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Endogenous Enforcement and Effectiveness of China's Pollution Levy System

Hua Wang
David Wheeler

How well air and water pollution regulation is implemented depends very much on both the level of economic development and actual environmental quality. Pollution pricing is closer to the dictates of environmental economics than China's formal regulatory statutes would suggest — and there is considerable scope for using economic instruments to reduce China's industrial pollution problems.

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Summary findings

Wang and Wheeler investigate two aspects of China's pollution levy system, which was first implemented about 20 years ago.

First, they analyze what determines differences in enforcement of the pollution levy in various urban areas. They find that collection of the otherwise uniform pollution levy is sensitive to differences in economic development and environmental quality. Air and water pollution levies are higher in areas that are heavily polluted.

Second, they analyze the impact of pollution charges on industry's environmental performance, in terms of the pollution intensity of process production and the degree of end-of-pipe abatement for both water pollution and air pollution.

Econometric analysis shows that plants respond strongly to the levy by either abating air pollution in the production process or providing end-of-pipe treatment for water pollution.

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 authors may be contacted at hwang1@worldbank.org or dwheeler1@worldbank.org. May 2000. (27 pages)

Endogenous Enforcement and Effectiveness of China's Pollution Levy System[1]

Hua Wang[2]
David Wheeler

Development Research Group
World Bank

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[2] Corresponding address: Hua Wang, MC2-626, 1818 H St., N.W., Washington, DC 20433, USA. Email: HWANG1@worldbank.org. Tel: 202-473-3255. Fax: 202-522-3230.

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1. Introduction

China's industrial growth has been extremely rapid during the period of economic reform. In the 1990's, the output of the country's millions of industrial enterprises has increased by more than 15% annually. Industry is China's largest productive sector, accounting for 47% of its gross domestic product and employing 17% of the country's total labor force in 1995. As a source of rapidly expanding income, Chinese industry has helped lift tens of millions of people out of poverty. Unfortunately, serious environmental damage has accompanied this rapid growth. In many urban areas, atmospheric concentrations of pollutants such as suspended particulates and sulfur dioxide routinely exceed World Health Organization safety standards by very large margins. While the WHO standard for particulates is below 100 ug/m^3, average concentrations for a sample of around 50 Chinese cities are above 300 ug/m^3 (Figure 1).

Chinese industry is a primary source of this problem. China's State Environmental Protection Administration (SEPA) estimates that industrial pollution accounts for over 70% of the national total, including 70% for organic water pollution (COD, or chemical oxygen demand); 72% for SO_2 emissions; and 75% for flue dust (a major component of suspended particulates) in 1995. Many polluting industries are located in densely-populated metropolitan areas, where emissions exposure can cause particularly serious damage to human health and economic activity.

One of China's responses to this problem has been its pollution charge, or levy system. Article 18 of China's 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." 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 which we will discuss, 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. This system is well worth understanding, both as an illustrative application of economic instruments, and as a documented case which sheds light on more general issues related to enforcement of environmental regulations in developing countries.

In this paper, we use new Chinese data to investigate two aspects of the pollution levy system. First, we analyze the determinants of differences in enforcement of the pollution levy across urban areas in China. In the formal regulatory system, the levy is based on standards which are supposed to be applied uniformly across China. We show that this is far from the reality, and that actual levy collections are sensitive to differences in economic development and environmental quality. Our results complement other recent research which suggests that "endogenous enforcement" is pervasive in developing countries ((Pargal and Wheeler, 1996; Hettige, Huq, Pargal and Wheeler, 1996; Hartman, Huq and Wheeler,1996).

Secondly, we analyze the impact of pollution charges on industry's environmental performance in different areas. Until recently, many policy analysts were skeptical about whether China's pollution levy provided significant incentives for pollution reduction. Florig et. al. (1995) argued that the levy's impact must be insignificant because plants only pay for "illegal" (above-standard) discharges, and the charges are not significant relative to firms' production costs and pollution abatement costs. Some case studies (Sinkule & Ortolano, 1995; CRAES, 1997) provided further support for this view by suggesting that the levy rate is less than the average cost of pollution abatement at the legal emissions standard.

While these studies were useful, data scarcity forced them to rely on anecdotes or arbitrary assumptions about emissions and cost parameters. New insights have been gained from more recent studies based on much larger datasets. Dasgupta, Huq, Wheeler and Zhang (1996) found that marginal abatement costs in China are much lower than previously supposed. In a complementary study at the provincial level, Wang & Wheeler (1996) found that water pollutant discharge has responded significantly to the pollution levy.

In this paper, we deepen the analysis in several ways. First, we decompose industry's response to the levy into two components: pollution intensity of process production and degree of end-of-pipe (EOP) abatement. To our knowledge, this is the first attempt to econometrically-estimate separate impacts of pollution charges on process and EOP determinants of pollution intensity. Secondly, we extend previous work on industry response to the levy from aggregative analysis at the provincial level to plant-level microdata. Our econometric work employs a new database for 3,000 polluting factories provided by China's State Environmental Protection Agency (SEPA). We find that both air and water emissions respond strongly to the levy.

The remainder of the paper is organized as follows. Section 2 describes China's pollution levy system, while Section 3 presents our models of pollution charge determination and industry responsiveness to charges. We present the econometric results in Section 4, while Section 5 summarizes the paper.

2. China's Pollution Levy System

China's pollution levy is the most extensive pollution charge system in the developing world or, for that matter, in the world. From the levy's inception in the early 1980's to 1996, Chinese regulators have collected about 30 billion RMB yuan[3] from more than 500,000 Chinese major polluters. In 1996 alone, the system collected about 4 billion RMB yuan. Charges are levied for water and air pollution, solid waste as well as noise, but water pollution charges contribute the greater share (63% in 1996) of the total.

The levy has been used for pollution source control, comprehensive clean-up projects and institutional development. As to 1994, about 4.5 billion yuan of levy collections had been used for development of environmental institutions; 3.1 billion yuan for purchasing monitoring equipment; and 1.4 billion for environmental education, environmental staff training, etc.. However, the lion's share – approximately 11.8 billion yuan through 1994 -- has been used for pollution abatement. This represents about 15% of China's total industrial pollution control budget, and as much as 30-40% for some cities. As of 1995, about 220,000 pollution control projects have been financed or cofinanced by the levy funds. These projects have provided abatement capacity sufficient for 16 billion tons of waste water, 4 billion cubic meters of waste gas, 70 million tons of solid waste, and 19,000 noise sources.

2.1 Development of the Levy System

Discussion of a possible pollution charge system began in China after the Stockholm Conference of 1972. The idea was formally adopted by the central government in 1978, when the Leaders Group for Environmental Protection in the State Council provided a work report to the Central Committee of the Chinese Communist Party. The report stated that "Pollution source control should be an important component of environmental management; fees should be charged against pollution discharge; and environmental protection authorities, in cooperation with other departments, should set up a detailed levy schedule." Article 18 of the "Trial Environmental Protection Law," which was enacted in 1979, stated that "the levy should be imposed on pollution discharges which exceed national pollution discharge standards, based on quantity and concentration of discharges and levy fee schedules established by the State Council." Several local governments immediately began experimenting with charges, and by the end of 1981, 27 of China's 29 provinces, autonomous regions and municipalities had established programs of some type.

After studying these local experiences, the central government issued an "Interim Procedure on Pollution Charges" in February, 1982. The procedure defined the system's

[3] One US dollar is about equal to 8.2 RMB yuan.

objectives, principles, levy standards, levy collection methods, and principles for fund use. Nationwide implementation rapidly followed.

The levy system is based on a discharge standard system, and only discharges exceeding the standards are subject to a fee. However, the regulations also specify that payment of the levy does not exempt polluters from legal liability for above-standard discharges. Thus, the levy system incorporates elements of both market-based and command-and-control regulation.

2.2 Design of the Levy

A nationally-uniform set of discharge standards and levies was designed by the State Council in 1982 and revised in 1991. The national discharge standards have been designed to promote a basic level of ambient environmental quality which is consistent with China's average level of economic, social and technological development. Polluters are charged a levy only for pollution which exceeds the legal standards, and the levy rate is supposed to exceed the average cost of abatement. The precise levy formula for water discharges is:

$$
\begin{aligned}
& P_{ij} = W_i \frac{C_{ij} - C_{sj}}{C_{ij}} \\
(1) \quad & L_{ij} = \begin{matrix} L_{0j} + R_{1j} P_{ij} \\ R_{2j} P_{ij} \end{matrix} \left. \right\} \left\{ \begin{matrix} P_{ij} < T_j \\ P_{ij} > T_j \end{matrix} \right.
\end{aligned}
$$

where, for facility i and pollutant j:

$R_2 > R_1$ and

P_{ij} = Discharge factor

W_i = Total wastewater discharge

C_{ij} = Pollutant concentration

C_{sj} = Concentration standard

L_{ij} = Total levy

L_{0j} = Fixed payment factor

Levy formula (1) incorporates both concentration and volume, since it calculates a pollutant-specific discharge factor (P) based on both total waste water discharge and the degree to which pollutant concentration (C) exceeds the standard (C_s). The charge rate is determined relative to a critical factor (T) which also incorporates concentration and scale considerations. For each polluter, the potential levy (L_j) is calculated for each pollutant. The actual levy is the greatest of these potential levies. Although this procedure provides an incentive to reduce pollution, it obviously differs from a Pigovian system which would charge for each unit of each pollutant.

The incentive to reduce pollution is compounded with the passage of time. After two years of paying the levy, polluters are subject to an annual 5% increase in the charge rate. For new facilities (those which began operations after 1979), the official charge rate is doubled.

The levy also includes two components related to water discharge. The first reflects standards established in 1988 for water discharge intensity (water/physical output) and water re-use. Excess water discharge is assessed at fees established by local governments. The second component levies a standard unit fee for wastewater discharge. In 1993, a maximum charge of 0.05 yuan per ton of waste water discharge was announced by the national government. Further reform on the current levy system has been studied (CRAES, 1997; SEPA, 1998; Bolm et al., 1998) and an implementation of the new proposal on a pilot basis began on July 1998 in three large metropolitan areas in different regions of the country – Hangzhou, Zhengzhou and Jilin.

2.3 Levy Verification and Collection

In the levy system, polluters report their emissions, and the local environmental authorities are responsible for verification. Self-reporting is quite extensive in the Chinese system. All polluters are required to register with local environmental authorities, and to provide information in the following categories: 1). basic economic information (sector, major products and raw materials); 2). production process diagrams; 3). volume of water use and waste water discharge; pollutant concentrations in waste water; 4). waste gas volume, and air pollutant concentrations (before and after treatment); 5). noise pollution by source; 6). discharge of solid wastes; 7). mandated ambient quality level for receiving air or water; and 8). discharge timing.

The local environmental authorities check polluter reports in several ways, including: internal consistency of reported data; consistency with material balance models; historical data from the facility; direct monitoring; and surprise inspections. When the data are cleared by the environmental authorities, they are used for assessments computed from the levy calculation manual. Penalties are imposed for false reporting and/or non-cooperation with government inspections. Polluters have a 20-day grace period to pay the monthly/quarterly levy, after which the required payment increases by 0.1% per day. Intractable disputes are resolved by the local courts or higher-level environmental authorities.

Polluters are required to report increased discharges, and rebates are possible when pollution reductions are verified. The levy can be reduced or even eliminated at the discretion of local regulators after appropriate inspections. The levy may also be postponed if the polluter cannot afford to pay it, although reductions or exemptions are not allowed in such cases. Of course, this degree of latitude introduces considerable variation in regional enforcement practices. These disparities are the object of frequent criticism although, as several recent papers have noted, they seem roughly consistent with the tenets of environmental economics (Wang and Wheeler, 1996; Dasgupta and Wheeler, 1997; Dasgupta, Wang and Wheeler, 1997).

2.4 Provincial Differences in the Effective Levy and Pollution Intensity

Although supervised by the central government, China's pollution levy system is implemented by the provincial and local governments. As Wang and Wheeler (1996) shows, there is significant variation in implementation. Estimates of effective levy rates (or levies actually collected per unit of above-standard wastewater discharge), denominated in 1990 yuan, revealed striking differences, both across provinces and through time. In the space of six years, the effective pollution levy rate more than doubled in some areas and fell significantly in others. In general, real effective provincial levies increased during the sample period. Cross-provincial variation in 1993 yielded ratios as high as 8:1 (Tianjin vs. Qinghai).

Inspection of these provincial differences suggests that variations in the effective levy rate are far from random. Figure 2 displays their geographic distribution. In 1993, many relatively affluent, heavily-industrialized coastal provinces had the highest effective levy rates, while many poorer interior provinces had levy rates at the bottom of the scale. It is also worth noting the experience of Guangdong, the site of China's fast-growing new economic zones. Since 1987, the ratio of rates in Guangdong and its neighboring province, Jiangxi, has jumped from 1:1 to 2.6:1.

The provincial data also reveal great variation in industry's environmental performance (see Wang and Wheeler, 1996). For the period 1987-1993, levels and changes of industrial emissions intensity for COD (organic water pollution) and TSP (total suspended particulates) vary widely across China, but striking evidence of progress in pollution control has also been found. During the six-year period, both air- and water-pollution intensities fell sharply in almost all provinces. Furthermore, the data suggest that they fell most rapidly in the areas where pollution intensity was initially highest.

Previous research has also suggested some important links among provincial pollution intensities, regulation and economic development. Dasgupta and Wheeler (1996) have shown that citizen complaints to the environmental authorities are highly responsive to visible pollution and measures of development such as income per capita and education. In a related exercise, Wang and Wheeler (1996) have shown that province-level water levy rates are also responsive to measures of ambient quality and development, while industrial water pollution intensity (pollution/output) responds significantly to the levy with an elasticity somewhat less than minus one. Because these exercises rely on province-level averages, however, they have not clarified the explicit links which tie provincial development levels to environmental outcomes. In this paper, we test the proposition that an important link passes through the formal regulatory system: More polluted and developed areas generate a higher incidence of citizen complaints, which in turn raise enforcement activity and effective (as opposed to nominal) levy rates.

3. Model, Data and Estimating Equations

In our model, each plant faces an expected marginal pollution penalty which is determined by local conditions and its own characteristics. Following Dasgupta and Wheeler (1996), we include plant size, ownership and sector among the latter, along with a measure of profitability which is intended to proxy the relative efficiency of the enterprise. We index local conditions with measures of the incidence of pollution-related complaints and local ambient quality. The impact of local development is incorporated in the incidence of complaints which, as Dasgupta and Wheeler (1996) have shown, is highly sensitive to income and education.

To summarize, we specify the following pollution charge equation for the ith plant in the jth region:

$$(1)\ P_{ij} = f(A_j, C_j, E_i, O_i, Q_i, S_i)$$

where the arguments of the function are indices of regional ambient quality (A_j), the local incidence of pollution-related complaints (C_j), factory profitability (E_i), ownership (O_i), production scale (Q_i) and sector (S_i).

Faced with a pollution price (P), cost-sensitive managers[4] should reduce emissions until the marginal cost of abatement (MAC) rises to parity with the pollution charge. Recent research in China and other Asian countries has provided good evidence on the determinants of MAC at the plant and firm levels. Scale economies in abatement mean that large plants will have lower MAC than small plants (Dasgupta, Huq, Wheeler and Zhang, 1996; Dasgupta, Wang and Wheeler, 1997); publicly-owned factories have higher MAC than others (Pargal and Wheeler, 1996). Different sectors have very different abatement problems, so we would expect MAC to vary by sector. More economically-efficient plants may have lower MAC, simply because they run all processes (production and abatement) more efficiently. In a similar vein, newer plants may have lower MAC because they generate fewer waste residuals. Prices of other factors such as energy prices may also affect MAC.

To summarize, we specify the following MAC function for the ith plant in the jth industry sector:

$$(2)\, MAC_{ij} = f(N_i, V_i, O_i, Q_i, E_i, S_i, W_i)$$

[4] While firms in China, including those state-owned enterprises, have become sensitive to pollution control costs since the economic reform to market-based economy which has taken place in China since the late 1970s, some state-owned enterprises may face additional constraints, such as in production and prices, in minimizing the total cost.

where the arguments of the function are, respectively, plant-level emissions intensity (N_i), plant vintage (V_i), ownership (O_i), production scale (Q_i), profitability (E_i), sector (S_i) and other prices (W_i).

Cost-minimizing plant managers will reduce emissions until MAC = P. Under this condition, we can substitute P for MAC in equation (2) and solve for the equilibrium emissions intensity (N_i) of the plant:

$$(3)\, N_{ij} = f(P_{ij}, V_i, O_i, Q_i, E_i, S_i, W_i)$$

To study adjustment in plant-level abatement, we further decompose (3) into process and end-of-pipe adjustments:

$$\begin{aligned} &N_{ij} = G_{ij} D_{ij} \\ (4)\ &G_{ij} = f(P_{ij}, V_i, O_i, Q_i, E_i, S_i, W_i) \\ &D_{ij} = f(P_{ij}, V_i, O_i, Q_i, E_i, S_i, W_i) \end{aligned}$$

where N_{ij} = post-abatement pollutant discharge per unit of output

G_{ij} = process (pre-abatement) pollutant generated per unit of output and

D_{ij} = pollutant discharge (post-abatement) per unit of process pollutant

Policy analysts have long been interested in the relative importance of process and end-of-pipe adjustments in industry's response to regulation, but to our knowledge this is the first occasion on which the data have been sufficient for an econometric test.

The data for this study are drawn from two sources. Data on local environmental conditions and pollution complaints have been assembled by the authors in a collaborative project with China's Research Academy for Environmental Sciences (CRAES). Factory-level data have been provided by China's State Environmental Protection Administration (SEPA). They are drawn from a nationwide database of 3,000 plants with serious pollution potential, which are monitored by the national authorities. The emissions data reflect regular sampling and verification activity, as described in Section 2. The SEPA database is extraordinarily detailed by any standard, and is undoubtedly the richest single source of information about industrial pollution in a developing country. The estimates presented in this paper are drawn from a cross-section of factories for 1993.

For this exercise, we estimate equations (1) and (4) in log-log form. Specifications and model variables are as follows:

Pollution Charges

(1a)

$$\log P_{Aij} = \alpha_0 + \alpha_1 \log TSP_j + \alpha_2 \log SO_{2j} + \alpha_3 \log C_j + \alpha_4 \log E_i + \alpha_5 O_i + \alpha_6 L_i + \alpha_7 \log V_i + \sum_1^L \delta_{il} S_{il} + \varepsilon_{ij}$$

(1b)

$$\log P_{Wij} = \beta_0 + \beta_1 \log COD_i + \beta_3 \log C_j + \beta_4 \log E_i + \beta_5 O_i + \beta_6 L_i + \beta_7 \log V_i + \sum_1^L \gamma_{il} S_{il} + \varepsilon_{ij}$$

where P = local pollution charge defined for water pollution as water levy collected divided by waste water discharge which did not meet discharge standards, and for air pollution as total air levy collected divided by total weight of air pollutant emitted; TSP, SO_2 are local measures of ambient concentration for the two pollutants. COD are local average concentration of COD discharge; C = pollution complaints per capita; E = profitability (1 if positive; 0 otherwise); O = state ownership (1 if state; 0 otherwise); L = a dummy variable identifying large plants; V = plant age; and S = a set of sectoral dummy variables.

Pollution Intensity

(4a)

$$\log \eta_{Aij} = \phi_0 + \phi_1 \log P_{Aij} + \phi_2 \log V_i + \phi_3 O_i + \phi_4 \log Q_i + \phi_5 E_i + \phi_6 Coast_i + \sum_1^L \lambda_{il} S_{il} + \varepsilon_{ij}$$

(4b)

$$\log \eta_{Wij} = \theta_0 + \theta_1 \log P_{Wij} + \theta_2 \log V_i + \phi_3 O_i + \phi 4 \log Q_i + \theta_5 E_i + \theta_6 Coast_i + \sum_1^L \mu_{il} S_{il} + \varepsilon_{ij}$$

where (besides the variables defined above) η is air pollution (subscript A) and water pollution (subscript W), Coast is a location dummy (1 if located in coastal provinces; 0 otherwise). Prices of labor and energy are higher in the coastal areas in China. Since we do not have price data, we hope variable Coast can capture some price effects other than pollution levy. However, informal regulation effects may also be stronger in coastal areas. So the sign of variable Coast could be positive or negative.

4. Results

We have estimated all the equations with standard corrections for heteroskedasticity. The results for the pollution charge equations (1a,b) are tabulated in Table 2. For both water and air pollution, they suggest that three factors have explanatory importance: ambient quality, citizen complaints and plant characteristics. For each plant, the local water pollution charge rate is affected by water pollution, as indexed by the overall concentration of COD in the area's industrial effluent. In the case of air pollution, local atmospheric TSP concentration (but not SO2 concentration) has a significant impact on the air pollution levy. The results for citizen complaints are mixed, but in a predictable way. In their study of citizen complaints, Dasgupta and Wheeler (1996) find that complaints are strongly related to air pollution but unrelated to the apparent severity of water pollution. Our results seem to reflect the same phenomenon: Citizen complaints have a positive, significant, and large impact on the air pollution levy -- a 1% increase in the incidence of complaints increases the air levy by about .7% --, but no apparent impact on the water levy.

State-owned plants pay less, but firms which are large, old or with positive profit pay high levy rates. Among industry sectors, building materials and paper have low water levies while petroleum production has disproportionately high water levy. Building materials has higher-than-average air levies, while the power sector's levy is strikingly low. The latter finding is important, because the power sector is one of the largest contributors to industrial air pollution in China. This result, combined with our elasticity estimate for industry responsiveness to the air levy, provides one possible explanation for part of the severity of the power-sector air pollution problem.

Our results for Equations 4(a and b) are tabulated in Tables 3 and 4. The results for air pollution in Table 3 are interesting for two primary reasons. First, they provide the first large-sample micro-evidence on the impact of the air pollution levy on emissions in China. Secondly, they provide the first decomposition of the levy's impact on process adjustment and end-of-pipe abatement. In Table 3, Column (1) reports the estimated impact of the levy on the TSP-intensity of industrial output for a sample of 600 plants. The estimated response elasticity is -.62, and highly significant: TSP discharges decline by .62% for each 1% increase in the air levy. The relative efficiency of plant operations (indexed by profitability) is not significant. As expected, sectoral variations in intensity are pronounced and significant in many cases. Not surprisingly, power and building materials (largely cement) are the greatest positive outliers.

The results in Column (2) provide evidence on process adjustment. Interpretation follows from the identity in Equation (4): N = GD, where N is plant emissions/output, G is process emissions/output and D is plant emissions/process emissions. G measures the pollution intensity of the plant's production process, while D measures the degree of end-of-pipe abatement. In this multiplicative relationship, the overall elasticity of pollution intensity w.r.t. the pollution charge is the sum of pollution charge elasticity for (process emissions/output) and (plant emissions/process emissions). Column (1) presents the results for N. The results in Column (2) provide evidence on G, and they suggest that most of the levy's impact on air emissions comes through process adjustment; the difference between the estimated elasticities for N and G (-.62, -.67) is very small. The end-of-pipe adjustment is not significant.

The results for water pollution in Table 4 are quite different. The result in Column (1) for 1360 plants provides an elasticity of -.2: For every 1% increase in the water levy, COD pollution intensity declines by .2%. But the result in Column (2) suggests that process adaptation has minor effect. Although the process elasticity has the appropriate sign, it is not highly significant. Coast has a negative effect on water intensity which implies that plants located in the coastal areas are cleaner even though they are facing higher energy prices and wages. As in the air pollution case, sectoral differences in water pollution are apparent. Not surprisingly, food, beer and paper are positive outliers (these industries are always heavy organic polluters), and power and building materials compensate somewhat for their higher air pollution intensity with lower water pollution intensity.

5. Summary and Conclusions

In this paper, we have used new Chinese data to investigate relationships linking economic development, environmental quality, regulation and industrial pollution. Across China's urban areas, we have analyzed the relationship between economic development and formal regulation by testing the impact of citizen complaints on pollution charge rates. From previous work (Dasgupta and Wheeler, 1996), we know that the incidence of citizen complaints is strongly affected by local education and income per capita. We find that complaints provide a potent feedback loop for air pollution, but not for water pollution. We also test the impact of local ambient quality on the pollution charge and find important effects. The air and water pollution levies are both higher in areas which are heavily polluted.

In a microeconometric analysis, we test the impact of variations in the pollution levy and other factors on plant-level environmental performance. We find that both the air and water pollution levies have significant impacts, but with differing magnitudes. The elasticity of TSP intensity w.r.t. to the air levy is about -.65, while the elasticity of COD intensity w.r.t to the water charge is about 0.27. Our decomposition of effects suggests that most of the air levy's impact is through process adjustment, while the water levy has most of its impact at the end-of-pipe.

To summarize, our results provide evidence in support of the hypothesis that the actual implementation of regulation in developing countries is strongly related to both economic development and actual environmental quality. Our results on per capita income (through complaints) and ambient quality suggest that pollution pricing is at least somewhat closer to the dictates of environmental economics than China's formal regulatory statutes would suggest. The fact that education has a separate impact on complaints, however, is disquieting. Education-based differences in complaints, pollution pricing and pollution intensity may suggest an important role for public policy in narrowing provincial gaps in environmental quality. Finally, our results suggest that variations in pollution charges do have significant consequences for the pollution intensity of Chinese industry. The estimated response elasticities are significant in magnitude, and suggest that there is considerable scope for using economic instruments to improve China's industrial pollution problem.

References

Bohm, R. A, C. Ge, M. Russell, J. Wang and J. Yang, 1998, "Environmental Taxes: China's Bold Initiative," *Environment*, September.

CRAES (Chinese Research Academy of Environmental Sciences), 1997, "A Report on the Study of Design and Implementation of China's Pollution Levy System," CRAES, October.

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 Department Working Paper**, No. 1630, August.

Dasgupta, S., M. Huq, and D. Wheeler, 1997, "Bending the Rules: Discretionary Pollution Control in China, **World Bank Policy Research Department Working Paper**, No. 1761, February.

Dasgupta, S., H. Wang and D. Wheeler, 1997, "Surviving Success: Policy Reform And The Future of Industrial Pollution In China," **World Bank Development Research Group Working Paper**, November.

Dasgupta, S., and D. Wheeler, 1996, "Citizen Complaints As Environmental Indicators: Evidence From China," **World Bank Development Research Group Working Paper**, November.

Florig, H.K., W.O. Spofford Jr., X. Ma and Z. Ma, 1995, "China Strives to Make the Polluter Pay," **Environmental Science and Technology**, Vol. 29, No 6

Hartman, R., M. Huq and D. Wheeler, 1996, "Why Paper Mills Clean Up: Determinants of Pollution Abatement in Four Asian Countries," **World Bank Policy Research Department Working Paper,** No. 1710.

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** , December.

Pargal, S. and D. Wheeler, 1996, "Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia," **Journal of Political Economy**, December.

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.

Wang, H. and D. Wheeler, 1996, "Pricing Industrial Pollution in China: An Econometric Analysis of the Levy System," **World Bank Policy Research Department Working Paper**, No. 1644, September.

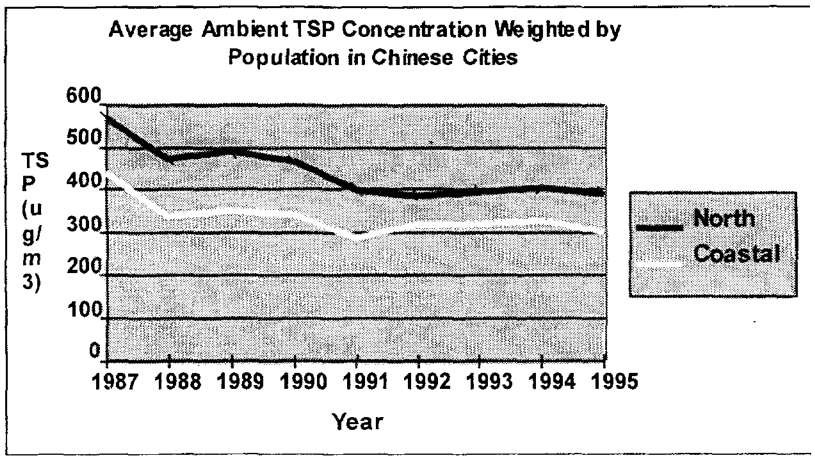

Figure 1

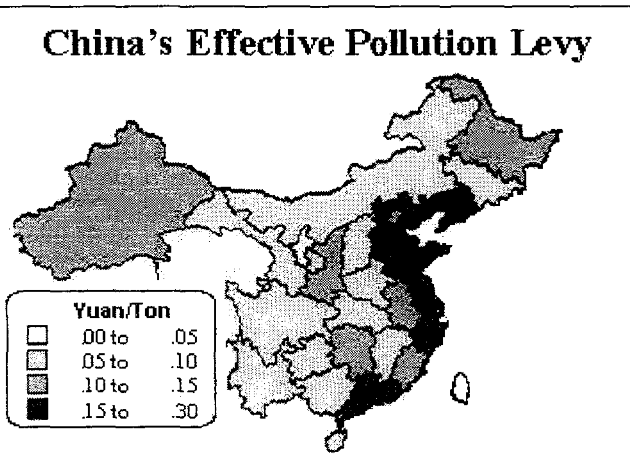

Figure 2

Table 1: Mean Values and Standard Variances of Major Variables

Variable and Definition	Mean Value	Standard Deviation.	Number of plants
Water Polluters:			
Value of Output in 10 thousand yuan	21450	59147	1986
Pollution charge defined as over standard water levy collected divided by wastewater discharge which did not meet discharge standards; unit: yuan/ton	1.83	1.99	1639
Profitability; 1=positive; 0=otherwise	0.55	0.50	2002
Ownership; 1=state owned; 0=otherwise	0.92	0.27	2002
Large plant	0.40	0.49	2002
Coast; 1=located in coastal areas; 0=otherwise	0.49	0.50	2004
Complaints/population; number of complaints received from per 10 thousands of population	3.45	1.44	2002
COD discharge (ton)	1497.57	3965.46	1946
COD generation (ton)	2253.86	9767.32	1855
COD removed (ton)	790.43	8335.71	1900
Air Polluters:			
Value of Output	23,626	61,834	966
Pollution charge defined as air levy collected divided by total weight of air pollutants (10 yuan/kg)	0.01	0.133	934
Profitability	0.70	0.46	966
Ownership (1=state owned)	0.92	0.27	966
Large	0.38	0.49	966
Coast	0.36	0.48	966
Complaints/population	3.30	1.55	966
TSP emission (10 thousand ton)	33.8	700	966
TSP generation (10 thousand ton)	408	2470	840
TSP removed (10 thousand ton)	371	2110	840

Table 2: Estimation Results for Air and Water Pollution Levies

	Log (Water Pollution Charge)	Log (Water Pollution Charge)	Log (Air Pollution Charge)	Log (Air Pollution Charge)
Constant	-5.09*** (-4.58)	-5.219*** (-4.75)	-16.89*** (-3.74)	-15.38*** (-9.45)
Log(Regional COD Discharge Concentration)	0.277 (1.577)	0.299* (1.665)		
Log (Regional TSP Concentration)			0.220 (0.37)	0.634** (1.96)
Log (SO_2 Ambient Concentration)			0.471 (1.38)	
Log (Complaints/ Population)	0.004 (0.031)		0.763** (2.11)	0.671** (2.20)
Profitability	0.549*** (4.12)	0.580*** (4.366)	1.482*** (2.99)	1.672*** (3.43)
State-Owned	-0.406* (-1.72)	-0.422* (-1.75)	0.060 (0.08)	
Large Plant	0.576*** (4.12)	0.604*** (4.267)	0.692 (1.45)	1.101** (2.40)
Log (Age)	0.287** (2.52)	0.271** (2.369)	0.555 (1.06)	
Coal	-0.515 (-1.00)		-3.985 (-1.16)	
Petrol	1.53*** (2.98)	1.535*** (3.433)	0.831 (0.40)	
Ferr_metal	-0.178 (-0.438)		0.844 (0.43)	
Non-Ferr-metal	1.01** (1.995)	1.029** (2.344)	1.519 (0.78)	
Building	-3.059*** (-6.507)	-3.12*** (-7.976)	2.141 (1.18)	2.731*** (4.54)
Food	-0.658* (-1.797)	-0.673*** (-2.702)	2.08 (0.70)	
Beer	0.405 (0.915)		-0.333 (-0.10)	
Textile	-0.212 (-0.496)		2.121 (0.46)	
Paper	-1.073*** (-3.34)	-1.08*** (-6.228)	-1.628 (-0.80)	
Power	0.190 (0.504)		-7.995** (-2.32)	-7.805** (-2.56)
Coke	0.651 (1.17)	0.656 (1.318)	-5.357* (-1.80)	-4.387* (-1.76)
Chemical	-0.013 (-0.042)		-1.608 (-0.92)	
Pharmaceuticals	-0.093 (-0.213)		-3.566* (-1.80)	-2.398** (-2.40)
Agri-chemical	0.108 (-0.181)		1.643 (0.72)	
Rubber/Plastics	-0.745 (-0.697)		-0.124 (-0.05)	
Metals	0.061 (0.052)		-0.866 (-0.25)	
Machinery	0.691 (1.422)	0.690* (1.685)	1.704 (0.86)	
Trans-eq	-0.021 (-0.036)		2.423 (1.15)	3.093** (2.43)
Elect-eq.	0.669 (0.914)		-0.141 (-0.07)	
F-Statistic	8.32	16.77	4.30	8.36
Sample Size	1557	1557	391	411

*** Classical significance at 99% confidence; ** 95%; * 90%

Table 3: Estimation Results for Factory-Level TSP Intensity

	Log (TSP Discharge/ Output)		Log (TSP Generation/ Output)		Log (TSP Discharge/TSP Generation)	
Constant	-4.17*** (-4.41)	-4.09*** (-14.99)	-2.15** (-2.23)	-2.07*** (-6.77)	-1.54** (-2.56)	-1.29*** (-15.31)
Log (Pollution Charge)	-0.538*** (-2.62)	-0.622*** (-3.14)	-0.662*** (-3.13)	-0.669*** (-3.23)	0.052 (0.39)	
Coast	-0.197 (-1.02)		-0.0103 (-0.05)		-0.116 (-0.94)	
Profit	-0.0707 (-0.34)		0.191 (0.88)		-0.169 (-1.25)	
State-Owned	0.294 (0.77)		0.461 (1.21)		-0.0568 (-0.23)	
Large Plant	-0.919*** (-4.44)	-0.959*** (-4.91)	-0.427** (-2.02)	-0.520** (-2.53)	-0.449*** (-3.40)	-0.325*** (-2.90)
Log (Age)	0.0428 (0.21)		-0.227 (-1.11)		0.083 (0.64)	
Coal	2.439** (2.21)	2.738*** (2.80)	1.513 (1.30)		1.226* (1.74)	1.110* (1.82)
Petrol	-1.720** (-2.33)	-1.444*** (-2.77)	-3.187*** (-4.11)	-3.161*** (-5.59)	1.493*** (3.17)	1.148*** (3.63)
Ferr_metal	1.092* (1.85)	1.263*** (3.96)	0.874 (1.41)		0.242 (0.64)	
Non-Ferr-metal	-0.390 (-0.63)		-0.802 (-1.24)		0.525 (1.32)	
Building	3.091*** (5.68)	3.249*** (15.11)	3.053*** (5.33)	2.834*** (10.55)	0.203 (0.58)	
Food	-0.448 (-0.41)		-1.471 (-1.26)		1.381* (1.95)	1.058* (1.73)
Textile	-5.172** (-2.30)	-4.947** (-2.28)	-6.538*** (-2.77)	-6.399*** (-2.78)	1.025 (0.71)	
Paper	-0.177 (-0.27)		-0.799 (-1.15)	-1.112** (-2.33)	0.890** (2.10)	0.613** (2.34)
Power	6.230*** (5.62)	6.431*** (6.56)	5.229*** (4.48)	5.165*** (4.92)	1.211* (1.71)	
Coke	2.148* (1.77)	2.260** (2.07)	0.364 (0.29)		1.622** (2.10)	1.360** (1.99)
Chemical	-0.151 (-0.28)		-0.695 (-1.22)	-0.919*** (-3.50)	0.782** (2.25)	0.523*** (4.34)
Pharmaceuticals			-6.502*** (-3.81)	-6.796*** (-4.18)		
Agri-chemical	-0.453 (-0.41)		-3.835*** (-3.51)	-4.504*** (-4.71)	1.214* (1.70)	
Rubber/Plastics	-5.151*** (-4.26)	-5.205*** (-4.77)	-4.661*** (-4.57)	-4.997*** (-5.63)	-1.262 (-1.64)	-1.656** (-2.43)
Metals	-2.553* (-1.88)	-2.313* (-1.84)	-2.961** (-2.07)	-3.077** (-2.30)	0.261 (0.30)	
Machinery	-1.895*** (-2.79)	-1.681*** (-3.66)	-2.332*** (-3.27)	-2.611*** (-5.23)	0.444 (1.02)	
Trans-eq	-3.188*** (-4.17)	-2.984*** (-5.12)	-3.636*** (-4.52)	-3.818*** (-6.09)	0.510 (1.04)	
Elect-eq.	-2.483*** (-2.79)	-2.305*** (-3.13)	-3.933*** (-4.35)	-4.197*** (-5.58)	1.153** (2.03)	0.816* (1.78)
F Value	26.25	42.93	28.19	43.57	2.66	5.51
N	634	640	659	665	634	645

*** Classical significance at 99% confidence; ** 95%; * 90%

Table 4: Estimation Results for Factory-Level COD Intensity

	Log (COD Discharge/ Output)		Log (COD Generation/ Output)		Log (COD Discharge/ COD Generation)	
	Full	Reduced	Full	Reduced	Full	Reduced
Constant	-3.9*** (-12.04)	-3.7*** (-13.42)	-3.3*** (-9.87)	-3.2*** (-2.63)	-0.342** (-1.98)	-0.432*** (-11.57)
Log (Pollution Charge)	-0.268*** (-2.84)	-0.268*** (-2.89)	-0.156 (-1.60)	-0.158 (-1.55)	-0.12** (-2.40)	-0.11** (-2.40)
Coast	-0.231*** (-2.85)	-0.231*** (-2.89)	-0.161* (-1.91)	-0.159* (-1.93)	-0.066 (-1.55)	
Profitability	0.005 (0.07)		0.031 (0.36)		-0.048 (-1.10)	
State-Owned	0.100 (0.69)		0.0388 (0.26)		-0.063 (-0.81)	
Large Plant	-0.526*** (-6.03)	-0.525*** (-6.05)	-0.466*** (-5.14)	-0.466*** (-5.19)	0.006 (0.13)	
Log (Age)	0.127* (1.79)	0.127* (1.83)	0.104 (1.41)	0.104 (1.45)	-0.013 (-0.36)	
Coal	-0.073 (-0.19)		-0.0734 (-0.18)		-0.015 (-0.07)	
Petrol	-1.760*** (-5.51)	-1.904*** (-6.66)	-1.009*** (-3.00)	-1.102*** (-4.01)	-0.744*** (-4.35)	-0.788*** (-6.05)
Ferr_metal	-0.832*** (-3.02)	-0.975*** (-4.14)	-1.180*** (-4.07)	-1.275*** (-6.12)	0.344** (2.31)	0.284*** (2.87)
Non-Ferr-metal	-2.317*** (-6.71)	-2.459*** (-7.80)	-2.736*** (-7.64)	-2.836*** (-9.58)	0.361** (1.98)	0.320** (2.39)
Building	-1.554*** (-4.60)	-1.718*** (-5.61)	-1.809*** (-5.17)	-1.917*** (-6.71)	-0.044 (-0.25)	
Food	2.486*** (10.21)	2.335*** (11.73)	2.346*** (9.24)	2.244*** (14.28)	0.097 (0.75)	
Beer	1.872*** (6.56)	1.720*** (6.93)	1.799*** (6.08)	1.700*** (7.80)	-0.008 (-0.05)	
Textile	-0.342 (-1.25)	-0.489** (-2.08)	-0.321 (-1.12)	-0.428** (-2.08)	-0.014 (-0.10)	
Paper	3.293*** (14.90)	3.137*** (18.30)	2.966*** (12.88)	2.861*** (25.09)	0.273** (2.31)	0.215*** (3.99)
Power	-0.914*** (-3.53)	-1.058*** (-4.90)	-1.219*** (-4.46)	-1.333*** (-7.22)	0.015 (0.11)	
Coke	0.423 (1.19)		0.155 (0.42)		0.120 (0.64)	
Chemical	0.424* (1.95)	0.275* (1.65)	0.118 (0.52)		0.223* (1.92)	0.171*** (3.38)
Pharmaceuticals	1.306*** (4.66)	1.157*** (4.77)	1.133*** (3.90)	1.034*** (4.90)	0.106 (0.72)	
Agri-chemical	0.617* (1.69)	0.471 (1.40)	0.595 (1.54)	0.499 (1.51)	-0.085 (-0.43)	
Rubber/Plastics	-1.719*** (-2.75)	-1.896*** (-3.12)	-2.015*** (-3.17)	-2.126*** (-3.55)	0.196 (0.61)	
Metals	-1.754* (-1.68)	-1.944* (-1.89)	-2.229** (-2.11)	-2.337** (-2.27)	0.413 (0.77)	
Machinery	-1.543*** (-4.96)	-1.685*** (-6.07)	-1.964*** (-6.14)	-2.064*** (-8.26)	0.369** (2.27)	0.309*** (2.59)
Trans-eq	-2.262*** (-6.30)	-2.414*** (-7.30)	-2.569*** (-6.99)	-2.668*** (-8.67)	0.299 (1.60)	0.233 (1.54)
Elect-eq.	-2.00*** (-4.44)	-2.139*** (-5.01)	-2.277*** (-4.97)	-2.380*** (-5.78)	0.322 (1.38)	0.238 (1.17)
F Value	88.50	105.53	77.81	98.16	3.96	9.91
N	1360	1360	1293	1293	1280	1345

*** Classical significance at 99% confidence; ** 95%; * 90%

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