POLICY RESEARCH WORKING PAPER 2198

How the Chinese System of Charges and Subsidies Affects Pollution Control Efforts by China's Top Industrial Polluters

China's unique combination of emissions charges and pollution abatement subsidies has given China's most heavily polluting industrial firms incentive to invest in pollution abatement

Hua Wang
Ming Chen

The World Bank
Development Research Group
Infrastructure and Environment
October 1999

Summary findings

There have been extensive theoretical studies of firms' responses to environmental regulations and enforcement but few empirical analyses of firms' expenditures on pollution abatement in response to different regulations and enforcement strategies.

Wang and Chen empirically analyze the pollution abatement efforts of Chinese industrial firms under a system combining pollution charges and abatement subsidies.

Using data on China's top industrial polluters and on regional development in China, they find that the combination of charges and subsidies used in China has provided effective incentives for the most heavily polluting industrial firms to abate pollution.

Chinese industries operate under a unique pollution control system, a market-based instrument combining emissions charges and abatement subsidies. This combination of charges and subsidies has given firms incentive to invest in wastewater treatment facilities. The pollution levy, although low, has significantly improved investments in abatement.

Wang and Chen found that the more pollution a firm generates, the more likely it is to invest in pollution abatement.

This study was only of top polluters, which are closely monitored by environmental agencies, so the results may not be valid for other sources of industrial pollution.

This paper — a product of Infrastructure and Environment, Development Research Group — is part of a larger effort in the group to identify appropriate policies for 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 Hua Wang, room MC2-626, telephone 202-473-3255, fax 202-522-3230, Internet address hwang1@worldbank.org. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/html/dec/Publications/Workpapers/home.html. October 1999. (28 pages)

How the Chinese System of Charges and Subsidies Affects Pollution Control Efforts by China's Top Industrial Polluters[1]

Hua Wang

Development Research Group

World Bank

Ming Chen

Department of Agricultural and Resource Economics

University of California, Berkeley

Key words: China; industrial firms; pollution abatement expenditure; pollution charge; pollution subsidy

JEL: Q28, L51, C51.

[1] Corresponding address: Hua Wang, World Bank, MC2-626, 1818 H St., N.W., Washington, DC 20433, USA; Telephone: 202-473-3255; Fax: 202-522-3230; E-mail: HWANG1@worldbank.org.

How the Chinese System of Charges and Subsidies Affects Pollution Control Efforts by China's Top Industrial Polluters

I. Introduction

Economists have conducted extensive theoretical analyses on the possible impacts of environmental policy instruments and monitoring and enforcement strategies. A number of the theoretical analyses have also been conducted on the combinations of the different environmental policy instruments. Porter (1974) and Kohn (1991) analyzed a combination of tax and subsidy for controlling pollution, in which "each polluting firm must pay a 'right to enter' tax each period that is based on the quantity of emissions it would emit if there were no abatement, then later receive a payment, called subsidy, for the quantity of emissions that the firm actually abated during the period." Kohn (1991) showed that this combination could be economically efficient and would have administrative advantages. Conrad (1993) analyzed the optimal environmental policy responses of international oligopoly to foreign emission tax and subsidy programs, and showed that a Pigouvian emission tax could restore efficiency in natural resource allocation, whereas subsidy programs were in principle used as instruments in imperfectly competitive international markets. Thomas (1995) also provided a theoretical model for the combined use of an emission tax and contract between an environmental agency and the industry according to the industry's abatement efficiency.

However, there are few empirical studies on how regulated firms respond to policy instruments, especially to those combinations of policy instruments implemented in an actual setting[2]. The use of environmental policy instruments in the real world can be very complex. Instead of pursuing efficiency, which might be technically or practically difficult because it requires extensive information, environmental agencies mostly pursue a goal of effectiveness. A combination of policy instruments is usually implemented simultaneously. In the context of industrial pollution control in China, several management measures have been concurrently implemented in order to enforce the environmental protection law. The measures include both the command-and-control approach, such as discharge standards, abatement facility installment deadlines and discharge permits, which provide a maximum discharge ceiling for firms, and market-based practices such as emission charges and pollution abatement subsidies.

This paper presents an empirical study of Chinese industrial firms' pollution control efforts in responding to the complex pollution management system. The effectiveness of the management system is evaluated. There are some unique features associated with the Chinese pollution control system and Chinese industries. While the command-and-control approaches may be 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 penalized, even when violating the abatement deadline requirements. To control pollution, the environmental regulators have relied heavily on the market-based approach since the early 1980's. For more than a decade, hundreds of thousands of firms have had

[2] To name the few empirical studies, Thomas (1995) analyzed how French firms respond to the tax-contract system. Pargal and Wheeler (1996) provided Indonesian evidence on how informal regulations could affect a firms' pollution abatement behaviors. Hartman, Huq and Wheeler (1997) show how formal and informal regulations jointly determine firms' pollution abatement efforts in four Asian countries. However, in the United States, a number of empirical analyses have been conducted of the impact of environmental regulation on productivity. For a recent study, refer to Berman and Bui (1998).

to pay a fee if their discharges did not meet the discharge standards[3]. Wang and Wheeler (1996) have shown that pollution intensities of Chinese industries have been significantly responsive to the levy system. To provide stronger incentives for firms to abate, most of the fees collected has also been used to subsidize firms' abatement investment projects. These incentives can be viewed as a charge-subsidy double incentive system with discharge standards embedded. On the other hand, unlike other free market economies, some Chinese firms are state-owned or collectively owned, and therefore, face imperfect competition. The prices of the outputs are partly regulated by the government while recent reforms have brought more autonomy to the state owned enterprises. To maximize profits, firms have to minimize costs as much as possible, with constraints set by both the market and the government. Even though some state-owned firms have soft budget constraints, existing incentives make it in firms' interests to minimize pollution control costs, like counterparts in a free market economy[4].

In this study, we develop an econometric model of firm's pollution control effort under a charge-subsidy double incentive system. The indicator of pollution control effort employed in this study is the firm's abatement investment and operating cost. A firm faces a pollution discharge levy, which is a function of pollutant discharged. Given the amount of pollutant generated from the production process, the discharge amount is a function of abatement expenditures. There are two sources of financing for pollution abatement: own investments and subsidies, while the latter depends on the former as well as the nature of the agencies that provide the subsidies. A firm's problem then is to

[3] Most small industries in the remote rural areas have effectively escaped paying the levy due to the weak enforcement capacity of local environmental protection agencies.
[4] In a free market economy, the pollution abatement cost may be more likely integrated with the production cost.

decide the level of investment in abatement in order to minimize the total cost of pollution control, which is a summation of levy and own expenditure in pollution control.

Data on more than a thousand industrial firms identified as China national top water polluters in 1993 have been acquired from the China State Environmental Protection Administration (SEPA). These top polluters, mostly large and state-owned, have been closely monitored by SEPA and local environmental agencies. Accurate information on production outputs, energy use, investments, pollution abatement expenditures, pollution discharges, paid pollution levies, etc. were available for analyses. However, the information on subsidies for different firms was not available, preventing a rigorous modeling and simulation on subsidies. To incorporate subsidies into the model, we collected a regional-level data set on income, education, industrial development, etc.

The econometric results indicate the Chinese pollution charge-subsidy system have been effective in promoting investment in firm-level pollution abatement and have significantly contributed to the national pollution control effort. The two components both have affected the pollution abatement investment positively. The subsidy component has enhanced the total abatement investment level through the direct effect, while the charge component has significantly affected the total abatement investment either through the indirect effect by providing incentives for more own investment, or through the direct effect by providing environmental agencies with more funding for subsidies, or both.

Section II discusses the policy context in which the Chinese charge-subsidy system is introduced. Section III presents the modeling framework of a firm's investment effort in pollution abatement under a charge-subsidy system. Econometric results of the estimations are presented in section IV. Discussions and conclusions are provided in section V.

II. Policy Context

2.1 Chinese Pollution Charge-Subsidy System

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. 4 billion RMB's ($1 = 8RMB) were collected from about half a million industrial firms. Numbers are increasing each year. Table 1 lists information about the total levy collected.

There are some unique features associated with the charge system. For wastewater, this system only imposes charges on the pollutants over the standard[5], among which, only the pollutant which violates the standards 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

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

all the pollutants. The Chinese central government constructs a uniform fee schedule, however the implementation in different regions is not uniform[6]. The levy collected is used to finance environmental institutional development and 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[7]. Penalties can not be used to subsidize firm-level pollution control projects. Table 2 provides information on how the collected levies are used.

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.

While it is clear that the pollution intensities are responding to the charges, whether the charge has been strong enough to provide incentives for firms to invest in pollution abatement facilities remains unclear. Another policy instrument – the subsidies may be jointly playing an important role in firms' investment decisions.

---

[6] For a detailed discussion, see Wang and Wheeler (1996) and SEPA (1998).
[7] The penalty schedule is usually referred as "four small parts" in Chinese.

To evaluate whether this combination of charge and subsidy policy can produce an economically efficient response would be beyond the scope of this study. The focus of this analysis is on how firms' abatement efforts respond to the charge-subsidy system. To better understand the structure of the Chinese system, we will present information about the overall abatement investment efforts in Chinese industries.

2.2 Investment and Abatement

Investment in pollution control in China was around 0.5% of GDP in 1996, which was quite low compared to most developed countries[8]. However, according to China's 9th Five-Year Plan, the investment in pollution control will reach about 1.3 % of GDP in the year of 2000. Wastewater treatment has been the largest expenditure in pollution abatement, followed by air, solid waste, and noise treatment (see Table 3). In 1996, investment in wastewater treatment has reached 4.74 billion RMB. This is nearly twice the investment in air pollution treatment (2.81 billion RMB). Wastewater treatment has been identified as the top priority in pollution control in the 9th Five-Year Plan period[9].

The Chinese accounting system divides the sources of financing pollution control projects into six categories: 1) budgetary funds for infrastructure construction; these funds are within national, provincial, sector or special bank budgets designated to infrastructure construction; 2) budgetary funds for technology renovation and restructuring; these funds are also within national, provincial, sector or special bank

---

[8] In 1985, the US spent 1.67% of GDP on pollution control, West Germany 1.52%, Finland 1.32%, Netherlands 1.26%, UK 1.25%, France 1.1%, and Norway 0.82%. (EPA, 1990).
[9] The 9th Five Year Plan of China called for a centralized wastewater treatment facility in all cities with over 500,000 urban population

budget designated for renovation and new technology adoption; 3) firms' own profits; 4) subsidies from the government; 5) environmental loans; which is a fairly new source of financing environmental projects, set up by local environmental protection agencies[10]; 6) other sources[11].

The government planning department endows the first two categories of funds. The funds are mostly used for construction of urban environmental facilities and other pollution control projects. What are in the firms' discretion are firms' profits, loans, as well as subsidies. Table 4 lists the sources of financing pollution control projects over the years. Figure 1 shows the trends of each share. The clearest trend is the share of the government subsidies decreasing over the years, while firms' using their own profits is increasing.

Table 5 lists the number of wastewater treatment equipment, the number of equipment purchases at year 1992-1996, original investment and operating costs. The stock of wastewater treatment equipment has been stable, with 10% of new equipment added to replace old ones. Although the stock of equipment has not significantly changed, both investments and operating costs have been increasing steadily.

III. Modeling Framework

3.1 Previous Research

[10] The government has been trying to use loans to replace subsidies. However, the principal of most loans are mostly waived if they are used for pollution abatement, which makes loans similar to subsidies.
[11] These include donations from other countries and loans from the World Bank and the Asian Development Bank.

For a firm who has to pay a levy on their pollution emissions, there are two general approaches to reducing the pollution levy. The first is to change production practices so less pollution is generated. This approach is referred to as pollution prevention (or source control), and often also entails installation of cleaner production technology. The second approach for controlling pollution is based on removal of pollutants after they have been generated but before they cause damage. Many countries, including the U.S. and China, emphasize pollution prevention as an objective and the importance of preventing emissions rather than trapping them at the end of the pipe.

Literature has looked at how the two approaches can be combined to achieve the optimal result. Shah, Zilberman and Lichtenberg (1995) present a model in which the optimal combination of these two kinds of policies is analyzed. Kohn (1998) models the case of less and non-polluting processes in the context of linear programming, linear activity analysis, and twice-differentiable equations. A linear programming model is used to illustrate when the combination is most efficient. Linear activity analysis considers a production possibility frontier, which consists of the amount of good produced and the amount of pollution it generates. Under perfect competition, the marginal costs are the respective Pigouvian tax and equilibrium market prices. With this exact combination of output and pollution, both marginal rates of substitution equal the corresponding ratio of prices. The third model, developed by Kohn, builds on non-linear processes, focuses explicitly on firms rather than sectors, and emphasizes pollution prevention. When emissions are associated with a particular input, it is possible to reduce emissions by partially substituting other inputs for the polluting input. In this model, there is both the substitution of a non-polluting input for a polluting input and a non-polluting process for a polluting process.

Understanding a firm's pollution abatement investment behavior lies in the general literature on voluntary compliance with the environmental policy. Literature has looked at the reasons why firms invest in pollution abatement from different perspectives, which include public information (Konar and Cohen, 1997), participation in voluntary programs (like EPA 33/50 program) (Arora and Cason, 1995), the legal side (Pashigian, 1982), and market structure (Farber and Martin, 1986). The literature usually assumes the agents are profit maximizers. Given the firm's size and other constraints, the firm selects the optimal prevention activity, and therefore decides the optimal level of investment. The benefit from prevention is measured in potential profits, reduction of legal expenses or cost cutting measures (Pashigian, 1982).

There are a number of empirical studies on pollution abatement investment efforts, most associated with studies of the impact of environmental regulations on industry productivity. Smith and Sims (1985) performed an econometric analysis of the impact of pollution charges on productivity in the Canadian brewing industry and found that pollution charges have a negative impact on productivity growth. Gray & Shadbegian (1995) analyzed the relationship between productivity and pollution abatement expenditures for plants in the paper, oil and steel industries, and found that plants with higher abatement cost levels had lower productivity levels. According to their study, in the United States, "$1 greater abatement cost appears to be associated with the equivalent of $1.74 in lower productivity for paper mills, $1.35 for oil refineries and $3.28 for steel mills." Gray & Shadbegian (1997) employed a simple regression of total abatement investment against the stringency of the regulation and tested the impact of environmental regulation on technology choices by new mills and investment decision by existing plants in the US. They found that new mills in states with strict environmental regulations are less likely to employ the more polluting technologies involving pulping. However, state regulatory stringency and plant technology have little or no effect on annual investment spending at existing plants.

Farber and Martin (1986) studied the effects of market structure on pollution investment under imperfect surveillance and concluded that the effects of market structure variables, including market concentration, establishment and firm size, and establishments per firm on pollution control effort were positive. There was an inverse relation between pollution control effort and firm rivalry even when monitoring intensity was independent of firm rivalry.

3.2 The Model

This section models a firm's decision on the level of pollution abatement investment under a charge-subsidy system, such as the one implemented in China. We focus on the end-of-pipe treatment investment. The firm is expected to minimize its pollution-related cost. This includes both pollution levies paid to the government, and pollution abatement cost, minus the subsidies [12] received from government.

[12] This could mean that production and abatement activities are mutually independent. As Thomas (1995) argued, this assumption may be justified by considering that the charge-subsidy mix may not be important relative to production cost. Hence the absolute level of charge and subsidy may not influence the input and

Assume a firm plans to invest I_f in wastewater treatment at year t. With this investment, the firm expects to obtain from government a subsidy S. The amount of subsidy is affected by the amount of self financing I_f, levy paid L, firm's own characteristics Z_{f1} , and regional characteristics Zg, i.e.,

(1) $S = f(I_f, L, Z_g, Z_{f1})$

Regional characteristics such as income, education, and industrial development can all affect subsidy budget and policy[13]. A firm's financial situation may also affect its subsidies from the government. Firms with higher profitability may get a lower subsidy simply because they can afford the abatement cost on their own. Also, the government may pay more attention to pollution abatement in certain sectors and may therefore favor one over the other in terms of the subsidy.

The total investment in water pollution abatement I_t is the sum of self investment and government subsidy, i.e.,

(2) $I_t = I_f + S$

The pollution discharge amount is a function of the total amount of pollution generated, P_g, total amount of investment in abatement facility, I_t, operating cost, V and the firm's characteristics.

technology of production process. This is more likely to be valid in the context of China top polluters where decisions on production and pollution abatement are more likely to be separated.

[13] These variables have also been found to affect China's effective levy rate (Wang and Wheeler, 1996), and therefore affecting the subsidy budget.

(3) $P_d = g(P_g, I_t, V, Z_{f2})$,

where Z_{f2} reflects firm's characteristics, which determine the nature of pollution abatement, such as the sector the firm belongs to.

The firm pays levy for its discharge according to some schedule set by the government.

(4) $L = h(P_d, C)$,

where C is the charge schedule.

The firm minimizes its total cost $L + I_f + V$ by choosing the amount of self-investment I_f and the amount of operation cost V subject to equation (1) to (4).

The total investment equation (2) can be solved as,

(5) $I_t = k(P_g, C, Z_g, Z_{f1}, Z_{f2})$.

The operation expenditure V can also be solved as,

(6) $V = m(P_g, C, Z_g, Z_{f1}, Z_{f2})$.

There are four sets of exogenous variables. The first is pollution generated from the production process, which sets up the scale for investment. P_g is expected to have a positive effect on I_t and V. The second set is the pollution charge schedule, which reflects the strength of the enforcement of government pollution control policy. C is also expected to have a positive impact on total investment. The third set of variables is regional or community characteristics, which are used as instrumental variables for government pollution control subsidy budget and policy. Income could affect the investment volume positively since a higher subsidy budget might be available. Education could have a negative effect on subsidies because people with higher education may favor to eliminate the subsidy policy while the total amount of subsidies is given and other pollution control instruments are in place. However education may have a positive impact on firms' abatement efforts. An industrial firm located in an area with a high industrial density may have a lesser chance of getting the subsidies, but subsidy fund availability may be higher. Therefore, it could have either a negative or positive sign in equation (5). The fourth set of determinants is the firm's own characteristics. It may be more difficult for firms with higher productivity to get subsidies, but they may be able to spend more money in the operation of the facilities. Sectors adopting government pollution control strategies may be easier to get subsidies. The costs associated with abating pollution across sectors are also different. Thus the signs of sector variables in equation (5) are empirical issues.

The expenditure model developed above is based on the assumption that a firm minimizes total cost associated with end-of-pipe treatment and a pollution emission charge, treating pollution generated in the production process as given. The firm adjusts its investment in pollution control in response to the two economic instruments: a tax and a subsidy.

IV. Econometric Results

4.1 Data

The data used for this study are from a database collected by SEPA on the industrial firms which were listed as top water polluters in 1993 in China. These firms are located in 28 provinces (except for Hainan and Tibet) and are under close monitoring of both central and local environmental agencies. They belong to a wide range of industries: coal mining; sugar; dye; paper; electricity; petroleum refinery; fertilizer; chemical pharmaceutical; cement, and steel. The data contain the value of each firm's wastewater treatment equipment, levy paid on wastewater discharge, wastewater treated by each abatement facility, and TSS and COD removed. The data contain additional information such as output, ownership, and number of workers. Regional data were obtained from the China Yearbooks covered provinces' social-economic development, which include disposable income, education level (percentage of employees with secondary schooling or higher) and industrial densities (industrial GDP as a percentage of total GDP).

4.2 Model and Variables

The econometric model estimated has the following format:

*log (total investment in wastewater treatment (or operation cost) / value of output) = a0 +a1 * log(wastewater generated / output) + a2*log (total water levy paid /*

*wastewater discharge not meeting standards) + a3*log(income) + a4*log(education) + a5*log(industrial share of GDP) + a6*log(output/worker)+ a7*age + a8* ownership dummy + a9*sector dummies.*

The dependent variables are, for model 1, the current value of total investment in wastewater treatment facilities divided by the total value of output, and for model 2, the total operational cost of abatement divided by the value of output. Wastewater generated is used as a proxy for total pollution generated from the production process. As in Wang and Wheeler (1996), an effective levy rate is defined as the total levy paid for water pollution discharge divided by the total wastewater discharge which did not meet discharge standards. Annual per capita consumption is used as a proxy for income. Education level is defined as percentage of employees with secondary schooling or higher. The industrial development level is defined as the share of industrial GDP in total GDP. Firm level variables include the total value of output divided by the total number of workers, number of years in operation, ownership dummies, and sector dummies.

Table 6 presents the mean values and standard variances of these variables. The regression results are presented in Table 7. The Log-log regression format and White (1990) approach are used to correct possible heterogeneity associated with the cross section data.

4.3 Results

The regression results shown in Table 7 generally support the modeling argument developed in last section. A higher amount of wastewater generated from the production process demands more investment and higher operation cost for end-of-pipe wastewater treatment facilities. The pollution levy variable has a positive, significant impact on pollution abatement investment effort and operation expenditure.

Income has a positive, but insignificant, effect which may imply that income does not have a strong relationship with the provincial pollution subsidy budget as expected. Industrial GDP share has a significant positive effect on investment effort, but this does not support the subsidy argument. Rather it supports the argument that firms located in more industrialized areas face higher pressure to invest in pollution abatement by themselves, controlling for the pure economic instrument: levy. Education has a significant, negative impact on total abatement investment and operation cost, which implies a strong negative correlation between subsidy and education. Without subsidy, education would have been expected to have positive impact on pollution control effort because education has been found to be positively correlated with pollution control pressures.[14]

The coefficients on the productivity of a firm are negative. Firms who are more productive need to spend less investment effort in pollution control. The reason might be that more productive firms are also cleaner[15]. State-owned enterprises were not found to have significant differences in pollution control effort from other types of enterprises. Neither were firms' vintages found to have a significant relationship with the investment effort. Beer, dye, coking and refinery industries were found to have invested more on

[14] see Wang and Wheeler (1996) and Dasgupta and Wheeler (1997).
[15] More expenditure on pollution abatement reduces profit, but the value of output should not be affected given the assumption that abatement expenditure is small relative to the production cost and does not affect the financial budget constraint. Therefore the value of output is exogenous to the abatement expenditure, but the profit is not.

wastewater treatment facilities[16], while the cement industry invested less. This could be related to the difference in the efficiency of pollution abatement among different sectors.

V. Discussion and Conclusion

Several empirical studies have been conducted in analyzing firms' behaviors in complying with pollution regulation.[17] The analyses usually looked at the firms' pollution control consequences such as pollution discharges, which may be associated with external pressures such as strength of regulation and social norms as well as firms' internal characteristics. There is little empirical study on efforts firms take to reduce their pollution. This study focused on the investment and operation cost for the end-of-pipe wastewater treatment, and looked at what determines firms' efforts in investing for the end-of-pipe treatment facilities.

Chinese industries operate under a unique pollution control system, which employs a market-based instrument combining emission charges and abatement subsidies. The results show that this combination of charge and subsidy has been effective in providing incentives for firms to invest in wastewater treatment facilities. The pollution levy has been found to have a significant positive impact on abatement investment effort. However, the elasticity is only about 0.06. While the levy rate has been generally regarded as low, the levy could affect investment decisions in two ways. One possibility is that the levy itself does provide incentives for firms to invest in pollution

[16] The most important reason could be that the cost per unit of abatement is higher with these secters.
[17] e.g., Pargal and Wheeler (1996).

abatement. Another possibility is that higher levies generate higher subsidies which firms can use to invest in pollution abatement.

Regional variables such as education and industrial intensity were also found to significantly affect firms' pollution abatement investment efforts. The industrial intensity of a region has been found to have a positive impact, implying that firms invest more in pollution abatement while industries in this area are more developed. Surprisingly, education was found to have a negative impact on firms' pollution control investment efforts. However this correlation is consistent with the model for subsidies where higher education could imply less subsidies, and therefore less total abatement investment. Empirical research has found that higher education generates higher pressure on industry for pollution control. Pargal and Wheeler (1996) found that while formal regulation was not in place, informal regulation could put significant pressure on the firms. When education is higher, the informal pressure would be stronger. Wang and Wheeler (1996) found that education was positively correlated with effective levy rate in China. While formal regulation is in place and effective levy is included in the modeling, education was found a negative impact on subsidy and therefore on total pollution control investment efforts.

Consistent evidence was also found with firms' own characteristics on pollution abatement investment. The more pollution a firm generates, the more investment the firm will invest. More productive firms need to invest less in pollution abatement. Neither the ownership effect nor the vintage effect was found. A close look at the modeling results reveals that the value of output can be cancelled out from both sides of the equation, which implies that total expenditure on pollution abatement is not strongly correlated with value of output.

In this paper firms' pollution control investment efforts under a combination of emission charges and abatement subsidies are modeled with an assumption that firms are minimizing pollution control costs subject to technical constraints. This requires an assumption that production process and end-of-pipe treatment costs are independent. The modeling is based on data collected on China's top polluters. The conclusion drawn in this paper applies only to those top polluters which are under close monitoring by the environmental agencies, and may not be valid for other industrial pollution sources.

References:

Arora, Seema and Timothy N. Cason., 1995, "An Experiment in Voluntary Environmental Regulation: Participation in EPA's 33/50 Program". *Journal of Environmental Economics and Management* 28, 271-286, 1995.

Barbara, A.J. and V. D. McConnell, 1990, "The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects," *J. of Environmental Economics and Management,* vol. 18.

Berman, Eli and L. T.M. Bui, 1998, "Environmental Regulation and Productivity: Evidence from Oil Refineries," NBER Working Paper Series, #6776.

Burrows,P. 1981. "Controlling the Monopolistic Polluter: Nihilism or Eclecticism?", *Journal of Environmental Economics and Management*, Vol. 8, pp.372-380.

Conrad, Klaus, 1993, "Taxes and Subsidies for Pollution-Intensive Industries as Trade Policy," *J. of Envir. Econ. Management*, Vol. 25.

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

Farber, S.C., and R.E. Martin. 1986. "Market Structure and Pollution Control under Imperfect Surveillance". *Journal of Industrial Economics*, Volume 35, Issue 2. Dec. 1986,147-160.

Gray, W. B and R. J. Shadbegian, 1995, "Pollution Abatement Costs, Regulation, and Plant-Level Productivity," NBER Working Paper Sries, #4994.

Gray, W. B and R. J. Shadbegian, 1997, "Environmental Regulation, Investment Timing, and Technology Choice," NBER Working Paper Sries, #6036.

Harford, Jon D., 1989 "Efficient Scale of the Pollution-Abating Firm: Comment." *Land Economics, 65*, 413-16, November, 1989.

Hartman, R., M. Huq and D. Wheeler, 1997, "Why Paper Mills Clean Up: Determinants of Pollution Abatement in Four Asian Countries," World Bank Policy Research Report #1710, 1997.

Hettige, H., M. Huq, S. Pargal, and D. Wheeler, 1996, "Determinants of Pollution Abatement in Developing Countries: Evidence from South and Southeast Asia," *World Development*, Vol. 24, No. 12 (1996).

Kohn, Robert E., 1991, "Porter's Combination Tax and Subsidy for Controlling Pollution," J. *of Environmental Systems*, Vol. 20(3).

Kohn, Robert E., 1998, Pollution and the Firm , Cheltenham, UK, Northhampton, MA, USA

Konar, Shameek and Mark A. Cohen, 1997, " Information As Regulation: The Effect of Community Right to Know Laws on Toxic Emissions. " *Journal of Environmental Economics and Management* 32, 109-124, 1997.

Lovei, Magda. 1995. "Financing Pollution Abatement: Theory and Practice" Environment Department Papers No. 028. World Bank, Washington, D.C.

Rozelle, S., X. Ma, L. Ortolano, 1993, "Industrial Wastewater Control in Chinese Cities: Determinants of Success in environmental Policy," Natural Resource Modeling, vol. 7.

Thomas, Alban, 1995, "Regulating Pollution under Asymmetric Information: The Case of Industrial Wastewater Treatment," *J. of Environmental Economics and Management*, vol. 28.

Pargal, Sheoli and David Wheeler, 1996, "Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia," *J. Political Economy*, Vol. 104, 1996.

Pargal, S., 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 Working Paper #1797, 1997.

Pashigian, B. Peter. 1982, "A Theory of Prevention and Legal Defense with an Application to the Legal Costs of Companies". *Journal of Law & Economics*, Vol. XXV, Oct 1982.

Porter, R.C, 1974, "The Long-Run Asymmetry of Subsidies and Taxes as Antipollution Policies," *Water Resources Research*, Vol. 10.

SEPA, 1994, Pollution Levy System, China Environmental Science Press.

SEPA, 1998, Proceedings of International Workshop on China's Pollution Levy System, China Environmental Science Press.

Shah, Farhed, David Zilberman and Erik Lichtenberg, 1995, "Optimal Combination of Pollution Prevention and Abatement Policies: The Case of Agricultural Drainage." *Environmental and Resource Economics* 5:29-49, 1995.

Smith, J.B. and W.A. Sims, 1985, "The Impact of Pollution Charges on Productivity Growth in Canadian Brewing," *Rand Journal of Economics*, vol. 16(3).

Wang, Hua, and David Wheeler. 1996. "Pricing Industrial Pollution in China." Policy Research Working Paper 1644. World Bank, Washington, D.C.

White, H. 1980. "A Heteroscedastic-consistent Covariance matrix and a Direct Test for Heteroscedasticity". *Econometrica* : 48 817-838.

World Bank. 1997. *Clear Water, Blue skies: China's Environment in the New Century.* Washington D.C.

Table 1 : Pollution Levy Collected[18]

(Million Yuan)

Year	Total Levy	Over Standard Charge					Waste Water	Four Small Parts	Industr. Output (Billion)	Levy /Outp (0.1%)
		Water	Air	Solid	Noise	Rad.				
1986	1190.1	711.5	329.0	25.3	18.9	0.7	7.7	97.1	1119.4	1.06
1987	1427.8	820.7	380.2	33.8	22.4	1.1	20.8	146.8	1381.3	1.03
1988	1609.0	868.8	440.9	32.6	30.6	0.6	29.5	206.0	1822.4	0.88
1989	1674.0	858.2	452.6	33.4	35.9	0.4	32.2	261.2	2201.7	0.76
1990	1751.6	899.8	447.8	30.8	34.0	0.3	51.8	287.2	2392.4	0.73
1991	2006.0	996.4	494.5	40.2	41.3	0.3	61.8	371.6	2824.8	0.71
1992	2471.0	1180.5	509.9	32.5	87.2	0.8	83.3	485.7	3706.6	0.67
1993	2680.1	1228.4	560.2	119.3	37.5	0.2	126.4	608.2	5269.2	0.51

Table 2 : Use of Pollution Levy Fund

(Million Yuan)

Year	Total Levy Used	Subsidies and Loans to Industries for Pollution Control		Institutional Development	
		Subtotal	% of Total Levy Used	Subtotal	% of Total Levy Used
1991	1,784	1,200	67.26	564	31.61
1992	2,165	1,398	64.57	744	34.36
1993	2,483	1,509	60.77	942	37.94
1994	2,700	1,619	59.96	1,047	38.78
1995	3,220	1,771	55.00	1,414	43.91

[18] Data in table 1-5 are collected from China's Environmental Yearbooks.

Table 3: Abatement Investment by Environmental Medium, 1991-1996

(Million Yuan)

	1991	1992	1993	1994	1995	1996
Wastewater	2921.39	2980.98	2942.25	3469.82	4559.09	4741.02
Air	1973.77	2151.62	2546.48	3036.62	3315.60	2808.03
Solid Waste	672.27	801.01	855.67	1210.58	1407.68	909.81
Noise	183.95	178.10	154.23	185.43	215.28	95.91
Other	224.06	354.91	434.07	430.68	376.11	1007.92
Total	5973.06	6466.61	6932.70	8333.13	9873.76	9562.70

Table 4: Sources of Financing for Pollution Abatement

	91	92	93	94	95	96
Budgeted Infrastructure Fund	1400.87	1400.25	1308.01	1882.51	2480.10	1809.70
Budgeted Renovation Fund	1720.50	1793.58	2088.80	2480.07	2861.87	1605.45
Profit within the Firm	213.21	215.94	319.93	333.43	459.47	671.40
Environ. Subsidy	1017.47	1089.90	1073.50	1032.25	1031.67	332.12
Environ. Loans	N/A	N/A	N/A	N/A	N/A	534.37
Other Sources	1620.93	1966.59	2138.40	2606.74	3041.39	4376.70
Total	5973.03	6466.27	6928.64	833.500	9874.50	9329.74

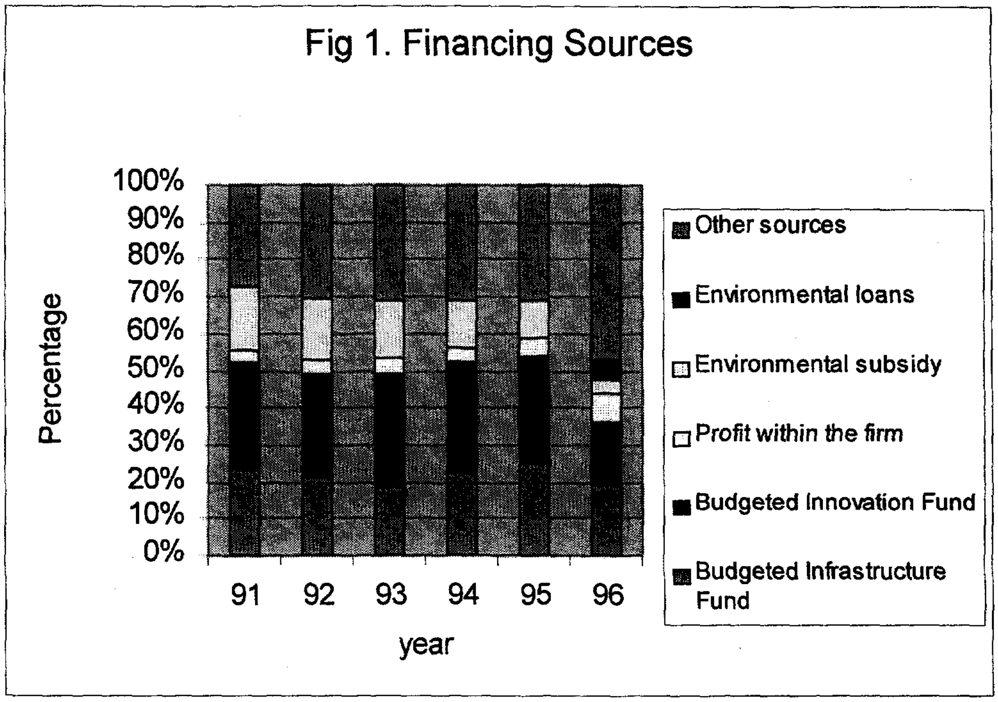

Table 5: Summary of Wastewater Treatment Equipment

	1992	1993	1994	1995	1996
Number of Working Equipment	39401	40482	42306	42192	40877
Equipment Purchased in That Year	4973	4581	4252	4286	N/A
Original Investment (million RMB)	16744.93	20591.46	23253.23	28325.04	37744.31
Operating Costs(million RMB)	3619.94	5103.712	5312.585	6838.215	8020.45

Table 6. Variable Names and Definitions

Region	**Definition and Unit**	**Mean**	**SD**
Income	Yuan/person Annual consumption	1010.73	402.85
Industrial share	%, industrial GDP/total GDP	41.06	6.56
Education	% of employees with secondary schooling or higher	49.13	12.35
Firm			
Age	Years the firm in operation	34.00	19.17
Owner	Dummy state-owned enterprise 1-yes, 0-no	.93	.26
Value of Output	Ten Thousand Yuan	20400	55813
Workers	# of workers	4193	19478
Wastewater Generated	Ten Thousand Tons	561.5	2090.7
Investment in wastewater treatment	Ten thousand yuan (in 1993 yuan) adjusted using CPI	2083	6647
Wastewater treatment operation cost	Ten thousand yuan	190	1593
Effective Levy Rate	Yuan/ton Levy per ton of wastewater not meeting standard	.13	.06

Table 7. Pollution Abatement Expenditure Regression Results

	Model 1: Ln (total fixed cost / value of output)	**Model 2: Ln (Operation cost / value of output)**
Pollution Regulation:		
Ln(effective levy rate)	.058 (2.38)**	.062 (2.14)**
Regional Characteristics		
Ln(income)	.083 (0.41)	.362 (1.58)
Ln(industrial share of GDP)	0.826 (2.48)**	1.38 (3.52)***
Ln(education level)	-.745 (-3.60)***	-.974 (-3.77)***
Firm Characteristics:		
Ln(pollution generated/output)	.380 (8.07)***	.482 (8.61)***
Ln(output/worker)	-.652 (-13.28)***	-.548 (-9.73)***
State Ownership	-.020 (-.13)	.009 (.03)
Ln(age of firm)	-.002 (-.032)	-.001(-.02)
Coal	-.425 (-1.98)**	-.760 (-2.29)**
Cane Sugar	-.295 (-1.35)	-.321 (-1.11)
Bean Sugar	.177 (.43)	-.485 (-1.27)
Liquor	.172 (.826)	-.191 (-0.62)
Beer	1.16(4.99)***	1.15 (3.176)***
Cotton	-.408(-.71)	-.57 (-1.08)
Dye	.707 (4.72)***	.919 (4.94)***
Paper	-.047(-.34)	-.045 (-0.30)
Pulp	.268 (.70)	.132 (.363)
Coking	.84 (3.31)***	1.22 (4.13)***
Electricity	.417 (1.81)*	-.096 (-.379)
Pesticide	.45(1.45)	.767 (2.00)**
Refinery	1.75 (9.24)***	2.47 (10.71)***
Nitrogen fertilizer	-.068 (-.04)	-.114 (-.505)
Phosphoric fertilizer	.048 (.178)	.244 (.755)
Organic chemical material	.51 (1.406)	.444 (1.01)
Chemical pharmaceutical	.116 (.36)	.104 (.28)
Cement	-1.81(-2.65)**	-1.12 (-1.60)
Iron	-.010 (-.038)	-.14(-.37)
Steel	-.159 (-.68)	-.006 (-.022)
Steel processing	-.77 (-1.14)	-1.32 (-2.24)**
Dye material	1.30 (5.15)***	1.53 (5.43)***
Constant	-.771 (0.442)	-5.27(-2.68)***
R Square	.762	.756
Number of Observations	1238	1046

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS2174	Prospective Deficits and the Asian Currency Crisis	Craig Burnside Martin Eichenbaum Sergio Rebelo	September 1999	E. Khine 37471
WPS2175	Sector Growth and the Dual Economy Model: Evidence from Côte d'Ivoire, Ghana, and Zimbabwe	Niels-Hugh Blunch Dorte Verner	September 1999	H. Vargas 37871
WPS2176	Fiscal Risks and the Quality of Fiscal Adjustment in Hungary	Hana Polackova Brixi Anita Papp Allen Schick	September 1999	A. Panton 85433
WPS2177	Fiscal Adjustment and Contingent Government Liabilities: Case Studies Of the Czech Republic and Macedonia	Hana Polackova Brixi Hafez Ghanem Roumeen Islam	September 1999	A. Panton 85433
WPS2178	Nonfarm Income, Inequality, and Land In Rural Egypt	Richard H. Adams Jr.	September 1999	M. Coleridge-Taylor 33704
WPS2179	How Child Labor and Child Schooling Interact with Adult Labor	Ranjan Ray	September 1999	M. Mason 30809
WPS2180	Regulating Privatized Infrastructures and Airport Services	Ofelia Betancor Robert Rendeiro	September 1999	G. Chenet-Smith 36370
WPS2181	Privatization and Regulation of the Seaport Industry	Lourdes Trujillo Gustavo Nombela	September 1999	G. Chenet-Smith 36370
WPS2182	The Integration of Transition Economies into the World Trading System	Constantine Michalopoulos	September 1999	L. Tabada 36896
WPS2183	Market Discipline and Financial Safety Net Design	Asli Demirgüç-Kunt Harry Huizinga	September 1999	K. Labrie 31001
WPS2184	Financial Services and the World Trade Organization: Liberalization Commitments of the Developing and Transition Economies	Aaditya Mattoo	September 1999	L. Tabada 36896
WPS2185	Financial Sector Inefficiencies and Coordination Failures: Implications for Crisis Management	Pierre-Richard Agénor Joshua Aizenman	September 1999	T. Shiel 36317
WPS2186	Contagion, Bank Lending Spreads, and Output Fluctuations	Pierre-Richard Agénor Joshua Aizenman Alexander Hoffmaister	September 1999	T. Shiel 36317

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS2187	Who Determines Mexican Trade Policy?	Jean-Marie Grether Jaime de Melo	September 1999	L. Tabada 36896
WPS2188	Financial Liberalization and the Capital Account: Thailand, 1988–97	Pedro Alba Leonardo Hernandez Daniela Klingebiel	September 1999	R. Vo 33722
WPS2189	Alternative Frameworks for Providing Financial Services	Stijn Claessens Daniela Klingebiel	September 1999	R. Vo 33722
WPS2190	The Credit Channel at Work: Lessons from the Republic of Korea's Financial Crisis	Giovanni Ferri Tae Soo Kang	September 1999	K. Labrie 31001
WPS2191	Can No Antitrust Policy Be Better Than Some Antitrust Policy?	Aaditya Mattoo	September 1999	L. Tabada 36896
WPS2192	Districts, Spillovers, and Government Overspending	Reza Baqir	September 1999	S. Devadas 87891
WPS2193	Children's Growth and Poverty in Rural Guatemala	Michele Gragnolati	September 1999	M. Gragnolati 85287
WPS2194	Does Democracy Facilitate the Economic Transition? An Empirical Study of Central and Eastern Europe And the Former Soviet Union	Jean-Jacques Dethier Hafez Ghanem Edda Zoli	October 1999	H. Ghanem 85557
WPS2195	Aggregating Governance Indicators	Daniel Kaufmann Aart Kraay Pablo Zoido-Lobatón	October 1999	D. Bouvet 35818
WPS2196	Governance Matters	Daniel Kaufmann Aart Kraay Pablo Zoido-Lobatón	October 1999	D. Bouvet 35818
WPS2197	Production Sharing in East Asia: Who Does What for Whom, and Why?	Francis Ng Alexander Yeats	October 1999	L. Tabada 36896

10/18