# 環境関連財政支出および企業の環境対策による
# マクロ的経済効果に関する日中比較研究

課題番号１２４３０００８



平成 12－14 年度文部科学省科学研究費補助金（基盤研究Ｂ１）研究成果報告書

平成１５年（２００３年）３月

研究代表者

名古屋大学経済学研究科助教授　荒 山 裕 行

## 研究組織および研究費

平成 12－14 年度文部科学省科学研究費補助金（基盤研究Ｂ１）研究成果報告書

**環境関連財政支出および企業の環境対策によるマクロ的経済効果に関する日中比較研究**

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### 研究組織

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|---|---|---|
| 荒山　裕行 | 名古屋大学<br>経済学研究科助教授 | 研究計画および研究の統括、環境政策の経済分析 |
| 薛　　進軍 | 大分大学<br>経済学部教授 | マクロ的経済効果の実証分析（中国担当） |
| 並河　良一 | 名古屋大学<br>経済学研究科教授 | 企業の環境対策とその経済効果の分析(日本担当) |
| 藤倉　良 | 立命館大学<br>経済学部教授 | 国及び地方の環境関連財政支出の分析(日本担当) |
| 竹歳　一紀 | 桃山学院大学<br>経済学部助教授 | マクロ的経済効果の実証分析（日本担当） |
| 厳　　善平 | 桃山学院大学<br>経済学部教授 | 郷鎮工業の環境対策の経済分析（中国担当） |

### 研究費

平成１２度：４，０００千円
平成１３年：３，７００千円
平成１４年：４，１００千円

はじめに

新興工業国は、経済発展の初期段階から一般の公害対策に加えて地球規模での環境問題への対応が迫られている。この点で先進工業国が、当初主として局所的な環境問題（公害）への対応することで経済成長を成し遂げてきた発展過程と大きく異なる。先進工業国は経済成長を成し遂げた後に地球規模の環境問題への対応が迫られるようになったことで、先進工業国の側に、新興工業国が現在抱える環境・経済問題解決のための十分な理解があるとは言えない状況にある。経済成長とともに加速する新興工業国の環境問題解決のためには、先進工業国は、環境汚染の内部化に成功したプロセスにおける政府・企業の役割（対策）を明らかにし、新興工業国がとるべき環境対策の方向を示して行く必要がある。

現代の新興工業国（中国およびアジア NIES）は、国際市場における工業製品の飽和を考慮すれば、いっそう厳しい経済条件下で環境保護を進める必要にさらされている。この現実をふまえ、本研究は、新興工業国側の要請に基づき、環境政策がそのマクロ経済全般にもたらす効果を明確にすることを試みたもので、経済成長の維持と地球規模での環境保全を合わせた持続的経済成長のための政策立案に対し有効な情報提供を通して、新興工業国が自らの環境対策を進めていくため指針の提供を目指してきた。

この報告書は、大きく二つの部分からなっている。第一部の「Economic Development : Environment Perspective（経済発展：環境の視点）」は、主としてこの研究に携わった研究者の経済発展と環境保護にかかる研究成果をまとめたものである。ここでは、2000 年にこの科研プロジェクトの一環として開催した国際シンポジウム「Environment and Our Sustainability in the 21st Century: Understanding and Cooperation between Developed and Developing Countries」において報告いただいた中国国家環境保護総局司長（部長）の彭 近新氏およびシカゴ大学経済学部のジョージ トーリイ教授の論文をプロシーディングスから再録させて頂いた。

第二部の「Economic Growth: Regional Perspective（経済発展：地域の視点）」は 2000 年に寧夏大学と共催した『中国西部経済発展国際シンポジウム』において報告された論文のうち地域開発の視点から経済発展を分析した研究を収録している。地域開発の論文を同時に収録したのは、環境問題の解決にはその地域それぞれの政府と民間の地道な取り組みがわけても重要であると私が考えたことに他ならない。発展途上国の環境問題を解決に導く鍵が、地域の経済発展パターンの厳密に分析を通して得られる可能性が高い。

第二部にも、シカゴ大学経済学部のトーリイ教授が『中国西部経済発展国際シンポジウム』に出された論文を収めさせていただいた。この論文は、寧夏大学の呉教授や私が、シカゴ大学でトーリイ教授の主宰されている中国の西部開発に関する研究会のメンバーに加えて頂いていたことから、このシンポジウムのために書いてくださったものである。また、名古屋大学大学院法学研究科の加藤久和教授、同経済学研究科の塚田弘志教授は、この科

研のメンバーではなかったが、それぞれご専門のお立場から中国の環境問題と地域開発に資するためということで論文を用意してくださるとともに本報告書への掲載を快く了承してくださった。

本報告書の構成にかかる話に加えて、寧夏大学と『中国西部経済発展国際シンポジウム』を共催するに至った経緯、この科研プロジェクトがもたらした思わぬ波及効果およびこの報告書が英語で編集された理由について簡単に触れさせて頂きたい。

現在の中国の重点政策である「西部開発」と「環境保護」の研究を進めるべく寧夏大学西部発展研究センターが 2001 年 10 月に設立されたことから、寧夏大学副学長で同センター主任（当時　現寧夏省社会科学院院長）の呉 海鷹教授からの強い研究協力要請があった。この要請に対し、研究分担者の大分大学の薛 進軍教授と相談の上、この科研プロジェクトの最終報告会を寧夏大学の『中国西部経済発展国際シンポジウム』に併せて開催することにした。中国の環境問題への貢献姿勢を明確できかつ我々の研究成果を公開できる絶好の機会ととらえ、積極的な協力を行うこととなった。もともと我々の研究は、先にも述べたとおり、先進国の公害克服の経験を経済学的に明らかとすることで環境問題に直面している新興工業国の環境政策に寄与することを目的としたものであることから、寧夏大学においてこのような形で我々の研究成果を発表する機会が与えられたことは、誠にうれしいことであった。

この研究プロジェクトでは、2002 年度に西安市、桂林市、南寧市、2003 年度には寧夏省で、政府の環境政策と企業の対応に関する質問票調査を実施した。この調査では、国家環境保護総局の彭 近新司長および北京大学環境科学研究所の栾 胜基教授の研究協力をお願いし、栾先生の大学院生をそれぞれの環境保護局に派遣してもらい、その院生が現地での調査員の指導を行うという形で企業調査を進めることができた。３人の北京大学の院生が協力をしてくれた。寧夏大学でのシンポジウムに栾先生がこの３名の大学院生を伴っていらしたが、驚いたことにはこの院生たちが、集めたデータをもとに自分たちですでに企業の環境対策に関する分析を始めており、その成果をシンポジウムで報告してくれた。寧夏大学の呉先生も、寧夏省での質問票調査のデータをもとにこの報告書の第７章に収録した研究をまとめられていた。

私は、この瞬間まで、中国において、研究者自らがデータを採りそれをもとにして自らが環境政策と企業の対応に関する分析を行い自らが政策提言を行うようになるには今しばらくの時間がかかると考えていた。このゆえに、「公害先進国・環境先進国」の日本が主導する形で、中国の環境をテーマとする研究プロジェクトを進めた。ところが、研究成果の公刊においても、寧夏大学の呉教授に先を越されてしまうというれしい誤算が生じた。我々の研究チームの報告を含む『中国西部経済発展国際シンポジウム』での報告論文は、中国語に翻訳され《中国西部経済発展理論と実証研究》として一足先に中国経済出版社から出版された。

出版の計画段階から、この科研プロジェクトに対して研究協力をしてくださった多くの方々、さらにはこの科研の研究分担者や研究協力者から、一連の研究成果を英語版として編集してほしいとの希望が出されていた。特に、中国の研究者に、この要望が強かった。この要請に応えるべく、また我々の研究のいっそうの国際化を図るという目的を兼ね、この報告書は英語で編集することとなった。本報告書が、表紙と前書きを除き、英語版となったのはこの事情による。

この文部科学省科学研究費補助金『環境関連財政支出および企業の環境対策によるマクロ的経済効果に関する日中比較研究』を終えるにあたり、このプロジェクトに対しさまざま形でご助力をくださった方々に対して、研究チームを代表しお礼を申し上げたい。わけても、名古屋大学名誉教授飯田経夫先生、中国国家環境保護総局司長彭　近新氏、シカゴ大学経済学部名誉教授ジョージ・トーリイ氏、韓国エネルギー経済研究所所長李 相騏氏、中国寧夏省社会科学院院長呉 海鷹氏からはなにものにも代え難い貴重なご助言と多くの支援を受けた。この方々のご理解なしにはこの研究プロジェクトはけっして成立しなかったといっても過言ではない。

最後に、名古屋大学経済学研究科事務局の効率的にしてかつ心のこもった研究サポートに対して感謝の意を表したい。事務長の鈴木宏治氏（ご退官）、同古田牧夫氏、庶務掛長の中山聖英氏、会計掛長の小林雪子氏（ご退官）、同林 光治氏、会計掛主任の伊藤 誠氏、会計掛事務官大場 亮氏、同小椋友明氏ほか大勢の方々の研究支援に対し感謝申し上げたい。

研究チームを代表して

名古屋大学大学院経済学研究科助教授　荒山裕行

# アクノレッジメント

| | |
|---|---|
| 飯田経夫 | 中部大学教授・名古屋大学名誉教授 |
| 彭　近新 | 中国国家環境保護総局政策・法規司長 |
| 李 相騉 | 韓国エネルギー経済研究所所長 |
| ジョージ・トーリイ | シカゴ大学経済学部名誉教授 |
| 呉 海鷹 | 中国寧夏省社会科学院院長 |
| 栾 胜基 | 北京大学環境科学研究所教授 |
| 沈　明明 | 北京大学行政管理学院副教授・中国国情研究中心長 |
| 夏　光 | 中国国家環境保護総局環境与経済政策研究中心副主任 |
| 張　玉柯 | 河北大学　日本研究所所長・教授 |
| 李　赶顺 | 河北大学　日本研究所教授 |
| 楊　明 | 北京大学中国国情研究中心主任 |
| 汪　勁 | 北京大学法学院副教授 |
| 李　東 | 光華管理学院副教授 |
| 具　度完 | 韓国環境部長官諮問官 |
| 張　衛国 | 寧夏大学西部発展研究中心主任 |
| 張　暁萌 | 寧夏大学経営管理学院副教授 |
| グレン・パオレット | 地球環境戦略研究機構 |
| 明石健吾 | 経済企画庁経済研究所国民経済計算部企画調査課課長補佐 |
| 大森恵子 | 環境庁地球環境部環境保全対策課 |
| 松葉清貴 | 愛知県環境部 |
| 野田眞男 | 国際環境技術移転研究センター技術顧問 |
| 大矢釼治 | 国連地域開発センター主任研究員 |
| 伊藤裕之 | 地球産業文化研究所地球環境対策部 |
| 笹之内雅幸 | トヨタ自動車東京本社環境部主査 |
| 奥野信宏 | 名古屋大学総長特別補佐・経済学研究科教授 |
| 加藤久和 | 名古屋大学法学研究科教授 |
| 江崎光男 | 名古屋大学国際開発研究科教授 |
| 山田鋭夫 | 名古屋大学経済学研究科教授 |
| 竹内常全 | 名古屋大学経済学研究科教授 |
| 多和田 眞 | 名古屋大学経済学研究科教授 |
| 塚田弘志 | 名古屋大学経済学研究科教授 |
| 並河良一 | 化学技術戦略推進機構研究開発事業部長（前経済学研究科教授） |
| 吉野文雄 | 拓殖大学経済学研究科教授 |
| 瀧敦弘 | 広島大学経済学部教授 |
| 鈴木宏治氏（ご退官） | 名古屋大学経済学研究科事務長 |
| 古田牧夫 | 名古屋大学経済学研究科事務長 |
| 石原　努　（ご退官） | 名古屋大学経済学研究科専門職員 |
| 中山聖英 | 名古屋大学経済学研究科庶務掛長 |
| 小林雪子氏（ご退官） | 名古屋大学経済学研究科会計掛長 |
| 林　光治 | 名古屋大学経済学研究科会計掛長 |
| 河合　明 | 名古屋大学経済学研究科教務掛長 |
| 河合成典 | 名古屋大学経済学研究科図書掛長 |
| 梅本秋子 | 名古屋大学経済学研究科庶務掛主任 |
| 伊藤　誠 | 名古屋大学経済学研究科会計掛主任 |
| 小椋友明 | 名古屋大学経済学研究科会計掛事務官 |
| 大場　亮 | 名古屋大学経済学研究科会計掛事務官 |
| 藤井真由美 | 名古屋大学経済学研究科庶務掛事務官 |
| 鷲見寿子 | 名古屋大学経済学研究科庶務掛 |
| 川原靖子 | 名古屋大学経済学研究科庶務掛 |

北京大学
胡　旋　徐 易偉　姜斌彤

名古屋大学
西山敦士　見吉克也　成 十　安　祺　桜井次郎　段 文潔　吉田智子　加藤泰幸
許 冬蘭　金　景根　手嶋典子　田畠幸枝　生田大輔

## Chapter 5

# Pollution, Policies and Affecting Economic Factors in China's Township and Village Industrial Enterprises

Kazuki TAKETOSHI†

### 1. 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 some 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 and makes up 56% of the total gross industrial output value in the country.[1] 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 estimated that major pollutants discharged by TVIEs reach 50% of the national total in 2000.[2]

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 sufficient 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 a great number of TVIEs are scattered in the huge scale of rural

† Kazuki TAKETOSHI, Associate Professor, Faculty of Economics, St. Andrew's University.

*This chapter is a revised version of Taketoshi (2001), which was written while the author stayed at the Center for Development Research (ZEF), University of Bonn, from 2000 to 2001.

[1] China Statistical Yearbook 1996.

[2] China Environment Yearbook 1996.

areas. Environmental problems will continue to be spread by TVIEs all over the rural areas as long as the current situation continues.

Some researchers have 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 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 survey data. However, their survey is regionally limited and the sample size is rather small.

Little comprehensive empirical research exists to date regarding TVIE environmental issues, mainly due to the lack of data. The environmental data reported in the China 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 factors affecting pollution by TVIEs in China and to discuss problems and directions in environmental policies for them. Following an overview of the characteristics of growing TVIEs, pollution by TVIEs, and environmental policies for TVIEs, 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 capital productivity and investment in facilities of wastewater treatment, are examined.

## 2. Pollution by TVIEs

Township and Village Industrial Enterprises (TVIEs) in China can be defined in simple terms as the industrial enterprises established by the people living in the rural areas. Some TVIEs are collectively owned and managed, while a greater number of TVIEs are nowadays privately owned and managed. Although most TVIEs are located in their towns or villages, some TVIEs invest in other areas, or even in foreign countries.

The most 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 the 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.

Pollutants discharged by TVIEs have been increasing at a remarkable rate with their rapid growth 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[3] 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.

The most of the 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.[4] 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 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.[5] 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 of China, as the raw

[3] This is reported in the China Environmental Yearbook 1996.
[4] China Environment Yearbook 1995.
[5] China Environment Yearbook 1996.

materials can be supplied in almost any village. This fact means that the pollution could be generated easily in any rural village or township. This is a serious characteristic of the environmental problems caused by TVIEs.

## 3. Environmental Policies for TVIEs

The "pollution charge system" and the system of "*three-synchronizations*" are characterized as the 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.

### 3.1 Pollution Charge System

China's pollution charge system 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 charge 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 charge $L_{ij}$ is calculated for each listed pollutant, the actual payment is the greatest amount of all the calculated levies.

In addition to the over-standard charge, which is explained above, the pollution charge system includes the standard unit fee, which is collected in proportion to the amount of discharged wastewater,[6] 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 charge fund*. This 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 charge can borrow or be granted up to 80% of the fees they paid. The rest of the pollution charge fund is used by the EPB for its own environmental protection projects.

Although TVIEs are included in this pollution charge 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 charge 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.

### 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). 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).

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

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.

### 3.3 Closedown Policy

A strict environmental policy for TVIEs in recent years has been to close down small factories. Small factories of TVIEs generally do not take any or sufficient 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.[7]

The *State Council Decisions Concerning Certain Environmental Protection Issues*, 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.[8]

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.

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7 Proceedings of the 4th National Conference for Environmental Protection, p.33.
8 China Environment Yearbook 1997.

### 3.4 Other Policies

In addition to the closedown policy, some other policies for TVIEs have been implemented since 1996.[9] 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 concern of the national government about the serious pollution by TVIEs.

## 4. 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,[10] 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 charge 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. 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.

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[9] See the China Environment Yearbook 1997 for these policies mentioned below.
[10] NSPT 1995 was implemented in 1996 based on the data as of 1995.

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.

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.[11] 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.

## 5. Economic Factors Affecting Pollution and Policies

### 5.1 Economic Factors Affecting 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.

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

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

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 charge, 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 charge. 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 charge is effective in promoting such investment. Since the investment in pollution abatement facilities can be promoted also by policies other than the pollution charge system, such as *three-synchronizations*, these relationships are important when considering the policies for TVIEs in total.

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:

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

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. Equation (1) implies that different ways of production discharge different amounts of COD even if the amounts of output are the same.

Assuming that discharged COD is proportional to output,[12] equation (1) can be rewritten as

$$\frac{COD}{Y} = \phi(W, \mathbf{Z}) \tag{2}$$

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

Following the theoretical model indicated as equation (2), some economic factors of COD intensity at TVIEs are investigated by estimating the following regression model. The explanation of the variables is as below.

$$\log CODI = \beta_{10} + \beta_{11}\log INV + \beta_{12}\log KPRD + \beta_{13}\log PAPER + \varepsilon_1 \tag{3}$$

[12] Since output and technological parameters might be correlated, this assumption is made to identify the effect of technological parameters.

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

*CODI* is used as the variable of COD intensity and log of *CODI* 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 treatment facilities per unit of discharged wastewater is used as an indicator of effort with regard to wastewater treatment. The negative sign of $\beta_{11}$ is expected.

$$KPRD = \frac{\text{gross output value}}{\text{value of fixed capital in TVIEs}}$$

The capital productivity is used as a measure of production technologies. Higher capital productivity implies that more efficient or labor-intensive technologies are adopted. Although the labor productivity can be considered as this measure, higher labor productivity is clearly achieved by higher capital intensity, which is correlated with the investment in wastewater treatment facilities. The capital productivity is used here to avoid this problem.

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

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.

$\varepsilon_1$ is an independently and identically distributed error term. It is assumed that neither $\varepsilon_1$ nor any of the other error terms in the equations estimated in this section are correlated to each other.

The regression equation (3) is estimated by OLS with the provincial data of NSPT 1995. The number of observations is 30, excluding the Tibet autonomous district.[13] Means and standard deviations of the variables are shown in Table 3.

The estimated coefficients are presented in equation (4) below.[14]

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

[14] t-values are in parentheses. ** and * denote the significance of coefficients at 5%

$$\log CODI = -12.20 - 0.444^{**} \log INV - 0.558^{*} \log KPRD$$
$$(-44.8)\ (-3.44)\qquad\qquad (-1.86)$$

$$+ 0.301^{**} \log PAPER + \varepsilon_1 \qquad (4)$$
$$(3.25) \qquad\qquad \bar{R}^2 = 0.601$$

We can see that the coefficient of investment in wastewater facilities (relative to discharged wastewater) is negative and significant. This result confirms that investment in wastewater treatment facilities reduces COD intensity. Since the model takes the 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 0.444% at the provincial level.

The negative coefficient of the capital productivity means that COD intensity is lower as the capital productivity is higher. We can consider two reasons for this result. Higher capital productivity may be observed in labor-intensive light industries. In this case, the amount of discharged COD could be low as the nature of such industries. On the other hand, it may be the result of efficient technologies, which can achieve low COD intensity. These two factors can be observed simultaneously.

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.

### 5.2 Effect of Pollution Charge on Investment in Water Pollution Abatement

In equation (4), it was confirmed that investment in wastewater treatment facilities reduces COD intensity. The next question raised here is whether the pollution charge system promotes the investment in water pollution abatement. Since an amount of pollution charge payment is simply expressed as a product of a unit rate of charge ($\tau$) and a discharged volume of over-standard wastewater (S), which is a function of investment in water pollution abatement (I), investment in water pollution

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and 10% level respectively. These notes also apply to the expression of other estimated equations in this paper.

abatement is determined so as to minimize the summation of pollution charge payment and investment in water pollution abatement,

$$\sum_{i=0}^{n} \theta^{i} \tau S(I, \boldsymbol{\omega}) + I, \quad \partial S/\partial I < 0, \quad \partial^2 S/\partial I^2 > 0 \tag{5}$$

where $\omega$ 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 $\theta^i$ is the discount factor of the value in i-th year after the investment is made. From the first order condition to minimize equation (5), we can get an optimum investment as a function of $\tau$, $\omega$ and $\theta$, under the assumption of the positive second derivative of S with respect to I,

$$I = g(\tau, \boldsymbol{\omega}, \theta) \tag{6}$$

It is a rule of the pollution charge system that the unit rate of pollution charge ($\tau$) must be the same for all enterprises and provinces.[1515] If this is actually true, we cannot observe the effect of $\tau$ on INV in our cross-sectional data. However, an actual rate of pollution charge that is calculated as a paid amount of charge divided by a discharged volume of over-standard wastewater varies among provinces and even factories (Wang and Wheeler, 1996, 2000).[16] This fact implies that the effect of an actual rate of pollution charge (t) on the investment in wastewater treatment facilities (I) can be estimated by using t instead of $\tau$ in equation (6).

Thus, an empirical model of equation (6) is specified as follows:

$$\log INV = \beta_{20} + \beta_{21} \log ERPL + \beta_{22} \log PDW + \varepsilon_2 \tag{7}$$

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

Wang and Wheeler (1996) define an effective rate of pollution charge as a payment of charge 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 charge reported in NSPT includes the levies for air pollution and others. Therefore, the share of the total over-standard wastewater charge in the total charge in each province is

15 Local standards in pollutants and the unit rate of pollution charge are adopted in only a few regions such as Shanghai and Beijing (Yang et al., 1998).
16 As shown in Section 3-1, the unit rate of pollution charge is different for each pollutant. The variation of actual unit rate in aggregate data includes this effect.

applied to calculate the amount of over-standard wastewater charge paid by the surveyed TVIEs in the province. ERPL defined by the above formula is used as the effective rate of pollution charge 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. Means and standard deviations are also shown in Table 3.

The estimated equation is:

$$\log INV = 0.852 + 0.899^{**} \log ERPL + 0.181 \log PDW + \varepsilon_3 \qquad (8)$$
$$(0.80) \quad (7.58) \qquad\qquad (1.23)$$
$$\bar{R}^2 = 0.834$$

We can conclude that the effective rate of pollution charge has a significant correlation with the investment in wastewater treatment facilities. If the effective rate of pollution charge is increased, TVIEs have more incentive to save pollution charge. 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 charge is not estimated. However, the result confirms that stricter enforcement of the pollution charge 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.

### 5.3 Determinants of the Effective Rate of Pollution Charge

As shown in Table 3, the effective rate of pollution charge paid by the surveyed TVIEs varies greatly among the provinces. The effective rate of pollution charge is considered to be determined by a number of factors, such as degree of enforcement of the pollution charge 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 charge by those factors. They reveal that the effective rate of water pollution charge 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 charge for TVIEs.

$$\log ERPL = \beta_{30} + \beta_{31} PDT + \beta_{32} \log CLR + \beta_{33} PINC + \varepsilon_3 \qquad (9)$$

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

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 charge 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 charge 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.[17]

The estimated equation is:

$$\log ERPL = -10.59^{**} - 0.217 \log PDT + 0.969^{**} \log CLR$$
$$(-3.37) \quad (-1.12) \qquad\qquad (2.64)$$
$$+1.095^{**} \log PINC + \varepsilon_4 \qquad (10)$$
$$(2.30) \qquad\qquad \bar{R}^2 = 0.420$$

The estimated coefficients of capital-labor ratio and per capita income are positive and significant. The effective rate of pollution charge 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 charge 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 charge 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 charge even at the same income level. This result suggests some difference in the effective rate of pollution charge among industries.[18]

Output value per enterprise does not have a significant coefficient. The size of TVIE is not related to the effective rate of pollution charge 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 charge. One possible factor is ownership of TVIEs (collective or private). Since the published data of NSPT does not

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[17] 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.

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

report any information of the ownership, my model has no variable for this. The relationship between enforcement of pollution charge or other environmental policies and ownership will be discussed in the last section of this paper.

## 6. Concluding Remarks

In this paper, econometric analyses of the provincial data of NSPT were performed to analyze the economic factors affecting pollution by TVIEs, which is estimated at nearly half of China's total major industrial pollution. The estimated equations provided the following results. First, COD intensity is decreased by investment in wastewater treatment facilities. Second, higher capital 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 the water pollution charge. That is, in the provinces where this environmental policy is strictly enforced, TVIEs invest more in pollution abatement facilities. Fifth, the effective rate of the pollution charge is higher in the provinces where per capita income of rural households is high and TVIEs are more capital intensive.

The regression result shows that stricter enforcement of the pollution charge system leads to more investment in pollution abatement facilities. Even though the real impact of raising an effective rate of the pollution charge 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 strictly.

Then, what makes the effective rate of pollution charge so different among the provinces? Although my study shows a few variables explaining the regional difference in the effective rate of pollution charge, it does not successfully clarify some 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 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 certainly are 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 may 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 could have a positive effect on strong enforcement of environmental policies for TVIEs,[19] while decentralization of the Chinese economy has been spreading environmental pollution over the rural areas, as pointed out above. Local governments should no longer be leading players but become managers of framework conditions and public goods in the Chinese 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. 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 this field of environmental management.[20]

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[19] 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.

[20] 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.

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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 (1995) | CEY[1] (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[2] | (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[3] | (thousand ton) | 175,841 | 70,482 |
| (h) | Pollution Charge 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) The data as of 1998 in the column of CEY is reported in the China Environmental Yearbook 1999.

2) 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.

3) 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 | Standard Deviations |
|---|---|---|---|
| CODI | COD Intensity (ton / million yuan) | 4.948 | 4.709 |
| INV | Relative Investment in Wastewater Treatment Facilities (yuan / ton) | 0.962 | 0.881 |
| KPRD | Capital Productivity (yuan / yuan ) | 2.477 | 0.767 |
| PAPER | Relative Share of Paper Manufacturing Industry | 1.389 | 1.679 |
| CAP | Value of Fixed Capital (million yuan) | 23,088 | 28,245 |
| LAB | Number of Employees in TVIEs (person) | 917,351 | 860,749 |
| PDW | Gross Output Value per Discharged Wastewater (yuan / ton) | 353.8 | 239.0 |
| PDT | Gross Output Value per TVIE (million yuan) | 2.673 | 4.296 |
| CLR | Capital-Labor Ratio (thousand yuan / person) | 24.46 | 13.49 |
| PINC | Per Capita Net Income of Rural Households (yuan) | 2,222 | 923 |