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Environmental Pollution and Policies in China's Township and Village Industrial Enterprises

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Abstract

The purpose of this paper is to empirically analyze economic and policy factors affecting pollution by Township and Village Industrial Enterprises (TVIEs) in China and to discuss problems and directions in environmental policies for them. With the rapid growth of TVIEs since the early 1980s, pollution has been spreading into the rural areas. The large number and small size of TVIEs makes it difficult for TVIEs themselves and the government to implement environmental measures. The econometric analyses with the provincial data of National Survey of Pollution by TVIEs (NSPT) show that COD (Chemical Oxygen Demand) intensity is decreased by investment in wastewater treatment facilities and by more efficient technologies, indicated by higher labor productivity and the fact that investment in wastewater treatment facilities has a significant correlation with the effective rate of water pollution levy. On the other hand, the result of the factory survey clarifies that many TVIEs suffer from a lack of external financial resources to invest in pollution abatement facilities. Local governments should strictly enforce the pollution levy system and other regulations for TVIEs, and at the same time they should make public loans for environmental measures easily accessible to TVIEs and provide environmental education and training for managers and workers at TVIEs.

Kurzfassung

Die vorliegende Arbeit untersucht die ökonomischen und politischen Faktoren, die die Umweltverschmutzung durch sogenannte Township and Village Industrial Enterprises (TVIEs), d. h. Industrieunternehmen auf Dorf- und Bezirksebene, in China beeinflussen. Darüber hinaus werden Probleme der Unternehmen und Trends von Umweltpolitiken diskutiert. Mit dem rapiden Anstieg der Anzahl an TVIEs seit den frühen 80er Jahren ist auch die Umweltverschmutzung im ländlichen Raum gestiegen. Die große Anzahl kleiner TVIEs macht es für die Unternehmen selbst und die Regierung schwierig, Umweltschutzmaßnahmen durchzuführen. Die ökonometrische Analyse der nationalen Provinzdaten zeigt, dass die CSB-(Chemischer Sauerstoffbedarf) Intensität durch Investitionen in Kläranlagen und effizientere Technologien gemindert wird. Dies zeigt sich in höherer Arbeitsproduktivität und der Tatsache, dass die Investitionen in Kläranlagen signifikant korreliert sind mit der effektiven Rate für Wasserverschmutzung. Andererseits zeigt das Resultat der Befragung auf Betriebsebene, dass viele TVIEs durch fehlende finanziellen Ressourcen Probleme haben, wirksame Investitionen in Umweltschutzmaßnahmen vorzunehmen. Örtlichen Kommunen sollten das Umweltabgabesystem und andere Auflagen für die TVIEs mit Nachdruck durchsetzen. Gleichzeitig sollten sie den TVIEs den Zugang zu öffentlichen Krediten für Umweltschutzmaßnahmen erleichtern und Fortbildungslehrgänge zum Umweltschutz anbieten, in denen Manager und Arbeiter der TVIEs entsprechend geschult werden.

Introduction

Township and Village Enterprises (TVEs) have been a strong driving force in the rapid economic growth in China since the early 1980s, when the reform and opening policy was set for the Chinese economy. Township and Village Industrial Enterprises (TVIEs) in particular produce 70% of the total value added of TVEs and have played an important role in the development of the rural areas in China. The total gross output value of TVIEs as of 1995 is 5.126 trillion yuan[1] and makes up 56% of the total gross industrial output value in the country.[2] This share was 19% in 1985.

With the rapid growth of TVIEs, environmental pollution by TVIEs has brought various problems to the rural areas. Also, their increasing share in total industrial pollution has become a serious problem at the national level. It is predicted that major pollutants discharged by TVIEs will reach 50% of the national total in 2000.[3]

The size of TVIEs is generally small. Both the financial and technological capabilities of most of TVIEs are far behind those of State Owned Industrial Enterprises (SOIEs). This fact means that most of TVIEs cannot afford to implement adequate environmental measures. Recently, the Chinese government has taken this problem seriously and enforced some policies for pollution-generating TVIEs, as described later in this paper. However, the policy enforcement and supervision by the national and local governments do not reach a satisfactory level, as an enormous number of TVIEs are scattered in the huge scale of rural areas. Environmental problems will continue to be spread by TVIEs all over the rural areas as long as the current situation continues.

Some researchers - as well as our research group - have recently pointed out the seriousness of the environmental problems caused by TVIEs. Vermeer (1998) discusses pollution by TVIEs as one of the major environmental concerns in China. He mentions the difficulties in controlling and monitoring TVIEs by the State Environmental Protection Administration (SEPA) because of the limited direct involvement of central government in the local economies. Ma and Ortolano (2000) examine whether the form of ownership (state-owned or not) affects the degree of compliance with environmental rules, based on their survey data. However, their survey is regionally limited and the sample size is rather small.

Little comprehensive and empirical research exists to date regarding TVIE environmental issues, mainly due to the lack of data. The environmental data reported in the China

1 1 yuan 0.12 USD 0.27 DEM as of December, 2000.
2 China Statistical Yearbook 1996.
3 China Environment Yearbook 1996.

Environment Yearbook does not include the data of most TVIEs. The only data on pollution by TVIEs that the government collects is that of the National Survey of Pollution by TVIEs (NSPT), implemented in 1989 and 1995, of which some aggregated results are open to the public.

The aims of this paper are to empirically analyze economic and policy factors affecting pollution by TVIEs in China and to discuss problems and directions in environmental policies for them. The economic and policy factors econometrically estimated from the provincial data of NSPT in this paper are investment in pollution abatement facilities, rate of pollution levy, efficiency of production, and so on. However, the magnitude of their effects on pollution can be changed by institutional reform in financing TVIEs, development of environmental technologies, education and training of workers, which will reduce TVIEs' difficulties in implementing environmental measures. Therefore, this paper also investigates what kind of problems TVIEs have with environmental measures and policies, using our factory survey in order to discuss policy directions.

The next section contains an overview of the characteristics of growing TVIEs, pollution by TVIEs, and environmental policies for TVIEs. In Section 3, some econometric analyses are implemented with the provincial data of the National Survey of Pollution by TVIEs in 1995. The relationships between pollution intensity and some economic variables, such as labor productivity and investment in facilities of wastewater treatment, are examined there. Section 4 introduces some results of the factory survey for TVIEs, which was performed in several regions by our research group, and the problems that face TVIEs are discussed. Section 5 provides summaries and concluding discussions.

2 Pollution by TVIEs and Environmental Policies

2.1 Characteristics of Growing TVIEs

Township and Village Enterprises (TVEs) in China can be defined in simple terms as the enterprises established by the people living in the rural areas. Some TVEs are collectively owned and managed, while a greater number of TVEs are nowadays privately owned and managed. Although most TVEs are located in their towns or villages, some TVEs invest in other areas, or even in foreign countries. After the economic reform in the late 1970s, it became possible for the governments and residents of towns and villages to earn their income by their own means. For this purpose, the relative surplus in the agricultural labor force was reallocated to the industrial and service sectors. The gross output value of the rural industrial sector was 19.5% of the total gross output value in the rural areas in 1980, which increased to 58.2% in 1995.[4] As a result of the development of rural non-agricultural sectors, the real income per capita in the rural areas has increased to nearly four times as high in the same period.

Focusing on Township and Village Industrial Enterprises (TVIEs), which occupy the major portion of TVEs, the share of value added is 70% of the total value added of TVEs, and the number of employees in TVIEs is 59% of the total in TVEs as of 1998.[5] The number of TVIEs increased from 4,930,000 in 1985 to 6,620,000 in 1998. The number of employees of TVIEs was 73,340,000 in 1998; this figure was 41,370,000 in 1985. The share of value added of TVIEs reached 46% of the total industrial value added in 1998. The gross output value of TVIEs is more than 50% of the total gross industrial output value.

The important characteristics of TVIEs are their large number and small size. As shown in Table 1, the number of State Owned Industrial Enterprises (SOIEs) was about 65,000 as of 1998, while the number of TVIEs was 6,620,000. The average number of employees in a TVIE is 11, while this number is 421 for a SOIE. The average value added of an enterprise is 17,120,000 yuan for a SOIE and 230,000 yuan for a TVIE. The small size of TVIEs corresponds to low capital intensity. Also, the level of technology and the education level of workers and managers are usually low in TVIEs. The shortage of both physical and human capital leads to the low productivity. The value added productivity of labor in TVIEs is 20,900 yuan, which is about a half of that in SOIEs.

[4] Annual Report of China's Rural Economic Development 1995 and Analysis of Development Prospect 1996, p.13.

[5] China Statistical Yearbook 1999.

2.2 Pollution by TVIEs

Pollutants discharged by TVIEs have been increasing at a remarkable rate for more than ten years. For example, it is estimated that the wastewater increased by a factor of 1.6 and solid wastes increased by a factor of 2.7 from 1985 to 1994. China's Official Report on the Environmental Situation in 1996[6] estimated that SO_2 (sulfur dioxide) discharged by TVIEs accounts for 28.2% of the total amount discharged by industry in China in 1995. It is estimated at 68.3% for industrial dust, 46.5% for COD (chemical oxygen demand) and 38.6% for solid and harmful wastes. One reason for the high share of industrial dust is that the coal and brick industries are proportionally well represented in the total number of TVIEs. Another reason is that the coal utilization rate is higher in TVIEs, and in most cases they do not have adequate treatment facilities.

Most seriously polluting TVIEs belong to the following 18 industries: paper manufacturing, dyeing, plating, chemicals, tanning, starch, brewing, sugar manufacturing, coke, sulfur, metal refining, mercury, gold, coal washing, coal concentrating, cement, brick, and ceramics.[7] These industries are common as TVIEs all over the country. The raw materials for these industries are supplied in the rural areas, and the processing degree is not high.

In particular, the paper manufacturing industry exists in many rural areas, since straw is used as a raw material. The wastewater from the paper manufacturing industry pollutes rivers, lakes and wetlands, and causes serious problems in many regions. According to the National Survey of Pollution by TVIEs in 1995, TVIEs in the paper manufacturing industry discharge 45% of all the wastewater from all of the surveyed TVIEs, and the discharged COD[8] accounts for 67% of the total COD from the surveyed TVIEs. The brick manufacturing industry is also distributed in many villages. The SO_2 emissions from the brick manufacturing industry are estimated to reach more than one third of the total SO_2 emissions from all of the surveyed TVIEs.[9] The brick manufacturing industry is a major source of air pollution among the TVIEs.

In those industries that are major sources of pollution by TVIEs, a large number of small factories are located all over the rural areas, as the raw materials can be supplied in almost any village. This fact means that the pollution spreads easily all over the rural areas. This is another serious characteristic of the environmental problems caused by TVIEs.

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6 This is reported in the China Environmental Yearbook 1996.
7 China Environment Yearbook 1995.
8 In fact, COD itself is not a pollutant but an indicator of pollutants discharged in effluent as a total. The usage of "discharged COD" is for the sake of simplicity of expression and follows other literature.
9 China Environment Yearbook 1996.

2.3 Environmental Policies for TVIEs

The "pollution levy system" and the system of "*three synchronizations*" are characterized as two major environmental policies in China. These policies are also applied to TVIEs. A great deal of literature has introduced and discussed the details of these systems (e.g., Imura and Katsuhara, 1995; Arayama et. al., 1997; Wang and Liu, 1998; Ma and Ortolano, 2000; Wang and Wheeler, 2000). Other than these policies, a closedown policy has been enforced for TVIEs. The following sub-sections provide a brief introduction to these policies.

2.3.1 Pollution Levy System

China's pollution levy system has had a long history since it was first included in the 1979 *People's Republic of China (PRC) Environmental Protection Law*. The system requires the enterprises that violate standards on emissions and effluent to pay fees. The fees are charged for gas emissions, wastewater, hazardous solid wastes, noise, and radioactive wastes. In the case of wastewater, the levy is basically calculated as follows (Yang et al., 1998; Wang and Wheeler, 2000):

$$P_{ij} = W_i \frac{C_{ij} - C_{sj}}{C_{ij}}$$

$$L_{ij} = L_{0j} + R_{1j} P_{ij} \quad (P_{ij} < T_j)$$

$$L_{ij} = R_{2j} P_{ij} \qquad (P_{ij} > T_j).$$

C_{ij} is the pollutant concentration of pollutant j of i-th facility, C_{sj} is the concentration standard of pollutant j, and W_i is the total wastewater discharged by i-th facility. If the discharge factor P_{ij} is less than the critical factor T_j, the B-class unit fee R_{1j} ($< R_{2j}$) is applied and the fixed payment L_{0j} is added. If P_{ij} exceeds T_j, the A-class unit fee R_{2j} is adopted without the fixed payment factor. Although the levy L_{ij} is calculated for each listed pollutant, the actual payment is the greatest amount of all the calculated levies.

In addition to the over-standard levy, which is explained above, the pollution levy system includes the standard unit fee, which is collected in proportion to the amount of discharged wastewater,[10] and four kinds of penalty charges ("*four small pieces*"). Also importantly, up to 80% of the over-standard levies collected by a local environmental protection bureau (EPB) is to be placed in a local *pollution levy fund*. The fund is available as grants and low-interest loans to subsidize enterprises to invest in new environmental management projects. The enterprises that have paid an over-standard levy can borrow or be granted up to 80% of the fees they paid. The rest of the pollution levy fund is used by the EPB for its own environmental protection projects.

[10] The standard unit fee is also levied for SO_2 in some areas.

Although TVIEs are included in this pollution levy system, the amount of levies collected from TVIEs is not large, compared with the magnitude of their discharge of pollutants. For example, according to a case study on Chonqing City in Sichuan Province, which is one of the most seriously air-polluted places in China, less than 2% of TVIEs paid levies in 1992, while 89% of the state or city owned enterprises paid them (Panayotou, 1998). TVIEs paid only 8% of the total levies collected in the city, although they make up 22% of the total industrial output. The major reason for such inadequate enforcement of the pollution levy system for TVIEs, a situation is not exclusive to Chonqing City, is the difficulty of monitoring and investigating the large number of TVIEs. EPBs do not have an adequate number of staffs and sufficient budget to supervise widely scattered TVIEs.

2.3.2 Three Synchronizations

"*Three Synchronizations*" mean that the design, construction, and operation of a new industrial enterprise or an existing factory that is expanding or changing its production process must be synchronized with the design, construction, and operation of appropriate pollution abatement facilities. Before construction of a new factory begins, the local EPB must review an environmental impact statement (EIS), which is the result of an environmental impact assessment for the new project. Without the approval of the EPB, the enterprise can receive neither loans nor material supplies. EPBs are also responsible for supervising actual implementation of the *three synchronizations* after their approval of EISs.

The policy of *three synchronizations* is defined in the 1989 *PRC Environmental Protection Law*. This policy has had a substantial effect on pollution abatement (e.g., Taketoshi and Arayama, 1998). In particular, it has stimulated investment in wastewater treatment facilities at new factories (Ma and Ortolano, 2000). However, many small TVIEs seem to escape from this policy. The lack of staff and budgets at EPBs makes the strict supervision of TVIEs difficult. Although the China Environment Yearbook 1999 reports the rate of enforcement of the *three synchronizations* as 95%, and the approval rate as 89.9%, these figures do not include the majority of TVIEs. The actual rate of enforcement for TVIEs is not clear.

2.3.3 Closedown Policy

A severe environmental policy for TVIEs in recent years has been to close down small factories. Small factories of TVIEs generally do not take any measures to prevent pollution, and they do not have the funds to invest in such measures. The closedown policy forces them to stop discharging pollutants by stopping production. In 1995, about 1,200 small rural factories in the Huai River basin, most of which were paper manufacturing factories, were closed down because of their discharge of heavily polluted wastewater.[11]

[11] Proceedings of the 4th National Conference for Environmental Protection, p.33.

The *State Council Decisions Concerning Certain Environmental Protection Issues*, which was released in 1996, establishes that fifteen categories of small TVIEs must be closed and never reopened. Those fifteen categories ("*fifteen smalls*") include: paper manufacturing factories with annual production capacities of less than 5,000 tons, tanneries with annual production of less than 30,000 equivalent cow hides, dye factories with annual production of less than 500 tons, and so on. As a result of this policy, more than 60,000 *fifteen smalls* had been closed down as of January 1997.[12]

It is important to note that local governments (at the prefecture level) have been responsible for enforcing the closedown. The same local governments had only loosely supervised TVIEs in most areas, bearing the economic benefits of their continuation in mind. Also, SEPA and the Office of Prosecution jointly investigate the enforcement by local government. This closedown policy has been rather strictly implemented, compared with other policies. The small cost of executing the policy is a major reason for this effect.

In addition to the closedown policy, some other policies for TVIEs have been implemented since 1996.[13] The Chinese Agricultural Bank has stopped loans to TVIEs that belong to the *fifteen smalls*, and it is promoting loans for adoption of new environmental technologies, efficient utilization of wastes, and preservation and recovery of the ecological environment in rural areas. The *Law of Township and Village Enterprises*, which came into effect in 1997, prescribes the rational utilization of natural resources and environmental protection by TVEs. These policies, including the closedown policy, reflect the growing concerns of the national government about the serious pollution by TVIEs.

[12] China Environment Yearbook 1997.
[13] See the China Environment Yearbook 1997 for these policies mentioned below.

3 Economic and Policy Factors Affecting Pollution by TVIEs

3.1 Results of the National Survey of Pollution by TVIEs in 1995

The Chinese government implemented nationwide surveys of TVIEs to obtain data on their pollution in 1989 and 1995. In the 1995 survey,[14] about 1,216,000 TVIEs in all the provinces, autonomous districts, and national municipalities were investigated with regard to their products, discharged pollutants, environmental measures, pollution levy payments, and so on. The National Survey of Pollution by TVIEs (NSPT) can provide more comprehensive information than the China Environment Yearbook (CEY), which reports the statistics of only 25,000 TVIEs. However, the micro-level data of enterprises has not yet been released. The aggregated data at the provincial level is open to the public, while the available surveyed items are limited.

Table 2 summarizes major totals in NSPT 1995, which are compared with the corresponding values in CEY 1999. Although more than one million TVIEs are surveyed, they make up only 16.9% of all the TVIEs in the country. The total of gross output value of the surveyed TVIEs is 1,926,000 million yuan. Its share is 37.6% of the total gross output value of all TVIEs. The average number of employees per surveyed TVIE is 23. This is greater than the value of 11 that was mentioned as the average number of employees per TVIE in Section 2.1. These figures indicate that the average size of the surveyed TVIEs is larger than the average of all TVIEs. It is likely that there was a bias that heavily polluting TVIEs were selected for the investigation.

Comparing the reported pollution between NSPT and CEY in Table 2, discharged COD in wastewater in NSPT 1995 is about three quarters of that in CEY 1999. On the other hand, the total gross output value of the surveyed TVIEs is less than half of the total reported in CEY 1999. Discharged COD per gross output value (e/c in the table), which is defined as COD intensity, is larger in NSPT than CEY. More precisely, discharged COD per unit of wastewater (e/d in the table) is much greater in NSPT, while discharged wastewater per unit of gross output value (d/c in the table) is less in NSPT. The fact that TVIEs tend to discharge more polluted wastewater would be a result of the low rate of wastewater treatment, which is also indicated in Table 2.

[14] NSPT 1995 was implemented in 1996 based on the data as of 1995.

The published report of NSPT 1995 includes some comparisons of pollution among industries and regions. Important results are the following: (1) 45% of the total wastewater is discharged by the paper manufacturing industry, (2) 50% of the total SO_2 is discharged by the non-metal-minerals producing industry, and (3) more than half of total wastewater and SO_2 are discharged in the eastern provinces.[15] These facts are basically true except for the precise figures. Since the surveyed TVIEs are not randomly sampled, we should be careful with these figures. Due to a sample selection bias, those percentages do not reflect the true values calculated from all the TVIEs in the country.

3.2 Economic Factors of COD Intensity

Using the data of NSPT 1995, economic factors affecting pollution by TVIEs are estimated in this section. Since it is the most serious form of pollution by TVIEs and many of them take measures to abate it to a greater or lesser extent, my study focuses only on the wastewater pollution, and COD intensity (= discharged COD / industrial output) is adopted as its indicator. In this section, economic factors affecting COD intensity, such as investment in wastewater treatment facilities and labor productivity, are estimated. In the following sections, relationships between those economic factors and environmental policies, such as the pollution levy and the closedown policy, are investigated.

3.2.1 Theoretical Model

Wang and Wheeler (1996) analyze economic factors of COD intensity with the pooled provincial data of CEY. They consider the effective rate of pollution levy, the output shares of SOIEs and large plants, etc., as the explanatory variables. Their result indicates that the effective rate of pollution levy and the output share of large plants affect the COD intensity at the provincial level.

Wang and Wheeler (2000) also estimate the effects of economic factors on COD and TSP (total suspended particulates) intensities with the factory-level data, most of which is on SOIEs. They show that the pollution levy, size of enterprise, dummies for coastal region, etc. are significant factors for COD intensity.

In their models, the marginal abatement cost is equated to a unit of pollution levy. In this approach, however, the relationships between production technologies, abatement activities, and discharged pollutants are not clarified. For example, it is not clear how investment in wastewater treatment facilities is effective in reducing pollution, and how the pollution levy is effective in promoting such investment. Since the investment in pollution abatement facilities can be promoted also by policies other than the pollution levy system, such as *three synchronizations*, these relationships are important when considering the policies for TVIEs in total.

[15] Xue (1999) describes more details of these results.

For this reason, I adopt a "pollution production function" approach rather than the "marginal abatement cost function" approach taken by Wang and Wheeler, in order to investigate the economic factors affecting COD intensity. In my approach, discharged COD is a function of output and effort of wastewater treatment under some technological parameters. It can be written as follows:

(1) $COD = f(Y, W; \mathbf{Z})$,

where Y is an amount of output, W expresses a degree of effort with regard to wastewater treatment, and **Z** indicates a vector of parameters of adopted technologies, which also includes industrial and regional variables.

Assuming that discharged COD is proportional to the amount of output, equation (1) can be rewritten as

(2) $COD = f(W, \mathbf{Z})Y$,

and then

(3) $\frac{COD}{Y} = f(W, \mathbf{Z})$.

Thus, COD intensity can be expressed as a function of effort with regard to wastewater treatment and technological parameters.

3.2.2 Empirical Model

Following the theoretical model indicated as equation (3), some economic factors of COD intensity at TVIEs are investigated by estimating the following regression model. The explanation of the variables is as below.

(4) $\log CODI = b_{10} + b_{11} \log INV + b_{12} \log LPRD + b_{13} \log PAPER + e_1$

$$CODI = \frac{\text{discharged COD}}{\text{gross output value}}$$

Log of COD intensity is adopted as the dependent variable.

$$INV = \frac{\text{investment in wastewater treatment facilities}}{\text{volume of discharged wastewater}}$$

The amount of investment in wastewater facilities per unit of discharged wastewater is used as an indicator of effort with regard to wastewater treatment. The negative sign of b_{11} is expected.

$$LPRD = \frac{\text{gross output value}}{\text{number of employees in TVIEs}}$$

The labor productivity is a measure of production technologies. Higher labor productivity implies that more efficient technologies are adopted and supposed to be polluting less. Therefore, the expected sign of b_{12} is also negative.

$$PAPER = \frac{\left(\frac{\text{paper production in i - province}}{\text{total paper production in all provinces}}\right)}{\left(\frac{\text{gross output value in i - province}}{\text{total gross output value in all provinces}}\right)}$$

As discussed before, paper manufacturing TVIEs tend to discharge more polluted wastewater. Since the data used here is aggregated at the provincial level, a share of the paper manufacturing industry should be used instead of a dummy variable in the factory-level data. However, NSPT does not investigate the value of paper production, only the amount of paper production. Hence, a relative share is calculated with the share of gross output value.

e_1 = independently and identically distributed error term

It is assumed that neither å1 nor any of the other error terms in the equations estimated in this section are correlated to each other.

The regression equation (4) is estimated by OLS with the provincial data of NSPT 1995. The number of observations is 30, excluding the Tibet autonomous district.[16] Means and standard deviations of the variables are shown in Table 3.

3.2.3 Estimation Result

The estimated coefficients are presented in equation (5) below.[17]

[16] The number of surveyed TVIEs in Tibet is only five.

[17] t-values are in parentheses. ** and * denote the significance of coefficients at 5% and 10% level respectively. These notes also apply to the expression of other estimated equations in this paper.

$$\log CODI = -11.71 - 0.262^{*} \log INV - 0.545^{**} \log LPRD \quad (5)$$
$$(-27.9)\ (-1.90) \qquad (-2.32)$$
$$+ 0.289^{**} \log PAPER + e_1$$
$$(3.21) \qquad \bar{R}^2 = 0.625$$

We can see that the coefficients of investment in wastewater facilities (relative to discharged wastewater) and labor productivity are negative and significant. The result confirms that investment in wastewater treatment facilities reduces COD intensity and that TVIEs with more advanced production technologies discharge less polluted effluent. Since the model takes log-log form, the estimated coefficients can be interpreted as elasticities. That is, a 1% increase in the relative investment in wastewater treatment facilities decreases COD intensity by 0.262%, and a 1% increase in labor productivity decreases COD intensity by 0.545% at the provincial level.

The estimated coefficient of the relative share of the paper manufacturing industry is positive and highly significant. It means that COD intensity in discharged wastewater is at a high level in the provinces where the relative share of paper production by TVIEs is large. Clearly, paper manufacturing TVIEs are a significant source of water pollution.

3.3 Effect of Pollution Levy on Investment in Water Pollution Abatement

3.3.1 Model

In the previous section, it was confirmed that investment in wastewater treatment facilities reduces COD intensity. The next question raised here is whether the pollution levy system promotes the investment in water pollution abatement. Since an amount of pollution levy payment is simply expressed as a product of a unit rate of levy (ô) and a discharged volume of over-standard wastewater (S), which is a function of investment in water pollution abatement (INV), investment in water pollution abatement is determined so as to minimize the summation of pollution levy payment and investment in water pollution abatement,

$$\sum_{i=0}^{n} q^{i} t\, S(INV; \mathbf{ù}) + INV, \quad \partial S/\partial INV < 0, \quad \partial^2 S/\partial INV^2 > 0, \quad (6)$$

where **ù** is a vector of other variables affecting the volume of over-standard wastewater, which include amount of production, technological parameters, and total volume of wastewater, and è^{i} is the discount factor of the value in i-th year after the investment is made. From the first order condition to minimize equation (6), we can get an optimum investment as a function of ô, **ù** and è, under the assumption of the positive second derivative of S with respect to INV,

(7) $INV = g(t, \mathbf{ù}, q)$.

It is a rule of the pollution levy system that the unit rate of pollution levy (ô) must be the same for all enterprises and provinces.[18] If this is actually true, we cannot observe the effect of ô on INV. However, an actual rate of pollution levy that is calculated as a paid amount of levy divided by a discharged volume of over-standard wastewater varies among provinces and even factories (Wang and Wheeler, 1996, 2000). This fact implies that the effect of an actual rate of pollution levy (t) on the investment in wastewater treatment facilities (INV) can be estimated by using t instead of ô in equation (7).

Thus, an empirical model of equation (7) is specified as equation (8):

(8) $\log INV = b_{20} + b_{21} \log ERPL + b_{22} \log PDW + e_2$.

$$ERPL = \frac{\text{payment of pollution levy} \times \dfrac{\left(\begin{array}{l}\text{over - standard wastewater levy}\\ \text{collected in the province}\end{array}\right)}{\left(\begin{array}{l}\text{total amount of pollution levy}\\ \text{collected in the province}\end{array}\right)}}{\text{discharged wastewater} - \text{treated wastewater}}$$

Wang and Wheeler (1996) define an effective rate of pollution levy as a payment of levy per unit of over-standard effluent. However, since NSPT does not report the volume of over-standard effluent, "treated wastewater" is used here instead of the discharged wastewater that meets the standard. Also, the amount of levy reported in NSPT includes the levies for air pollution and others. Therefore, the share of the total over-standard wastewater levy in the total levy in each province is applied to calculate the amount of over-standard wastewater levy paid by the surveyed TVIEs in the province. ERPL defined by the above formula is used as the effective rate of pollution levy in this study, whereby it contains some errors due to those approximations.

$$PDW = \frac{\text{total output value of surveyed TVIEs}}{\text{volume of discharged wastewater}}$$

As explained above, the amount of production and the total volume of wastewater would be associated with the volume of over-standard wastewater. Therefore, these variables might affect the investment in wastewater treatment facilities. Since the investment is adjusted by the volume of discharged wastewater in this model, the total output value of surveyed TVIEs, which is a proxy of amount of production, is also adjusted by the same variable and included in the regression equation as the output value per discharged wastewater.

[18] Local standards in pollutants and the unit rate of pollution levy are adopted in only a few regions such as Shanghai and Beijing (Yang et al., 1998).

Means and standard deviations of the variables in equation (8) are also shown in Table 3.

3.3.2 Estimation Result

The estimated equation is:

$$\log INV = \underset{(0.80)}{0.852} + \underset{(7.58)}{0.899^{**}} \log ERPL + \underset{(1.23)}{0.181} \log PDW + e_2 \quad (9)$$

$$\bar{R}^2 = 0.834$$

We can conclude that the effective rate of pollution levy has a significant correlation with the investment in wastewater treatment facilities. If the effective rate of pollution levy is increased, TVIEs have more incentive to save pollution levy. This incentive promotes the investment in pollution abatement, and hence discharged pollutants are reduced. It implies that the marginal abatement cost curve is downward sloping as pollution increases. Since the model does not take account of the effects of other regulatory policies that might be associated with pollution levies, the exact effect of an increase in the effective rate of pollution levy is not estimated. However, the result confirms that stricter enforcement of the pollution levy system for TVIEs would reduce the discharge of pollutants.

The estimated coefficient of the output value per discharged wastewater is not significant. The investment in wastewater treatment facilities is determined independently of the value of output as long as they are adjusted by the volume of wastewater. Therefore, we can say that TVIEs in the paper manufacturing industry, which produce low output value compared to the volume of discharged wastewater, do not invest especially more or less than those in other industries. The effort of investment in water pollution abatement facilities is not related to the properties of industries but with the enforcement of environmental policies for TVIEs.

3.4 Determinants of the Effective Rate of Pollution Levy

3.4.1 Model

As shown in Table 3, the effective rate of pollution levy paid by the surveyed TVIEs varies greatly among the provinces. The effective rate of pollution levy is considered to be determined by a number of factors, such as degree of enforcement of the pollution levy system, ability to monitor pollutants in each province, size and profitability of each enterprise, and type of industry. Wang and Wheeler (2000) estimate a model to determine the effective rate of pollution levy by those factors. They reveal that the effective rate of water pollution levy is responsive to regional COD discharge concentration, an enterprise's profitability, ownership, size and age of plant, and some industrial dummies.

In this paper, the following model is estimated to investigate determinants of the effective rate of water pollution levy for TVIEs.

$$\log ERPL = b_{30} + b_{31} PDT + b_{32} \log CLR + b_{33} PINC + e_3 \quad (10)$$

$$PDT = \frac{\text{total output value of surveyed TVIEs}}{\text{number of surveyed TVIEs}}$$

Wang and Wheeler (2000) show that the effective rate of pollution charge is high for large plants, using a dummy variable in their factory-level data. Since the provincial data is used in this paper, the average output value per surveyed TVIE is employed to represent the size of TVIEs in each province.

$$CLR = \frac{\text{value of fixed capital}}{\text{number of employees}}$$

The capital-labor ratio represents the industrial structure of TVIEs in each province. Heavy industries have higher capital-labor ratios and light industries have lower ones. If the effective rate of pollution levy is related to the industrial structure, the estimated coefficient of this variable will be significant.

$$PINC = \text{per capita income in rural households}$$

The effective rate of pollution levy might be correlated with the level of income. As income level rises, people will demand a better environment, and they are more concerned about environment in their neighborhood. This puts pressure on local governments to enforce environmental policies more strictly. Thus the estimated coefficient is expected to be positive. The data for this variable comes from the Rural Socio-Economic Survey as of 1997, which is reported in the China Statistical Yearbook 1999.[19]

3.4.2 Estimation Result

The estimated equation is:

$$\begin{aligned} \log ERPL = & -10.59^{**} - 0.217 \log PDT + 0.969^{**} \log CLR \\ & (-3.37) \quad (-1.12) \qquad\quad (2.64) \\ & + 1.095^{**} \log PINC + e_3 \\ & (2.30) \qquad\qquad \overline{R}^2 = 0.420 \end{aligned} \quad (11)$$

.

[19] The reason that I adopt the data as of 1997 is that the data as of 1996 and before does not include Chongqing, which became a national municipality in 1997.

The estimated coefficients of capital-labor ratio and per capita income are positive and significant. The effective rate of pollution levy is higher in provinces where there is a high density of heavy industries and per capita net income of rural households is high. As Wang and Wheeler (1996) describe, in more industrialized regions, where an advantage of agglomeration economies has already been gained, the government might be less concerned about the impact of stricter enforcement of the pollution levy system. Also in those regions, as I mentioned, people at higher income level are more concerned about the environment. The estimated significant coefficients are considered to represent these effects.

From the positive significant coefficient of the capital-labor ratio, we cannot conclude whether it stands for a difference in the effective rate of pollution levy between heavy industries and light industries or the effect of economic development stated above, because the data is aggregated at the provincial level. However, the estimated model implies that different capital-labor ratios lead to different effective rates of pollution levy even at the same income level. This result suggests some difference in the effective rate of pollution levy among industries.[20]

Output value per enterprise does not have a significant coefficient. Size of TVIE is not related to the effective rate of pollution levy as long as at the provincial level, although micro level data reveals higher rates for large plants (Wang and Wheeler, 2000).

A slightly low adjusted R-square indicates that some other factors exist to explain the difference in the effective rate of pollution levy. One possible factor is ownership of TVIEs (collective or private). Since the published data of NSPT does not report any information of the ownership, my model has no variable for this. The relationship between enforcement of pollution levy or other environmental policies and ownership will be discussed in the last section of this paper.

3.5 Size and Productivity of TVIEs

3.5.1 Model

In equation (5) we see the significant negative coefficient of labor productivity affecting COD intensity. This implies that inefficient TVIEs tend to discharge more pollutants. Therefore, if smaller TVIEs have lower productivity, the closedown policy that forces small TVIEs to shut their factories based on their size is a move in the right direction. To investigate it, we assume a Cobb-Douglas production function:

$$(12) \qquad Y = AK^a L^b ,$$

[20] Wang and Wheeler (2000) show that the effective rate of pollution levy is significantly higher in some industries, such as petrol, building and paper industries, with their micro level data.

where Y is production, K is capital, and L denotes labor.[21] Then, labor productivity is written as:

$$(13) \qquad \frac{Y}{L} = AK^{a} L^{b-1}.$$

If $a + b - 1 = 0$, which means constant return to scale, labor productivity is constant with respect to scale of production. If $a + b - 1 > 0$, smaller TVIEs have lower productivity.

Hence, the following model is estimated:

$$(14) \qquad \log LPRD = b_{40} + b_{41} \log CAP + b_{42} \log LAB + e_4 .$$

$$LPRD = \frac{\text{gross output value}}{\text{number of employees in TVIEs}}$$

$$CAP = \text{value of fixed capital}$$

$$LAB = \text{number of employees in TVIEs}$$

3.5.2 Estimation Result

The estimated equation is:

$$(15) \qquad \log LPRD = \underset{(-3.29)}{-1.63^{**}} + \underset{(9.57)}{0.868^{**}} \log CAP - \underset{(-7.28)}{0.672^{**}} \log LAB + e_4 \qquad \overline{R}^2 = 0.784 .$$

The Cobb-Douglas production function is well estimated and the estimated $a + b - 1$ is 0.196. The F-value for the null hypothesis of $a + b - 1 = 0$ is 29.3, which rejects the hypothesis of constant return to scale. This result proves that a larger TVIE produces more efficiently in terms of labor input. Since there is higher COD intensity at less productive TVIEs, as we saw in Section 3.2.2, the estimation result means that the discharged COD intensity is higher at smaller TVIEs. As long as we consider this result, the closedown policy discussed in Section 2.3.3 is a move in the right direction.

[21] Since the available data for production (Y) is not value added but gross output value in NSPT, intermediate inputs (M) should be considered in the production function: $Y=AK^{á}L^{â}M^{ã}$. However, the data for intermediate inputs is not available, either. Therefore, we assume that the intermediate inputs are proportional to capital (K), that is, M=ëK. Then, the same discussion as below can be applied.

4 Difficulties in TVIEs' Environmental Measures

4.1 Purpose of the Factory Survey

From the econometric analyses of the provincial data of NSPT 1995, we can conclude that investment in wastewater treatment facilities by TVIEs decreases their discharging pollution intensity and that a higher effective rate of water pollution levy promotes the investment in wastewater treatment facilities. Hence, a higher effective rate of water pollution levy is desirable in order to reduce the pollution. However, the magnitude of this relationship between the effective rate of pollution levy and the investment in pollution abatement also depends on a number of other factors, such as manageability of suitable environmental technologies and availability of financial resources for the investment. If TVIEs have any difficulties in these areas, an increase in the effective rate of pollution levy does not have a large effect in decreasing pollution, as a result of a steep slope of the downward long-run marginal abatement cost curve.[22]

As shown in Section 2.1, the number of TVIEs is large and their average size is small. This fact is compacted by the technological and financial disadvantages at TVIEs. To investigate the difficulties facing TVIEs in implementing environmental measures, a factory level survey for TVIEs was performed. The results are discussed in the following sections.

4.2 Outline of the Factory Survey

The survey was run between fall 1997 and spring 1998 at Xishuangbanna and Kunming in Yunnan Province, several towns in Hebei Province, Qingdao and Weihai in Shandong Province, Zhangjiagang in Jiangsu Province, and Tianjin City. With the cooperation of the local Environmental Protection Bureaus, three to five townships or villages were selected in each area, and questionnaire sheets were distributed to about 10 TVIEs in each township or village.[23] In total, 228 answer sheets were collected, of which 54 are from Yunnan Province, 38 from Hebei Province, 50 from Shandong Province, and 60 from Tianjin City.[24]

The basic statistics of answering TVIEs are shown in Table 4. The mean of the gross output value is the highest at 135,750,000 yuan in Jiangsu Province and the lowest at 9,450,000 yuan in Yunnan Province.

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[22] The "long-run" marginal abatement cost curve takes the investment activity into account.

[23] For details of the questionnaires, see Arayama et al. (1999).

[24] Later in this paper, these five provincial names are used for the regional categorization, whereby the survey was run at a limited number of places in those provinces.

The mean of the number of employees is the highest at 654 in Jiangsu and the lowest at 94 in Yunnan. 60% of the answering TVIEs have less than 50 employees in Yunnan Province, while nearly 30% of the answering TVIEs have more than 1,000 employees in Jiangsu (Table 5). The size of the TVIEs is largely diverse among those regions. The average foundation year is 1982 in Jiangsu and 1989 in Yunnan and Tianjin. Major products of the surveyed TVIEs are also shown in Table 4. Typical products are rubber and tea in Yunnan, wool and cotton fabrics in Jiangsu, automobile parts in Tianjin.

Zhangjiagang in Jiangsu Province, where many large-scale TVIEs are located, is selected as a model city of TVIEs' environmental protection by SEPA. The reason TVIEs have developed since the early period in this area is that large SOIEs did not exist in this area, and in that sense, the economic conditions were not good. In contrast, the development of TVIEs started relatively late in Tianjin, where conventional SOIEs were accumulated. Yunnan Province is located in inland China. Economic development started late in this area. This economic differential is indicated by the per capita net income of rural households that is presented in Table 4.

4.3 Pollution Levy and Three Synchronizations

In Shandong Province, 100% of the surveyed TVIEs paid pollution levies in both 1995 and 1996, and 92% in Hebei Province (Table 6). In Jiangsu Province and Tianjin City, TVIEs that paid pollution levies comprise less than half of the total surveyed TVIEs in each location, while the amount of payment of pollution levies is high because of their large scale of production. The average amounts of payment are between about 4,000 and 20,000 yuan per year. These are about 0.01% of the average gross output values shown in Table 4. This ratio is lower than the 0.03% calculated from the figures reported in NSPT 1995.

We cannot conclude from these results whether the pollution levy system is strictly enforced in Jiangsu and Tianjin or in these five provinces compared with other areas, because the amount of pollution levies must be lower in the areas where environmental policies promote enterprises' pollution abatement activities. However, taking account of the enforcement rate of *three synchronizations* (Table 7), enforcement of environmental policies, including the pollution levy system, is expected to be relatively strict in Jiangsu and Tianjin. The figures in Table 7 are interpreted as a result of this. Meanwhile, most of the surveyed TVIEs in Yunnan Province gave no answer regarding the payment of pollution levies. It is likely that most of them evade the system.

Three synchronizations have been implemented by all the surveyed TVIEs in Jiangsu Province. On the other hand, 35% of the surveyed TVIEs in Yunnan Province and 47% in Hebei Province have not executed *three synchronizations*. Since the policy of *three synchronizations* had started before most of the TVIEs launched operations, those TVIEs had to implement *three*

synchronizations. However, as can be seen from the result of our survey, this policy has not been strictly enforced for TVIEs in certain areas.

4.4 Environmental Technology

Most of the TVIEs adopt "conventional domestic technology" to abate pollution, which include both end-of-pipe and cleaner-production technology, except in Jiangsu Province (Table 8). In Jiangsu Province, 76% of them adopt "newly developed domestic technology" with new production technology employed by the developed TVIEs there.

As regards the problems with the currently adopted environmental technology, 40% of the total surveyed TVIEs and more than 50% in Jiangsu and Tianjin answered with "high costs of operation" (Table 9). In Hebei Province, the most common answer is "high prices of machinery and facilities." In Yunnan Province, the same number of respondents answer with "low level of technology" and "high costs of operation." We can conclude from these results that the cost is the greatest problem as regards environmental technology for most of the TVIEs rather than the level of technology, even if the adopted environmental technology is conventional and domestic.

For the future adoption or development of environmental technology, more than half of the TVIEs answered "adoption of technology developed by the government" in Shandong, Hebei and Tianjin (Table 10). It is difficult for most of the TVIEs to develop environmental technology by themselves or to buy new technology developed by other domestic enterprises. On the other hand, more than 50% of the TVIEs in Jiangsu answered "development of own technology." This shows that the TVIEs in this area have a high level of technology.

The answers regarding the problems with the future adoption or development of environmental technology have the same tendency as the answers regarding the problems with the currently adopted environmental technologies. That is, the greatest problem is the cost. However, "difficulties in maintenance of facilities" and "difficulties in learning operation" were given as regards the future adoption or development of environmental technology by more TVIEs relative to answers regarding the currently adopted environmental technology.

4.5 Financial Resources for Environmental Measurements

As shown in Table 11, the share of "internal reserves" in the total financial resources for TVIEs' environmental measures, such as investment in pollution abatement facilities and introduction of new environmental technology, is 86% on average. The share of "borrowings from banks" is 33% in Yunnan Province and 18% in Jiangsu Province. Internal reserves are not sufficient in Yunnan because of the smaller size and lower profitability of TVIEs, and also it is not sufficient to allow investment of a large amount in environmental measures in Jiangsu.

The most important finding here is that the share of "borrowings from the government" and "subsidies from the government" is almost zero. Since 80% of the collected pollution levies are used as subsidies or loans for environmental measures, it is possible for TVIEs as well as SOIEs to receive subsidies or loans from the government. However, most of the surveyed TVIEs have not utilized the benefits of the pollution levy system, while about a half of the TVIEs have paid pollution levies as seen in Table 6.

As regards the problems with financing environmental measures, many of the TVIEs answered to the effect that they can get only "insufficient funds" to implement environmental measures (Table 12). This means that their internal reserves are not sufficient for the purpose. Table 12 also shows that "high interest rates" and "strict loan conditions" are not major problems. These are not the main reasons that the TVIEs do not borrow from the government or banks.

On the other hand, in Hebei and Tianjin, over 80% of the TVIEs include "borrowings from the government" or "subsidies from the government" in their future plan involving financial resources for environmental measures (Table 13). Thus, those TVIEs that cannot provide enough money for their environmental protection activities and place their hope in external financial resources do not really have easy access to these resources. The reason for this is presumed to be that the government gives priority to SOIEs as regards subsidies and loans. It is more efficient for the government to use the limited money for a small number of large SOIEs than a large number of small TVIEs. In that sense also, TVIEs are not completely covered by the pollution levy system.

4.6 Relationships between Technology and Financial Resources for Environmental Measures

Relationships between the answers regarding technology and financial resources for environmental measures are investigated with a statistical method in this section. Three-dimensional cross tabulations including the regional variable are made,[25] and the log-linear analysis is used to interpret the result of tabulations.[26] Since the regional variable is included, relationships between the answers for the other two questions can be understood as common

[25] This means that cross tabulations are made for each region.

[26] The log-linear analysis attributes the odds of event to the factors of variables and their correlations. Assuming a question is answered by 60 men and 40 women, and 50 answers are yes and 50 are no. If 30 men and 20 women answer yes, the odds of "men answer yes" is attributed to the factors of only these variables: the sex and the answer. If 40 men and 10 women answer yes, however, the odds will be explained also by the factor of correlation between these variables. Although the chi-square test can do this kind of test, the log-linear analysis can be applied to more complicated models and clarify which event includes the correlation factors. See, for example, Matsuda (1988) for more details.

tendencies among those regions, as long as the factor of correlation is independent of the regional factor.[27]

Table 14 presents some correlations between the answers for the currently adopted environmental technology and the problems associated with them. The TVIEs that adopt foreign environmental technologies tend to have problems of high prices of machinery and facilities and difficulties in their maintenance and learning their operation. On the other hand, the TVIEs that use conventional domestic environmental technology have fewer problems. Foreign environmental technologies are adopted by some TVIEs in Jiangsu Province, which are expected to have a higher level of production technology. However, even those relatively developed TVIEs have some difficulties in managing imported environmental technology.

The TVIEs that currently adopt conventional domestic environmental technologies tend to answer that "adoption of technologies developed by the government" is their future plan (Table 15). In contrast, the TVIEs that adopt foreign environmental technology tend to answer "adoption of foreign technology." The TVIEs do not anticipate any large-scale change in their policies for future adoption of environmental technology.

Table 16 indicates correlations between the problems with financing environmental measures and future plans for it. The TVIEs that are faced with the problem of "insufficient funds" hope to use "subsidies from the government" as the future financial resources for pollution abatement activities, and the answer "strict loan conditions" is positively correlated with the answer "internal reserves." These results can be interpreted as indicating that the TVIEs are considering their plans to finance environmental measures in order to evade the current problems with the matter. Table 16 also indicates that the TVIEs that answered "insufficient funds" for environmental measures tend to adopt conventional domestic environmental technology, not foreign technology. This suggests that the financial problem is one factor influencing the adoption of environmental technology.

[27] With the log-linear analysis, several models with different relationships of correlation among the three variables are estimated. Then, if a model with the correlation factor between the two variables other than the regional variable is selected, based on Akaike's Information Criteria (AIC), some correlation is considered to exist between those variables. This procedure follows Arayama, Yan and Taketoshi (1997).

5 Summary and Concluding Discussion

Environmental pollution by township and village industrial enterprises (TVIEs) is estimated at nearly half of China's total major industrial pollution. TVIEs have been rapidly developing since the open and reform policy was introduced in the late 1970s. With the increase in TVIEs' share of industrial output value, which is now over 50% of the national total, pollution has been spreading over the rural areas. There are over 6,000,000 TVIEs and they are geographically scattered. The average size of TVIEs is significantly smaller than that of state owned industrial enterprises (SOIEs). These characteristics make it difficult for the TVIEs themselves and the government to implement environmental measures.

To analyze the economic and policy factors affecting pollution by TVIEs, the econometric analyses of the provincial data of NSPT were performed, and they provided the following results. First, COD intensity is decreased by investment in wastewater treatment facilities. Second, more efficient technology, indicated by higher labor productivity, leads to lower COD intensity. Third, paper manufacturing TVIEs discharge effluent with significantly higher COD intensity. Fourth, investment in wastewater treatment facilities has a significant association with the effective rate of water pollution levy. That is, in the provinces where this environmental policy is strictly enforced, TVIEs invest more in pollution abatement facilities. Fifth, the effective rate of pollution levy is higher in the provinces where per capita income of rural households is high and TVIEs are more capital intensive.

From these results, we can derive two correct directions to prevent further pollution by TVIEs: investment in pollution abatement facilities (end-of-pipe technologies) and adoption of more efficient or advanced technology (cleaner-production technologies). These are absolutely natural solutions. However, the question is how to induce TVIEs to take this action. The regression result shows that stricter enforcement of the pollution levy system leads to more investment in pollution abatement facilities. Even though the exact impact of raising an effective rate of pollution levy on pollution intensity is not clear, because it may be correlated with the degree of enforcement of other visible or invisible direct regulations, it will certainly have some positive effect if environmental policies are implemented more firmly.

Then, another question what makes the effective rate of pollution levy so different among the provinces is raised. Although my study shows a few variables explaining the regional difference in the effective rate of pollution levy, it does not successfully clarify some basic reasons that could make the difference. One possible factor is that EPBs' policy is not independent of local economic interests. As many authors have mentioned (e.g., Oi, 1995), local governments tend to seek their economic benefits through their TVIEs (or TVEs in general) in the process of decentralization of the Chinese economy. Especially in relatively less developed

rural areas, more TVIEs are collectively owned. In those areas, it is often difficult for EPBs to enforce strict policies independently of local authorities' economic interests, because local EPBs depend on the local governments for their budgets. In contrast, in more developed areas where most of TVIEs are privately owned, EPBs' policies can be strict.

People's awareness and complaints may be another factor influencing differences in the degree of environmental policy enforcement. These are expected to have a relationship with the level of income, education, and also privatization. If any enterprises are collectively owned in a township, people there will hesitate to complain about pollution by those enterprises, because all residents are in one economic community. However, the more enterprises are privately owned and managed, the more complaints about pollution will be expressed. People working for a private TVIE have different interests from those of other private TVIEs' workers or even their own employer.

Therefore, more privatization will have a positive effect on strong enforcement of environmental policies for TVIEs,[28] while decentralization of the Chinese economy has been spreading environmental pollution over the rural areas, as pointed out in this paper. Local governments should no longer be leading players but become managers of framework conditions and public goods in the economy, which is becoming increasingly market-oriented.

The important tasks of local government in preventing further environmental deterioration in the rural areas are to supervise TVIEs and to help them to implement environmental measures. As clarified by the analysis of the factory survey in this paper, many TVIEs suffer from a lack of external financial resources to invest in pollution abatement facilities. Insufficiency of human resources for environmental management is also a significant problem. Local governments have to regulate TVIEs strictly regarding pollutant discharge, and at the same time they should make public loans for environmental measurements easily accessible to TVIEs and provide environmental education and training for managers and workers of TVIEs. Of course, local governments alone cannot be burdened with these tasks. The national government must back them up. Also, international cooperation, especially "inter-local-governmental" assistance will be important in the field of environmental management.[29]

[28] More privatization might have a negative effect on pollutions directly. It is left to a future study to investigate these hypotheses and the total effect of privatization on the environment.

[29] Some international projects between local governments in China and Japan, such as Dalian-Kitakyushu, Shanghai-Osaka and Tianjin-Yokkaichi, have already started. It is expected that this kind of project will be expanded into other areas and extended to more TVIEs.

Annexure

Table 1: Basic Statistics of TVIEs and SOIEs

		TVIEs	SOIEs
(a) Number of Enterprises		6,620,000	64,700
(b) Number of Employees		73,342,000	27,210,000
(c) Total Value Added	(million yuan)	1,553,030	1,107,690
b / a	(person)	11	421
c / a	(yuan)	235,000	17,120,000
c / b	(yuan)	20,900	40,700

Source: China Statistical Yearbook 1999

Table 2: Statistics of Pollution Reported in NSPT and CEY

			NSPT[1] (1995)	CEY[2] (1998)
Number of:				
(a)	Surveyed Enterprises		1,216,018	74,101
(b)	Employees		27,524,131	?
b / a		(person)	22.63	?
Total Amount of:				
(c)	Gross Output Value	(million yuan)	1,926,039	4,259,137
(d)	Wastewater	(thousand ton)	5,908,308	20,046,580
	Treated Wastewater	(thousand ton)	2,367,608	27,727,056
	Investment in Wastewater Treatment Facilities[3]	(thousand yuan)	5,611,376	7,167,940
(e)	COD in Wastewater	(ton)	6,112,800	8,006,094
(f)	Exhausted Gas	(million cubic meter)	2,804,698	12,120,300
(g)	SO_2 in Exhausted Gas	(ton)	4,411,227	15,944,432
	Discharged Soot	(ton)	8,495,245	11,785,377
	Disposed Solid Wastes[4]	(thousand ton)	175,841	70,482
(h)	Pollution Levy Payment	(thousand yuan)	617,477	4,901,919
e / c		(ton / million yuan)	3.17	1.88
d / c		(ton / thousand yuan)	3.07	4.71
e / d		(1/1000)	1.03	0.40
f / c		(cubic meter / yuan)	1.46	2.85
g / f		(ton / million cubic meter)	1.57	1.32
h / c		(1/1000)	0.32	1.15

Notes:
1) NSPT is the abbreviation of National Survey of Pollution by TVIEs.
2) The data as of 1998 in the column of CEY is reported in the China Environmental Yearbook 1999.
3) Investment in wastewater treatment facilities reported in CEY is the amount of investment in the facilities of which construction was completed in 1998. The figure in NSPT would be the total amount of past investment.
4) The amount of disposed solid wastes in CEY does not include temporarily stocked wastes. This is unclear in the NSPT.

Table 3: Means and Standard Deviations of the Variables

Variables	Definitions and Units	Means of Provincial Data[2]	Values Calculated from National Totals[3]
CODI	COD Intensity (ton / million yuan)	4.948 (4.709)	3.174
INV	Relative Investment in Wastewater Treatment Facilities (yuan / ton)	0.962 (0.881)	0.950
LPRD	Labor Productivity[4] (thousand yuan / person)	57.68 (30.08)	69.98
PAPER	Relative Share of Paper Manufacturing Industry	1.389 (1.679)	
ERPL	Effective Rate of Water Pollution Levy (yuan / ton)	0.109 (0.928)	0.110
PDW	Gross Output Value per Discharged Wastewater (yuan / ton)	353.8 (239.0)	326.0
PDT	Gross Output Value per TVIE (million yuan)	2.673 (4.296)	1.584
CLR	Capital-Labor Ratio (thousand yuan / person)	24.46 (13.49)	25.17
PINC	Per Capita Net Income of Rural Households (yuan)	2,222 (923)	
CAP	Value of Fixed Capital (million yuan)	23,088 (28,245)	
LAB	Number of Employees in TVIEs (person)	917,351 (860,749)	

Notes:
1) Standard deviations are in parentheses.
2) The Tibet autonomous district is not included in the provincial data.
3) National totals include Tibet.
4) This is defined as gross output value per employee.

Table 4: Basic Statistics of the Factory Survey

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Mean of the Gross Output Value (thousand yuan)	9,450 (17,660)	41,320 (48,970)	14,820 (12,930)	135,750 (153,560)	98,940 (418,600)	66,620 (231,600)
Mean of the Number of Employees (person)	110 (206.6)	94 (73.9)	115 (67.7)	654 (625.5)	248 (325.9)	263 (412.3)
Mean Year of Foundation	1989 (8.8)	1987 (4.6)	1983 (10.9)	1982 (10.2)	1989 (5.5)	1986 (8.4)
Major Products	Rubber, Tea, Paper	Metals, Stone Materials, Wool Fabrics	Castings, Foods	Wool and Cotton Fabrics	Auto-mobile Parts, Chemical Products	
Number of the Surveyed TVIEs	54	38	26	50	60	228
Per Capita Net Income of Rural Households[1] (yuan)	1,195	2,286	2,292	3,270	3,244	2,162 (National Average)

Notes:
1) The presented values of per capita net income of rural households are the provincial averages as of 1997 reported in the China Statistical Yearbook 1999.
2) Standard deviations are in parentheses.

Table 5: Number of Employees

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
49 and under	59	37	8	2	18	26
50-99	20	26	35	8	10	18
100-499	13	37	58	46	62	42
500-999	6	0	0	16	7	7
1000 and over	2	0	0	28	3	7

Table 6: Pollution Levy Payment

		Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Paid (%)	in 1995	4	92	100	44	38	47
	1996	9	92	100	44	43	50
Not Paid (%)	in 1995	0	0	0	56	35	21
	1996	0	0	0	56	35	21
Average Payment	(yuan)						
	in 1995	6200	4800	5400	20300	15000	8700
	1996	3800	4700	4400	19000	21400	9900
N.A. (%)	in 1995	96	8	0	0	27	31
	1996	91	8	0	0	22	29

Table 7: Enforcement of Three Synchronizations

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Enforced	35	47	92	100	93	73
Never Enforced	26	39	8	0	7	15
N.A.	39	13	0	0	0	11

Table 8: Currently Adopted Environmental Technologies

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Conventional Domestic Technology	41	84	88	16	95	62
Newly Developed Domestic Technology	0	3	12	76	5	20
Foreign Technology	0	0	0	8	0	2
N.A.	59	13	0	0	0	0

Table 9: Problems with Currently Adopted Environmental Technologies

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Low Level of Technology	17	32	31	4	20	19
High Prices of Machinery and Facilities	11	42	35	24	0	19
High Costs of Operation	17	18	42	50	67	40
Difficulties in Maintenance	6	0	12	8	0	4
Difficulties in Learning Operation	0	5	0	4	0	2
No Specific Problems	0	0	23	28	2	9

Note: Multiple answers are allowed.

Table 10: Future Development and Adoption of Environmental Technologies

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Development of Own Technology	2	3	12	54	27	21
Adoption of Technology Developed by the Government	28	55	69	30	52	44
Adoption of Technology Developed by Other Domestic Enterprises	9	32	15	4	20	15
Adoption of Foreign Technology	0	0	4	4	0	1
Others	0	3	0	8	0	2
N.A.	61	8	0	0	2	16

Table 11: Financial Resources for Environmental Measures

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Internal Reserves	67	100	88	71	98	86
Borrowings from Banks	33	0	6	18	1	10
Borrowings from the Government	0	0	3	0	0	0
Subsidies from the Government	0	0	0	1	2	1
Others	0	0	2	9	0	3

Note: The average share of each is presented.

Table 12: Problems with Financing Environmental Measures

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Insufficient Funds	19	79	96	20	90	57
High Interest Rates	7	0	0	2	0	2
Strict Loan Conditions	2	13	4	76	2	20
Others	2	0	0	0	0	0
N.A.	70	8	0	2	8	21

Table 13: Plan to Finance Environmental Measures

(%)

	Yunnan	Hebei	Shandong	Jiangsu	Tianjin	Total
Internal Reserves	2	3	62	84	10	29
Borrowings from Banks	30	0	12	8	2	11
Borrowings from the Government	6	16	15	0	13	9
Subsidies from the Government	0	71	12	0	67	31
Others	2	0	0	8	0	2
N.A.	61	11	0	0	8	18

Table 14: Problems with Currently Adopted Environmental Technology (Log-Linear Analysis)

	Low Level of Technology	High Prices of Machinery and Facilities	High Costs of Operation	Difficulties in Maintenance	Difficulties in Learning Operation	No Specific Problems
Currently Adopted Env. Technology						
Conventional Domestic						+
Newly Developed						
Domestic Foreign		+		+ +	+ +	

Note: + + and + indicate that the corresponding coefficients are positive and significant at 5% and 10% respectively.
and indicate the same for the negative coefficients.

Table 15: Future Development and Adoption of Environmental Technology (Log-Linear Analysis)

	Development of Own Technology	Adoption of Technology Developed by the Government	Adoption of Technology Developed by Other Domestic	Adoption of Foreign Technology
Currently Adopted Env. Technology				
Conventional Domestic		+ +		
Newly Developed Domestic				
Foreign				+

Note: + + and + indicate that the corresponding coefficients are positive and significant at 5% and 10% respectively.
and indicate the same for the negative coefficients.

Table 16: Problems with Financing Environmental Measures (Log-Linear Analysis)

	Insufficient Funds	High Interest Rates	Strict Loan Conditions
Plan to Finance Environmental Measures			
Internal Reserves			+ +
Borrowings from Bank			
Borrowings from the Government			
Subsidies from the Government	+ +		
Currently Adopted Env. Technologies			
Conventional Domestic	+ +		
Newly Developed Domestic			
Foreign			

Note: + + and + indicate that the corresponding coefficients are positive and significant at 5% and 10% respectively.
and indicate the same for the negative coefficients.

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