Policy Research Working Paper #1761

Bending the Rules:
Discretionary Pollution Control in China

by

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February, 1997

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1. Introduction

Industry compliance with pollution regulations is far from universal, even in North America (Magat and Viscusi, 1990; Laplante and Rilstone, 1995; Dion, Lanoie and Laplante, 1996). In developing countries, compliance rates are often quite low (Hettige, Huq, Pargal and Wheeler, 1996). Since budget-constrained regulatory agencies cannot monitor all facilities, some non-compliance is attributable to optimizing behavior: Firms may choose to remain non-compliant if the incremental cost of moving to compliance is greater than the expected loss associated with discovery and payment of penalties. Where inspectors are scarce or the courts lenient, non-compliance may be quite common (Afsah, Laplante and Makarim, 1996). In addition, of course, corruption of inspectors may play a significant role in some countries.

Strictness of enforcement can also vary substantially across plants. In the US, for example, numerous press accounts and case studies have identified political pressure as a source of variation in local enforcement of national regulations (Wheeler, 1991). Environmental regulators have proven quite reluctant to impose stiff penalties on financially-strapped plants which are major employers (Deily and Gray, 1991). In many developing countries, state-owned factories seem to have been treated more leniently than their private-sector counterparts (CETESB, 1994; Pargal and Wheeler, 1996; Huq, Hartman and Wheeler, 1996).

Although anecdotes are plentiful, systematic research on determinants of compliance and enforcement is rare even in industrial societies because the necessary information is seldom provided by regulatory agencies.[1] To our knowledge, no such studies have been done for developing countries. In this paper, we use new plant-level data provided by China's National Environmental Protection Agency (NEPA) and the Tianjin Environmental Protection Bureau (TEPB) for an analysis of variations in both compliance and enforcement. These data provide a unique opportunity for regulatory analysis in a developing country, because NEPA has operated and documented a country-wide emissions charge system for over ten years. We focus on regulation of water pollution because the appropriate data are more plentiful in the factory sample available to us.

The paper is organized as follows. In Section 2 we review China's system for enforcing industrial pollution regulations. Section 3 develops models for the analysis of compliance and enforcement, while Section 4 introduces the data. We discuss the econometric results in Section 5 and provide a summary and conclusions in Section 6.

2. China's Pollution Levy

In China's regulatory system, emissions which exceed official standards are not treated as legal violations. Rather, 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." This compensation fee, or levy, has been implemented nationally since 1982. Almost all of China's counties and cities are now operating the levy system, and approximately 300,000 factories have been charged for their emissions (NEPA, 1994).

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[1] In many countries, such records are protected by law. Even in the U.S., the Environmental Protection Agency has only recently announced plans to publish records of inspections, violations and emissions at the plant level.

The water pollution levy is not a true Pigovian charge; it is assessed on emissions which exceed established discharge standards for pollutant concentration in waste water. Chinese discharge standards vary across pollutants, industrial sectors, and "water environment function areas" which distinguish receiving waters by the quality of intended use. They also vary by age of plant, with more lenient standards for facilities established prior to 1979. With NEPA's permission, local areas can impose stricter standards and higher levy rates if they think it appropriate. Pollutant-specific levies are calculated by multiplying three elements together: a unit fee; the volume of waste water discharged; and the ratio of effluent concentration to the standard concentration.[2] For plants with multiple pollutants, the maximum concentration ratio is used for levy assessment. Unit fees escalate with discharge volume.[3]

3. Model Specification

3.1 The Economics of Compliance

Non-compliant factories simply have to pay the levy, so pollution control is largely an economic issue for Chinese managers. In the case of a single pollutant, the total levy for the jth non-compliant plant is given by the formula:[4]

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[2] The terms 'influent' and 'effluent' refer to the waste stream before and after end-of-pipe abatement.

[3] For more discussion of the levy and its impact on pollution, see Florig and Spofford (1994) and Wang and Wheeler (1996).

[4] Model variable definitions are summarized in Table 1.

$$(3.1)\quad L_j = \rho_j \frac{\mu_j}{\mu_s} W_j$$

where L_j = Expected total levy payment
ρ_j = Levy rate
μ_j = Effluent concentration
μ_s = Concentration standard
W_j = Waste water volume

Recent econometric work on factory-level abatement costs in China (Dasgupta, Huq and Wheeler, 1996) suggests the following model for the case of a single pollutant:

$$(3.2)\quad A_j = \gamma_0 W_j^{\gamma_1} \left\{ \left[\frac{\mu_j}{\mu_{0j}} \right]^{-\gamma_2} - 1 \right\} \prod_{m=1}^{M} Z_{jm}^{\beta_m}$$

where $0<\gamma_1<1$, $\gamma_2 > 0$

and A_j = Total abatement cost
μ_{0j} = Influent concentration
μ_j = Effluent concentration
Z_j = A vector of plant characteristics which affect costs (sector, age, scale, ownership, etc.)

At the plant level, γ_1 is significantly less than unity (i.e., abatement is subject to scale economies). While total abatement cost rises less-than-proportionately with scale of waste water treatment, marginal abatement cost increases with percent reduction in pollutant concentration from influent to effluent. Total pollution-related cost is therefore given by:

$$(3.3)\quad C_j = L_j + A_j = \rho_j \frac{\mu_j}{\mu_s} W_j + \gamma_0 W_j^{\gamma_1} \left\{ \left[\frac{\mu_j}{\mu_{0j}} \right]^{-\gamma_2} - 1 \right\} \prod_{m=1}^{M} Z_{jm}^{\beta_m}$$

Cost minimization implies choosing an effluent concentration μ such that

$$(3.4)\quad \frac{\partial C_j}{\partial \mu_j} = 0$$

Cost-minimizing managers in regulated private firms and township-village enterprises will reduce pollution to the point where the expected levy rate is equal to the marginal cost of abatement. Managers in state-owned enterprises (SOEs) with hard budget constraints should exhibit similar behavior; their response to pollution charges may be less elastic where soft budget constraints persist. For a plant j which adjusts so as to minimize pollution-related costs, optimal effluent concentration is given by the solution to (3.4):

$$(3.5)\quad \mu_j^* = (\gamma_0\gamma_2)^{\frac{1}{\gamma_2+1}} W_j^{\frac{\gamma_1-1}{\gamma_2+1}} \mu_{0j}^{\frac{\gamma_2}{\gamma_2+1}} \mu_{sj}^{\frac{1}{\gamma_2+1}} \rho_j^{-\frac{1}{\gamma_2+1}} \prod_{m=1}^{M} Z_{jm}^{\frac{\beta_m}{\gamma_2+1}}$$

A cost-minimizing plant will be compliant if $\mu_j^* \leq \mu_{sj}$. By conventional reasoning, μ_j^* should never be less than μ_{sj} because the levy is zero for discharges whose effluent concentration is below the standard. However, a number of factors may lead some plants to perform better than the standard requires. These include the market value of environmental reputation (particularly for large enterprises) and pressure from local communities (Pargal and Wheeler, 1996; Afsah, Laplante and Wheeler, 1996; Wheeler and Afsah, 1996).

In equation (3.5), we have the following expectations about the impact of plant-level variables on effluent concentration and compliance:

1. **Discharge Volume (W_j):** Since waste water treatment is subject to very significant scale economies, optimal effluent concentration will fall as discharge volume increases, and the probability of compliance will increase.
2. **Influent Intensity (μ_{j0}):** Optimal effluent concentration increases less-than-proportionately with influent concentration ($0 < \gamma_2/(\gamma_2+1) < 1$); the probability of compliance will decrease as influent concentration rises.

3. **Concentration Standard (μ_{js}):** As the standard is tightened, more abatement will be warranted to avoid higher levies. The impact on optimal effluent concentration is inversely related to the abatement cost elasticity (γ_2), since managers faced with rapidly-escalating abatement costs will be more willing to pay additional fines. By the same reasoning, the probability of compliance will decrease as μ_{js} increases.
4. **Pollution levy rate (ρ_j):** Increases in the levy will reduce optimal effluent concentration and increase the probability of compliance.
5. **Plant Scale:** Abatement, process modification and production are joint activities. In larger plants, the fixed costs associated with engineering skills and other relevant inputs can be distributed across a larger number of activities. This should lower the cost of pollution reduction, through its impact on process modification and end-of-pipe abatement. We therefore expect optimal effluent concentration to fall (and the probability of compliance to rise) with increasing plant scale. We use total employment as our proxy for scale.
6. **Age:** Pollution control has been increasingly embodied in new process technologies. In addition, installation of end-of-pipe abatement equipment during plant construction is cheaper than retrofitting. With a steady increase in regulatory pressure since 1980, we expect newer plants in China to exhibit better environmental performance. Probability of compliance should therefore be negatively affected by age of plant.
7. **Ownership:** Even after age and scale are accounted for, we expect public ownership to increase pollution intensity and reduce the probability of compliance. State-owned enterprises (SOEs) are likely to be less efficient, creating more waste residuals and

pollution than their private counterparts. Soft budget constraints for many SOEs should also reduce their managers' responsiveness to pollution charges.

3.2 The Political Economy of Regulation

Relying on anecdotal evidence, critics of China's pollution control system have asserted that enforcement of the levy system is relatively arbitrary. (Qu, 1991). Personal ties between regulators and plant managers and other forms of favoritism are commonly cited. To our knowledge, however, the sources of variation in regulatory enforcement have not been analyzed systematically. As we noted in the introduction, variation in enforcement may reflect social welfare concerns as well as personal ties.

In practice, regulators have considerable discretion in two dimensions of regulation: The formal identification of factories as non-compliant (and therefore subject to the levy); and the strictness of their enforcement response (measured by the *effective* levy rate which is applied to excess discharges). For analytical purposes, we specify two adjustment equations which relate plant characteristics to officially-recognized effluent concentration and the effective levy rate.

(3.6) $$\hat{\mu}_j = \left[\alpha_0 W_j^{\alpha_w} \prod_{m=1}^{M} Z_{mj}^{\alpha_m}\right]\mu_j$$

(3.7) $$\hat{\rho}_{0j} = \left[\beta_0 W_j^{\beta_w} \prod_{m=1}^{M} Z_{jm}^{\pi_m}\right]\rho_{0j}$$

The variables in these two adjustment equations include:

1. **Discharge Volume (W_j):** Although Chinese regulations focus on concentration standards, actual pollution damage is also a subject of concern. The levy system

recognizes this problem by applying higher rates to large dischargers. It is also likely that Chinese regulators pay closer attention to such plants. We might therefore expect discharge volume to have a positive effect on the regulators' identification of non-compliance, as well as on the levy rate.

2. **Plant Scale:** Given the political importance of employment, Chinese regulators may well be more lenient toward facilities which are large employers.
3. **Age:** Plants constructed prior to 1979 face laxer regulatory standards than newer facilities. Even so, plant managers could be expected to invoke 'grandfathering' arguments when confronted by regulators with evidence of non-compliance. If age has any impact on regulator discretion, we would expect it to be toward lenience in both identification of non-compliance and assessment of the levy.
4. **Ownership:** In mixed economies, it has often proven difficult for government regulators to punish violations by state-owned enterprises. Political and bureaucratic factors seem to prevent effective supervision of one government agency by another. If China's experience is similar, we would expect laxer enforcement for its SOEs. However, they might well be given extra scrutiny for non-compliance even if enforcement is more difficult.

3.3 Compliance Equation Specification

In our treatment of compliance, we distinguish between actual plant-level emissions intensity (μ) and officially-recognized intensity ($\hat{u}$). Our compliance equation incorporates two sets of factors: economic calculations and regulator discretion. Substituting (3.5) into (3.6) we obtain:

$$(3.8)\quad \hat{\mu}_j = \alpha_0(\gamma_0\gamma_2)^{\frac{1}{\gamma_2+1}} W_j^{\left\{\alpha_w+\frac{\gamma_1-1}{\gamma_2+1}\right\}} \mu_{0j}^{\frac{\gamma_2}{\gamma_2+1}} \mu_{sj}^{\frac{1}{\gamma_2+1}} \rho_j^{-\frac{1}{\gamma_2+1}} \prod_{m=1}^{M} Z_{jm}^{\left\{\alpha_m+\frac{\beta_m}{\gamma_2+1}\right\}}$$

Information problems have forced us to simplify (3.8) for econometric estimation. Our data base does not include observations on the local standards (μ_{sj}) faced by individual factories. In addition, we have to exclude the pollution levy rate (ρ_j) because we use a non-zero levy as our indicator of non-compliance.[5] To control for these factors, we introduce sector dummy variables (S_{jn}) in (3.10). They proxy the effects of the following composite term in (3.8):

$$(3.9)\quad \left[\frac{\mu_{sj}}{\rho_j}\right]^{\frac{1}{\gamma_2+1}}$$

Following (3.9), we expect effluent concentration to be higher in sectors with high concentration standards relative to their unit levy rates. The impact of the standard/levy ratio on effluent concentration and compliance will vary inversely with abatement cost elasticity. After substitution of dummy variables, the effluent concentration equation becomes:

$$(3.10)\quad \hat{\mu}_j = \alpha_0(\gamma_0\gamma_2)^{\frac{1}{\gamma_2+1}} W_j^{\left\{\alpha_w+\frac{\gamma_1-1}{\gamma_2+1}\right\}} \mu_{0j}^{\frac{\gamma_2}{\gamma_2+1}} \prod_{m=1}^{M} Z_{jn}^{\left\{\alpha_m+\frac{\beta_m}{\gamma_2+1}\right\}} \prod_{n=1}^{N-1} e^{\theta_n S_{jn}}$$

The associated log-log form is:

$$(3.11)\quad \begin{aligned} \log \hat{\mu}_j = {} & \left\{\log \alpha_0 + \frac{1}{\gamma_2+1}\log(\gamma_0\gamma_2)\right\} + \left\{\alpha_w + \frac{\gamma_1-1}{\gamma_2+1}\right\}\log W_j + \frac{\gamma_2}{\gamma_2+1}\log \mu_{0j} \\ & + \sum_{m=1}^{M}\left\{\alpha_m + \frac{\beta_m}{\gamma_2+1}\right\}\log Z_{mj} + \sum_{n=1}^{N-1}\theta_n S_{jn} \end{aligned}$$

With composite parameters η, this becomes:

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[5] Technical issues of probit estimation are discussed later in this section.

(3.12) $\log \hat{m}_j = h_0 + h_w \log W_j + h_m \log m_{0j} + \sum_{m=1}^{M} h_{zm} \log Z_{mj} + \sum_{n=1}^{N-1} h_{sn} S_{jn}$

Regardless of its true compliance status, a factory is judged compliant if $\hat{u} \leq \mu_s$. Since we have no observations on μ_s, the effluent standard for each plant, we cannot observe officially-recognized compliance directly. However, we know that all levy-paying plants are recognized as non-compliant by NEPA and the TEPB. We therefore use our data set to construct a binary dependent variable C_j , whose value is 1 for factories which pay no levy and 0 otherwise. Assuming that log $\hat{u}_j$ is normally distributed[6], the probability of compliance (log $\hat{u} \leq \log \mu_s$) can be calculated from the cumulative normal probability distribution. The parameters of (3.12) can be estimated by probit, with $C_j = 1$ when the factory is officially compliant and zero otherwise. As we noted previously, our use of the pollution levy for identifying non-compliant factories excludes the use of factory-specific levy rates on the righthand side of the estimating equation.[7]

In (3.12), Z_{mj} includes measures of plant age, scale (employment) and state ownership (a dummy variable whose value is one for SOEs). Our expectations about the signs of estimated parameters in the compliance equation are summarized in Table 2.

3.4 Enforcement Equation

When formula (3.1) is actually applied by Chinese regulators, the effective levy rate is a function of sector, discharge volume, and the adjusted unit levy rate (from (3.7)):

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[6] Since plant-level pollution intensities are highly skewed, the log-log specification of (3.12) has the advantage of imposing quasi-normality in the underlying error distribution.

[7] Given the match between left- and righthand zeros, the probit estimator obtains a spurious ‘perfect fit’ if the levy is included as an explanatory variable.

$$(3.13)\quad \hat{\rho}_j = \hat{\rho}_{0j} \prod_{n=1}^{N-1} e^{\left\{\delta_n S_{jn}\right\}} W_j^{\phi} = \beta_0 \rho_{0j} W_j^{\{\beta_w+\phi\}} \prod_{n=1}^{N-1} e^{\left\{\delta_n S_{jn}\right\}} \prod_{m=1}^{M} Z_{jm}^{\pi_m}$$

The effective levy is given by:

$$(3.14)\quad \hat{L}_j = \hat{\rho}_j \frac{\hat{\mu}_j}{\mu_s} W_j = \beta_0 \rho_{0j} \frac{\hat{\mu}_j}{\mu_s} W_j^{\left\{\beta_w+\phi+1\right\}} \prod_{n=1}^{N-1} e^{\left\{\delta_n S_{jn}\right\}} \prod_{m=1}^{M} Z_{jm}^{\pi_m}$$

For multiple pollutants, the levy is based on the pollutant with the maximum ratio of effluent concentration to the regulatory standard. We specify the associated estimating equation in log-log form:

$$\begin{aligned} (3.15)\quad \log \hat{L}_j &= \log \beta_0 \rho_0 + \theta \log\left\{\max \frac{\hat{\mu}_j}{\mu_s}\right\} + \left\{\beta_w + \phi + 1\right\} \log W_j \\ &\quad + \sum_{n=1}^{N-1} \delta_n S_{jn} + \sum_{m=1}^{M} \pi_m Z_{jm} + \varepsilon_j \end{aligned}$$

With composite parameters ω this becomes:

$$\begin{aligned} (3.16)\quad \log \hat{L}_j &= \omega_0 + \theta \log\left\{\max \frac{\hat{\mu}_j}{\mu_s}\right\} + \omega_w \log W_j + \sum_{n=1}^{N-1} \delta_n S_{jn} \\ &\quad + \sum_{m=1}^{M} \pi_m Z_{jm} + \varepsilon_j \end{aligned}$$

where ε_j is a random error term and Z_j includes measures of age, scale and ownership. Since the maximum concentration/standard ratio is part of the levy formula, its inclusion in (3.16) is particularly important. We use national sectoral standards as our proxies for values of μ_s.

No levy is paid by factories whose officially-recognized effluent concentrations are all equal to or below the relevant standards. Since this is true for some plants in our sample, the dependent variable is left-censored at zero but takes on a broad range of positive values. We therefore estimate the parameters of (3.16) using tobit. Table 3 summarizes our prior predictions on signs.

4. Data

For this analysis, NEPA and the TEPB have provided us with 1993 data for 328 factories scattered across China's urban/industrial areas.[8] The sample has broad sectoral coverage (Table 4). Not surprisingly, it has very heavy public-sector representation: 291 plants are state-owned enterprises (SOEs), 20 are collectives, and 9 are joint ventures or wholly-owned by foreign firms.[9] The sample plants appear to be older and larger than average, but nonetheless exhibit wide variation in age, scale, pollution intensity and abatement cost. Years of operation vary from 3 to 93, with the median at 35. The majority of plants were established prior to 1979, and therefore face lower emissions standards then newer facilities. Employment varies from 139 to 37,000; the median plant has 1781 employees.

Some plants report significant abatement activity and effluent concentrations below the designated emission standards, while others show no sign of abatement effort, despite extremely high levels of influent concentration. Within the sample, influent COD concentrations can be as high as 100,000 mg/l, while effluent concentrations are as high as 22,800 mg/l.[10] Abatement costs also vary substantially: The highest cost incurred by a plant in the sample is RMB 68.75 million, but the median is only RMB 0.3 million. The incidence of levies suggests that the environmental performance of SOEs follows the pattern observed elsewhere in Asia (Pargal and Wheeler, 1996; Hartman, Huq and Wheeler, 1996): 73% of

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[8] We believe this to be an approximately random sample from NEPA's database of 3000 top polluters. Of course, these plants are not a random sample of Chinese industrial facilities. As a group, they are likely to have higher-than average pollution intensity. Although this may affect average compliance status, we have no reason to believe that it will bias our estimates of incremental relationships.

[9] In the sample of 328 plants, 320 are identifiable by ownership class.

[10] These maximum values contrast with official COD concentration standards in the range of 100-200 mg/l.

SOEs pay levies, compared with 52% of non-SOEs. Both the incidence of levy payments and the average levy differ substantially across sectors (Table 4).

5. Econometric Results

5.1 Probit Results: Determinants of Compliance

Table 5 presents the full set of probit results for the compliance equation (based on 3.12); variables are successively deleted from the full specification until significant factors remain. Total sample size is constrained by data availability, particularly for the influent intensities (inclusion of the latter reduces the estimation sample size from 276 to 107). The results confirm our prior expectations in cases where the predicted signs are unambiguous (see Table 2): SOEs are significantly less likely to be compliant than plants in other ownership categories; large plants (measured by employment) are significantly more likely to be in compliance. Where prior expectations were ambiguous, our results are mixed. Older plants are significantly less likely to be in compliance, suggesting that the economic impact of age on abatement cost outweighs the effect of laxer regulations and any inclination toward leniency on the part of regulators. On the other hand, the results for discharge volume suggest that large polluters face compliance-related scrutiny which outweighs the abatement cost advantage of scale. Plants with large waste water discharges are significantly less likely to be judged compliant.

In the initial regression, we incorporate influent intensity measures for all three major pollutants in the data set (total suspended solids (TSS); chemical oxygen demand (COD); biological oxygen demand (BOD)). There are clearly collinearity problems; when only BOD intensity is included, its estimated parameter has the expected sign but a low significance level. The large standard error makes the point estimate [$\gamma_2/(\gamma_2+1) \cong -.25$] consistent with a wide range of abatement cost elasticities (γ_2). Dummy variables are included for sectors which are heavily represented in the regression subsample. Their collective insignificance suggests that sectoral standards and levies vary together [i.e., μ/ρ remains approximately constant in (3.9)].

5.2 Tobit Results: Determinants of Enforcement

Our tobit results for equation (3.16) are reported in Table 6. In this case, heteroskedasticity across observations can be a source of serious estimation error. Maddala and Nelson (1975) have shown that uncorrected estimates are inconsistent. Although our log-log specification is a common expedient for avoiding heteroskedasticity, Fishe, et. al. (1979) have shown that the log transformation does not solve the problem in tobit models. We have therefore estimated the final form of our tobit equation with and without a heteroskedasticity correction. The corrected equation is estimated by maximum likelihood, under the assumption that error variance is a function of output. The results are strongly consistent with the existence of heteroskedasticity [$t(\sigma) = 8.928$] and confirm the significance of output as the control variable ($t(\text{Output}) = 2.269$). However, we find that in this case the parameter estimates in the corrected equation are nearly identical to those in the uncorrected equation.

Deletion of insignificant variables again leads us to drop the sector dummies from the final equation. Our results for the two variables in the levy formula conform to prior expectations: The elasticity for the maximum concentration/standard ratio is positive and not significantly different from one; the waste water discharge elasticity is positive and significantly greater than one. Among the plant characteristics, the effect of facility scale is also as we expected: Large employers are assessed at much lower rates than other plants. However, our results contain two major surprises: Older firms are assessed at significantly higher rates, and SOEs at far higher rates than other facilities. Although these results are contrary to our expectations, they are consistent with the estimates for the same variables in the compliance equation. In China, state-owned enterprises are apparently subject to more rigorous enforcement than collectives and factories with private shareholders.[11] This is an important reversal of previous findings for mixed Asian economies (Pargal and Wheeler, 1996; Huq, Hartman and Wheeler, 1996, Hettige, Huq, Pargal and Wheeler, 1996).

6. Summary and Conclusions

In this paper, we have investigated the determinants of plant-level compliance and enforcement in China's water pollution levy system. Our study incorporates three factors:

1. **The mechanics of official regulation:** A plant is judged non-compliant if its officially-reported waste water discharge contains at least one pollutant whose concentration is above the regulatory standard. For non-compliant plants, the official levy incorporates several factors: A unit levy rate which varies by sector and, in some cases, by locality; a standard (upward) adjustment of the unit rate as discharge volume increases; and multiplication of the adjustment rate by (a) the plant's maximum effluent concentration/standard ratio and (b) the volume of waste water discharge.
2. **The economics of compliance:** Cost-sensitive plants will attempt to adjust emissions to the point where the marginal levy is equal to the marginal cost of abatement.

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[11] Representation of private facilities in the subsample is too sparse for meaningful separation of collective and private-sector effects.

3. **Regulators' discretion:** In practice, local regulators have considerable discretion in judging both compliance and appropriate penalties for non-compliance.

Our results suggest that all three factors play significant roles in compliance and enforcement. The compliance results highlight the significance of economic factors. As expected, compliance probability is negatively related to state ownership and age, positively related to plant scale. However, our results also suggest that regulators' discretion has a strong effect on outcomes. Abatement economics imply higher rates of compliance for large dischargers, because China regulates effluent concentration and marginal costs are lower in large abatement facilities.[12] However, waste stream volume has a large negative impact on reported compliance, suggesting that regulators give little or no slack to large dischargers.

Our enforcement results indicate that assessment of the levy is typically consistent with the *form* dictated by regulatory statutes. The effective levy rate goes up sharply with discharge volume, as mandated, and the levy-elasticity of plant-specific maximum concentration/ standard ratios is not significantly different from one. However, the results also suggest that the *substance* of levy assessment reflects a large measure of regulator discretion: Old factories pay more, state-owned factories pay higher rates, and big employers get a discount.

We conclude that China's regulators play by the rules, but frequently bend them. Compliant factories would be unlikely to accept non-compliant status, so the estimated impact of plant characteristics on reported compliance and enforcement suggests that under-reporting and under-assessment are common in China. In this paper, we have found that variable regulation is systematic, not random, and that it seems to reflect important environmental and social concerns.

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[12] See Dasgupta, Huq and Wheeler (1996) for evidence on abatement costs.

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Table 1: Variable Definitions

r_j = Levy rate
L_j = Expected total levy payment
$\hat{r}_j$ = Effective levy rate
$\hat{L}_j$ = Actual total levy payment
W_j = Waste water volume
A_j = Total abatement cost
C_j = Total pollution-related cost
m_j = Effluent concentration
$\hat{m}_j$ = Officially-recognized effluent concentration
m_s = Concentration standard
m_{0j} = Influent concentration
Z_j = A vector of plant characteristics which affect costs (sector, age, scale, ownership, etc.)

Table 2: Predicted Signs, Compliance Equation

Variable	Predicted Full Sign	Regulators' Discretion	Enterprise Costs
Discharge Volume (W_j)	?	-	+
Influent Concentration (μ_{0j})	-	0	-
Scale (Employment) (Z_1)	+	+	+
Age (Z_2)	?	+	-
SOE (Z_3)	-	- or 0	-
Sectors ($Z_4 \ldots Z_M$)	Variable	Variable	Variable

Table 3: Predicted Signs, Enforcement Equation

Variable	Predicted Full Sign	Partial Effects	Partial Effects
Discharge Volume (W_j)	+ (>1)	$\beta_w>0$	$\varphi>0$
Influent Concentration Ratio (μ_{0j})	+ ($\theta=1$)		
Scale (Employment) (Z_1)	-		
Age (Z_2)	-		
SOE (Z_3)	-		
Sectors ($Z_4 \ldots Z_M$)	Variable		

Table 4: Levy Incidence Across Sample Industry Sectors

Sector	Total Number of Plants	Proportion Paying Levy	Mean * Levy (10,000 RMB yuan)
Food	46	0.80	39.95
Beverages	42	0.69	21.05
Textile	63	0.68	16.94
Leather	25	0.56	10.04
Pulp and Paper	26	0.85	146.36
Power	22	0.73	54.14
Petroleum Refining	9	0.78	119.57
Chemicals	41	0.78	83.25
Pharmaceuticals	11	1.00	28.44
Plastic	3	1.00	60.71
Cement	14	0.36	11.86
Iron and Steel	7	0.71	7.49
Others	19	0.37	21.68

* Calculated on the basis of levy-paying plants only.

Table 5: Probit Estimates (Compliance Equation)

Dependent Variable: Compliance Status (1 if Compliant)

Variable Descriptions:

LDISCHARGE (W): Log (amount of waste water discharged)
LTSSINF (μ_{0T}): Log (TSS concentration in the influent)
LCODINF (μ_{0C}): Log (COD concentration in the influent)
LBODINF (μ_{0B}): Log (BOD concentration in the influent)
LAGE (Z_1): Log (age of the plant)
SOE (Z_2): Dummy variable = 1 if the plant is state owned
= 0 otherwise
LEMP (Z_3): Log (number of employees)

Model 1			**Model 2**		**Model 3**		**Model 4**	
	Coefficient	**Z**	**Coefficient**	**Z**	**Coefficient**	**Z**	**Coefficient**	**Z**
Intercept	2.609	1.206	1.481	0.771	1.524	0.804	-0.598	-0.811
LDISCHARGE	-0.419**	-2.626	-0.427**	-3.009	-0.428**	-3.043	-0.242**	-3.780
LTSSINF	-0.021	-0.387	-0.025	-0.475				
LCODINF	0.011	0.199	0.011	0.196				
LBODINF	-0.258	-1.385	-0.247	-1.462	-0.237	-1.439		
LAGE	-0.597**	-2.427	-0.611**	-2.573	-0.611**	-2.600	-0.196*	-1.660
SOE	-1.948**	-3.340	-1.769**	-3.320	-1.767**	-3.387	-0.548**	-2.184
LEMP	0.296	1.016	0.445*	1.677	0.432*	1.636	0.308**	2.505
Paper	-0.227	-0.294						
Food	0.172	0.255						
Textiles	0.023	0.050						
Petroleum	1.552	1.401						
Cement	0.589	0.455						
No. of obs.	107		107		107		276	
Chi sq	30.82		28.39		28.03		21.88	
Probability	0.002		0.0002		0.00		0.00	

* Significant at 10%
** Significant at 5%

Table 6: Tobit Estimates

Dependent Variable: Log [Effective Levy]

Variable Descriptions:

LCONCSTD (max $\frac{\hat{m}}{m_s}$): Log{max (concentration of pollutant i in the effluent/
concentration standard for i)}
where i= BOD, COD and TSS.

LDISCHARGE (W): Log (amount of waste water discharged)

LTSSINF (μ_{0T}): Log (TSS concentration in the influent)

LCODINF (μ_{0C}): Log (COD concentration in the influent)

LBODINF (μ_{0B}): Log (BOD concentration in the influent)

LAGE (Z_1): Log (age of the plant)

SOE (Z_2): Dummy variable = 1 if the plant is state owned
= 0 otherwise

LEMP (Z_3): Log (number of employees)

σ: Test statistic for heteroskedasticity

Output: Value of output in millions of RMB Yuan

	Model 1		**Model 2**		**Model 3**	
	Coefficient	**t**	**Coefficient**	**t**	**Coefficient**	**z**
Intercept	-2.474	-0.413	1.283	0.235	0.754	0.154
LCONCSTD	0.850*	1.717	0.785*	1.659	0.758	0.879
LDISCHARGE	2.621**	5.792	2.502**	6.212	2.352**	4.567
LAGE	1.565**	2.005	1.500**	1.987	1.289*	1.681
SOE	7.893**	3.825	8.050**	3.917	7.808**	3.859
LEMP	-1.961**	-2.264	-2.375**	-3.012	-2.060**	-2.380
Paper	-1.123	-0.647				
Food	-0.841	-0.447				
Textile	0.762	0.588				
Petrol	-4.740	-1.419				
Cement	-2.110	-0.444				
σ					4.895**	8.928
Output					0.0003**	2.269
No. of obs.	133		133		133	
Chi sq	55.90		52.72			
Probability	0.00		0.00			

* Significant at 10%
** Significant at 5%