effective strategy for China to focus more on paper industries' pollution abatement in order to address the industrial organic water pollution problem.. While they are close to those estimates with engineering approaches conducted in China, the results of this study could be the lower bounds of the true abatement costs due to that the input price effects are assumed to be zero in the estimations.

It is also worthwhile to point out that the estimated levy price is only about half of the estimated marginal abatement cost in this study. This should not be viewed as in conflict with the conclusion, which can also be drawn from this study, that the Chinese pollution levy instrument is an effective policy instrument. The reason is that there are other formal and informal regulations which are jointly with the pollution levy system providing incentives for industrial firms to abate pollution. In practice, an effective levy price should always be lower than a firm's marginal abatement cost as long as there are other positive pressures for the firm to abatement pollution and the firm is to minimize the total cost.

References:

Dasgupta, Susmita and D. Wheeler, 1997, "Citizen Complaints as Environmental Indicators: Evidence from China," World Bank Policy Research Working Paper #1704.

Dasgupta, S., B. Laplante, N. Mamingi and H. Wang, 2000, "Local Enforcement of Environmental Regulation in China: the Role of Inspection and complaint," World Bank Policy Research Working Paper (forthcoming).

Dasgupta, S., M. Huq, D. Wheeler and C.H. Zhang, 1996, "Water Pollution Abatement by Chinese Industry: Cost Estimates and Policy Implications," World Bank Policy Research Working Paper #1630.

Pargal, Sheoli & David Wheeler, 1996, "Informal Environmental Regulations in Developing Countries," Journal of Political Economy, vol. 104, no. 6.

Pargal, Sheoli, H. Hettige, M. Singh and D. Wheeler, 1997, "Formal and informal regulation of industrial pollution: comparative evidence from Indonesia and the United States," World Bank Policy Research Working Paper #1797.

SEPA (China State Environmental Protection Administration), 1998, Proceedings of the International Workshop on the Reform of China Pollution Levy System, China Environmental Sciences Press, January.

Sinkule, J. Barbara and Leonard Ortolano, 1995, Implementing Environmental Policy in China, Praeger Publishers, 1995.

Wang, Hua & David Wheeler, 1996, "Pricing Industrial Pollution in China: An Econometric Analysis of the Levy System," World Bank Policy Research Working Paper #1644.

Wang, Hua & David Wheeler, 1999, "Endogenous Enforcement and Effectiveness of China's Pollution Levy System," World Bank Policy Working Paper (forthcoming), presented in the workshop "Market-Based Environmental Instruments" sponsored by the Association of Environmental and Resource Economists and Harvard University, July, 1999.

Table 1. Variable Description

Variable name	Definition	Mean	Variance
COD	Total COD discharge (10,000 ton)	248.2	942.6
OUTPUT	total value of output (10,000 yuan)	25746	91304
STATE	Dummy for state-owned firms	.71	.46
PRICE	total levy on COD over-standard discharge / total over-standard COD discharge: yuan / ton	700	855
WAGE	average wage of the city where the firm locates	3869.9	1208.5
CODCON	average COD discharge concentration of the region	341.5	177.4
POPDEN	Population density (1/Km2)	1604	1340
CHEMICAL	Dummy for chemical industry	.14	.34
DRUG	Dummy for drug industry	.15	.36
FOOD	Dummy for food industry	.22	.42
PAPER	Dummy for paper industry	.14	.34
TEXTILE	Dummy for textile industry	.17	.38

Table 2: Discharge Function Estimation

Dependent variable: Log(COD)

	Full Model	Reduced Model
Log(OUTPUT)	.625***	.614***
	(9.31)	(9.34)
STATE	.407*	.387*
	(1.68)	(1.65)
CHEMICAL	1.110***	1.106***
	(3.07)	(3.08)
DRUG	.740**	.768**
	(2.10)	(2.21)
FOOD	.838***	.879***
	(2.61)	(2.75)
PAPER	2.462***	2.512***
	(6.48)	(6.67)
TAEXTILE	.622*	.673**
	(1.84)	(1.99)
Log(PRICE)	-.992***	-.984***
	(-12.98)	(-12.89)
Log(WAGE)	.484	
	(0.87)	
Log(CODCON)	-.370	-.384*
	(-1.41)	(-1.75)
Log(POPDEN)	-.183	
	(-1.45)	
COASTAL	-.545*	-.417*
	(-1.87)	(-1.89)
Constant	10.892**	13.627**
	(2.00)	(8.54)
N	177	177
R2	0.76	0.75
F-value	38.21	45.50

t-statistics are included in parentheses under the estimated parameters. Asterisks indicate the associated significance levels: * for .10; ** for .05; *** for .01.

Table 3: Levy and Non-levy Prices by Industries
(RMB yuan / ton)

	P1 (levy price)	P2 (non-levy price)	P1+P2	P2/P1
	By average values			
Whole sample	700.1	743.0	1443.1	1.06
Non-coastal	711.1	454.7	1165.8	0.64
Coastal	691.2	975.4	1666.7	1.41
Non-state	588.2	826.6	1414.8	1.41
state	746.7	708.2	1454.9	0.95
Chemical	864.3	934.7	1799.0	1.08
drug	559.5	656.1	1215.6	1.17
food	668.1	703.9	1372.1	1.05
paper	212.1	160.1	372.1	0.75
Textile	802.1	822.5	1624.6	1.03
large	630.4	695.8	1326.2	1.10
medium	737.9	808.8	1546.7	1.10
small	728.6	704.8	1433.5	0.97
	By Median values			
Whole sample	414.26	399.5	813.7	0.96
Non-coastal	324.4	194.1	518.6	0.60
coastal	463.5	635.2	1098.7	1.37
Non-state	361.5	439.3	800.8	1.22
state	450.2	318.7	768.9	0.71
Chemical	420.1	473.0	893.1	1.13
drug	367.5	194.1	561.6	0.53
food	504.2	439.1	943.3	0.87
paper	91.5	83.3	174.8	0.91
textile	648.0	599.9	1247.8	0.93
large	246.4	225.3	558.0	0.91
medium	495.5	442.3	1019.4	0.89
small	458.5	404.2	859.0	0.88

Table 4: Marginal Abatement Costs (MAC)

Sector	Scale	# of firms in sample	Typical value of output (10k yuan)	Typical COD discharge (10k tons)	Current MAC (yuan/ ton)	MAC 10% reduction	MAC 30% reduction	MAC 50% reduction	MAC 70% reduction	MAC 90% reduction
Total	Large	58	25000	45	582.3	647.5	834.2	1171.1	1960.1	5933.5
Total	Medium	73	4000	12	775.6	862.5	1111.2	1560.0	2610.9	7903.7
Total	Small	49	900	2	1652.3	1837.5	2367.4	3323.5	5562.4	16838.2
Chemical	Large	10	25000	75	454.3	505.2	650.9	913.8	1529.3	4629.4
Chemical	Medium	10	3500	13	770.2	856.5	1103.5	1549.2	2592.8	7848.8
Chemical	Small	4	1200	18	2879.8	3202.5	4126.0	5792.4	9694.5	29346.5
Drug	Large	13	15000	58	293.9	326.9	421.2	591.2	989.5	2995.5
Drug	Medium	10	4000	12	625.7	695.9	896.5	1258.6	2106.5	6376.6
Drug	Small	4	1000	1.5	2125.6	2363.8	3045.5	4275.5	7155.7	21661.1
Food	Large	8	30000	30	976.3	1085.7	1398.8	1963.7	3286.6	9949.0
Food	Medium	17	5000	10	955.5	1062.6	1369.1	1922.0	3216.7	9737.5
Food	Small	14	1000	3.5	998.7	1110.7	1430.9	2008.9	3362.2	10177.7
Paper	Large	7	20000	1330	85.0	94.5	121.8	170.9	286.1	866.0
Paper	Medium	10	3400	360	103.9	115.5	148.8	209.0	349.7	1058.7
Paper	Small	7	1000	10	1781.2	1980.8	2552.0	3582.6	5996.1	18151.1
Textile	Large	7	32000	22	1118.0	1243.3	1601.8	2248.7	3763.6	11392.8
Textile	Medium	15	6000	6.5	1330.9	1480.1	1906.9	2677.0	4480.4	13562.9
extile	Small	8	1400	2.2	1585.7	1763.4	2271.9	3189.5	5338.1	16159.2

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS2314	Technological Leadership and Foreign Investors' Choice of Entry Mode	Beata K. Smarzynska	April 2000	L. Tabada 36896
WPS2315	Investment in Natural Gas Pipelines in the Southern Cone of Latin America	Alejandro Jadresic	April 2000	M. Salehi 37157
WPS2316	Distrubutional Outcomes of a Decentralized Welfare Program	Emanuela Galasso Martin Ravallion	April 2000	P. Sader 33902
WPS2317	Trade Negotiations in the Presence of Network Externalities	Keiko Kubota	April 2000	L. Tabada 36896
WPS2318	Regulatory Reform, Competition, and Innovation: A Case Study of the Mexican Road Freign Industry	Mark A. Dutz Aydin Hayri Pablo Ibarra	April 2000	H. Sladovich 37698
WPS2319	Externalities and Production Efficiency	Gunnar S. Eskeland	April 2000	H. Sladovich 37698
WPS2320	Does More Intense Competition Lead to Higher Growth?	Mark A. Dutz Aydin Hayri	April 2000	H. Sladovich 37698
WPS2321	Algorithms for Purchasing AIDS Vaccines	David Bishai Maria K. Lin C. W. B. Kiyonga	April 2000	P. Sader 33902
WPS2322	Self-Targeted Subsidies: The Distributional Impact of the Egyptian Food Subsidy System	Richard H. Adams, Jr.	April 2000	M. Coleridge-Taylor 33704
WPS2323	Globalization and Firms' Financing Choices: Evidence from Emerging Economies	Sergio Schmukler Esteban Vesperoni	April 2000	E. Khine 37471
WPS2324	Give Growth and Macroeconomic Stability in Russia a Chance: Harden Budgets by Eliminating Nonpayments	Brian Pinto Vladimir Drebentsov Alexander Morozov	April 2000	H. Makarenko 87832
WPS2325	Banking Systems Around the Globe: Do Regulation and Ownership Affect Performance and Stability?	James R. Barth Gerard Caprio, Jr. Ross Levine	April 2000	A. Yaptenco 31823
WPS2326	How Urban Concentration Affects Economic Growth	Vernon Henderson	April 2000	R. Yazigi 37176
WPS2327	How the Republic of Korea's Financial Structure Affects the Volatility of Four Asset Prices	Hong G. Min Jong-goo Park	April 2000	P. Rathan-Raj 33705

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS2328	Social Transfers and Social Assistance: An Empirical Analysis Using Latvian Household Survey Data	Branko Milanovic	April 2000	P. Sader 33902
WPS2329	Improving Russia's Policy on Foreign Direct Investment	Joel Bergsman Harry G. Broadman Vladimir Drebentsov	May 2000	S. Craig 33160
WPS2330	Reducing Structural Dominance and Entry Barriers in Russian Industry	Harry G. Broadman	May 2000	S. Craig 33160
WPS2331	Competition, Corporate Governance, and Regulation in Central Asia: Uzbekistan's Structural Reform Challenges	Harry G. Broadman	May 2000	S. Craig 33160
WPS2332	Financial Intermediary Distress in the Republic of Korea: Small Is Beautiful?	Paola Bongini Giovanni Ferri Tae Soo Kang	May 2000	K. Labrie 31001
WPS2333	Output Fluctuations in Latin America: What Explains the Recent Slowdown?	Santiago Herrera Guillermo Perry Neile Quintero	May 2000	C. Palarca 35328
WPS2334	Sex Workers and the Cost of Safe Sex: The Compensating Differential for Condom Use in Calcutta	Vijayendra Rao Indrani Gupta Smarajit Jana	May 2000	P. Sader 33902
WPS2335	Inflation and the Poor	William Easterly Stanley Fischer	May 2000	K. Labrie 31001
WPS2336	Endogenous Enforcement and Effectiveness of China's Pollution Levy System	Hua Wang David Wheeler	May 2000	Y. D'Souza 31449