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Abstract

This study examines, with a focus on regional environmental states in China, whether regional latecomers enjoy the spillover effects of nation-wide progress in environmental management and technology, or stay behind from environmental progress, or even suffer the "pollution heaven" effects through the relocation of polluters towards those regions, using the analytical framework of the environmental Kuznets curve.

The study's main findings are as follows. First, the provincial panel data proved the validity of the EK curve hypothesis in industrial emissions in China. Second, the regional latecomer's advantage was verified in the case of waste water, while its disadvantage was identified in waste gas and solid waste. Third, as for nation-wide technological progress, the national latecomer's advantage was identified in the case of waste water, sulfur dioxide, and soot. We speculate that the contrasting result on regional latecomer's effects between waste water, waste gas, and solid waste comes from the difference in policy performances: the matured and well-designed water pollution control may have regional latecomers enjoying the spillover effects of nation-wide progress, while the premature and ineffective control of air and solid waste pollution may cause pollution leakage for regional latecomers. We also presume that nation-wide technological progress in waste and air pollution control may reflect the fact that China, as a developing country, is obtaining technological transfers from advanced countries.

Key words: regional environmental states in China, environmental Kuznets curve, regional latecomer's advantage, pollution heaven

JEL Classification Codes: Q53, Q56, R01

1. Introduction

China’s growth has significantly improved the country’s living standards, but has brought serious damage to its environment. China’s air and water, particularly in urban areas, are among the most polluted in the world. Ambient concentrations of most pollutants exceed international standards several times over, burdening China with vast human and economic costs. In addition, China’s sheer size, together with its speed of growth, means that its environmental problems spill over to the rest of world, not only through cross-border pollution in the form of acid rain and dust storms but also in contributions to global warming and damage to the ozone layer. China’s prospects for controlling environmental damage is not, therefore, just a domestic issue; it must be a concern for the rest of the world as well.

Two forces are responsible for much of China’s environmental degradation. The first is China’s extreme dependence on coal. Today, coal satisfies more than 60 percent of China’s demand for energy, making China the world’s largest coal consumer. The second factor is China’s booming cities. Rising urbanization, accompanied by increased automobile use and largely untreated emissions of municipal waste, has increased the portion of the population exposed to the greater pollution found in urban areas.

The government has recognized the environmental challenges confronting the country, and over the past decade has established environmental authorities and introduced a comprehensive legal framework to protect the environment. It has also invested considerable resources in protecting its air and water. It is said that these efforts can claim some successes, but much remains to be done.

One crucial issue seems to be the problems of the implementation of the local level environmental protection. MacBean (2007) argues that “In spite of the mass of laws and policy tools in place in China and the widespread of environmental officials throughout the country it seems that compliance with regulations is poor. The main reason lies in the higher value placed on conventionally measures economic growth and job maintenance or expansion by other departments and local governments.” In fact, according to reports on the state of the environment in China by the State Environmental Protection Administration, the government of China, for both water and air quality, some percentage of monitoring sections of the seven major rivers and cities still remains at extremely polluted levels, although the percentage with higher grade standards rose, and the percentage with lower grade standards fell from 2001 to 2005. China’s environmental prospects, therefore, appear to depend highly on how each region addresses environmental problems.

The purpose of this study, with a focus on regional environmental states in China, is to examine whether regional latecomers enjoy the spillover effects of nation-wide progress in environmental management and technology, or stay behind from environmental progress, or even suffer the “pollution heaven” effect through the relocation of polluters toward those regions. In short, this study intends to verify whether underdeveloped regions enjoy a so-called latecomer’s advantage or suffer its disadvantage in the area of environmental management and technology. The analytical framework of the Environmental Kuznets curve (EK curve) is used to arrive at a conclusion. We focus on the per capita emission of waste gas, waste water, and solid wastes as environmental indices of Chinese provinces. In the following sections, we will first review previous studies and clarify this article’s position (Section 2), present our own empirical study (Section 3), and end with some concluding remarks (Section 4).

2. Previous Studies, Our Position

The EK curve provides an analytical framework to examine how economies deal with environmental issues. The curve postulates an inverted-U relationship between pollution and economic development. At early stages of development, environmental quality deteriorates with increases in per capita income, while at higher levels of development, environmental degradation is seen to decrease with further increases in per capita income. Kuznets's name was apparently attached to the curve by Grossman and Krueger (1993), who noted its resemblance to Kuznets inverted-U relationship between income inequality and development. Dasgupta et al. (2002) describe the process as conceived by the “conventional” explanations for the inverted-U relationship as follows: “In the first stage of industrialization, pollution … grows rapidly because people are more interested in jobs and income than in clean air and water, communities are too poor to pay for abatement, and environmental regulation is correspondingly weak. The balance shifts as income rises. Leading industrial sectors become cleaner, people value the environment more highly, and regulatory institutions become more effective. Along the curve, pollution per capita levels off in the middle-income range and then falls toward pre-industrial levels in wealthy societies.”

2.1 Empirical Testing of the EK Curve, Debates

The issue of the EK curve was first discussed in the World Bank’s 1992 World Development Report (World Bank, 1992). Since the World Bank’s report, there have been numerous empirical tests and theoretical debates on the EK curve. Empirical evidence has been accumulating, supporting the validity of the EK curve for some regions and environmental problems. Grossman and Krueger (1995) found an EK-curve relationship between the per capita GDP and urban air quality (the concentration of suspended particulate matter (SPM) and sulfur dioxide (SO_2)), while Selden and Song (1994) discovered the existence of an EK-curve relationship for the aggregate emissions of SPA, SO_2, oxides of nitrogen and carbon monoxide. The theoretical works have also shown that an environmental Kuznets curve can result if a few plausible conditions are satisfied as income increases in a society. At the first stage, Grossman and Krueger (1991) argued that economic growth affects the quality of environment in three different channels of scale effects, technological effects, and composition effects. Lopez (1994) used a fairly general theoretical model to show that if producers pay the social marginal cost of pollution, then the relationship between emissions and income depends on the properties of technology and preferences. Stokey (1998) made a theoretical contribution to the explanation of the EK curve using dynamic growth models.

Since the mid 1990s, however, the EK curve has been attacked on empirical, methodological, and interpretative grounds. From an empirical aspect, Shafik (1994) presented more ambiguous results, seemingly implying that the EK curve may not hold at all times and for all pollutants. Furthermore, empirical research has been limited to the environmental problems for which data exist, such as the concentration of pollutants in urban areas. It has also methodologically been shown that the very existence of an EK curve is questionable; the EK curve may well arise as a “methodological artifact” (Nahman and Antrobus 2005). The methodological problem of cross-sectional approach will be discussed later. One of the most damaging criticisms of the EK curve that advocates caution in interpreting its causes and implications is based on the linkage between the EK curve and the international trading of industrial goods. Suri and Chapman (1998) and Rothman (1998), notably, argued that the EK curve might arise due to the relocation of “dirty” industries to developing countries as a country reaches higher levels of development. Nahman and Antrobus (2005) stated that the EK curve may thus be no more than a “historical artifact.”

2.2 Frontiers of EK-Curve Studies

Most of the empirical studies so far have concentrated on validating the EK curve hypothesis and its requirements, using cross-sectional data. This cross-sectional approach adopted by most studies might, as Borghesi (1999) argued, be misleading, since environmental degradation is generally increasing in developing countries and decreasing in industrialized ones; the EK curve within the cross-sectional framework might reflect the mere juxtaposition of two opposite trends rather than describe the evolution of a single economy over time.

One of the frontiers of EK-curve studies, thus, is to examine the EK curves of specific countries using time-series data, to compare them in terms of the height and timing of their peaks, their shapes, etc., and to investigate the causes of different EK-curve patterns. De Bruyn et al. (1998), noticing that conventional cross-section estimation techniques have generated spurious estimates of the EK curve, estimated time series models individually in four countries (the Netherlands, the UK, the US, and then-West Germany) for three types of emissions (CO_2, NO_x, and SO_2) and showed that the time patterns of these emissions correlate positively with economic growth, and that emission reductions may have been achieved as a result of structural and technological changes in the economy. Irie et al. (2000) tested the empirical validity of the EK curves of individual countries for SO_2, using relevant time-series data from 30 developed countries (OECD countries and the former Soviet Union). The main findings were that 1) the EK curves were verified for SO_2 emissions in 17 countries, 2) the EK curves varied in the shape of their trajectories and the height and timing of their peaks, and 3) the differences in height can be explained by five factors: the technology available in the country, the scale of the economy, the quality of the fuel used, the leading industries, and the political system.

This time-series approach has been developed, as Dasgupta et al. (2002) argued, to examine the hypothesis that developing societies, by utilizing progressive environmental management and the technologies of more advanced countries, might be able to experience an EK curve that is lower and flatter than what conventional wisdom would suggest; they might be able to develop their economies from low levels of per capita income with little degradation in environmental quality, and then at some point experience improvements in both income and environmental quality. Concerning environmental management, Panayotou (1997)—formulating a tentative equation for a sample of 30 developed and developing countries for 1982-1994—found that effective policies and institutions can significantly reduce environmental degradation at low income levels and speed up improvements at higher income levels, thereby lowering the EK curves, at least for ambient sulfur dioxide levels. Matsuoka et al. (2000) compared the EK curves of various Asian countries and explained the differences in their height by the dissemination of environmental monitoring systems in those countries. As for environmental technology, Martin and Wheeler (1992) argued that, because increased openness to trade tends to lower the price of cleaner imported technologies while increasing the competitive pressure to adopt them, firms in relatively open developing economies adopt cleaner technologies more quickly.

One counter-argument to this hypothesis of the latecomer's advantage is the well-known "pollution heaven" hypothesis. For example, Dasgupta et al. (2002) argues that the relatively high environmental standards in high-income economies impose high costs on polluters, and shareholders pressure the firms to relocate to low-income countries, whose people are so eager to get jobs and income that their environmental regulations are weak or nonexistent. The scenario may not shift the latecomers' EK curves downward; on the contrary, it may even lift them.

2.3 Application of the EK curve analyses to China, Our position

Although there has been a large body of literature on the EK curve studies for several countries and for several environmental quality indices as shown above, it is in recent times that the studies on the EK curve of China have increasingly appeared in the literature. Shen and Hashimoto (2004) investigated whether the EK curve hypothesis may exist on a country level by using the cross-province panel data of the seven pollutants of China, and found that the EK curve hypothesis is verified in five of these pollutants, while the other two reveal an N-shape relationship between pollutant emission and per capita income. Liu et al. (2007) showed that, by utilizing environmental monitoring data from Shenzhen on concentration of pollutants in ambient air, main rivers, and near-shore waters from 1989 to 2003, production-induced pollutants support EKC while consumption-induced pollutants do not. Shen (2006), by using Chinese provincial data from 1993 to 2002 to investigate the relationship between per capita income and per capita pollutant emission based on a simultaneous equation model, reported that an EKC relationship is found in COD, arsenic, and cadmium emissions, but SO2 shows a U-shaped curve and "dust fall" indicates no relationship. Song et al. (2008), the latest study in the literature, re-examined the relationship between environmental pollution and economic growth in China through a sophisticated method of a panel cointegration approach with Chinese provincial data over 1985-2005. They found that there is a long-run cointegrating relationship between the per capita emission of waste gas, waste water, and solid wastes and the per capita GDP; all three of these pollutants are inverse U-shaped.

All these studies discussed above stay at the stage of examining the validating the EK curve hypothesis and its requirements, but do not appear to step into the analysis of the shift of the EK curve. This article, with a focus on regional environmental states in China, tries to examine the shift of Chinese provincial EK curves and to verify the existence of the latecomer's advantage or disadvantage in underdeveloped provinces in the area of environmental management and technology. Our contribution to the EK curve literature may consist in the sub-regional analysis within China in the context of the environmental latecomer's effects. As regional environmental indices, the per capita emission of waste water, waste gas, and solid wastes in the provincial level will be examined in the following section.

3. Empirical Studies

We now turn to the empirical studies within the analytical framework of the environmental Kuznets curve. Our analysis consists of two steps. First, we will simply overview the relationships between per capita real GDP and environmental indices in Chinese provinces. We then move to a regression analysis using provincial panel data to examine the existence of the EK curve pattern and to see whether the latecomer's advantage or its disadvantage dominates in the environmental management of undeveloped Chinese provinces.

3.1 Data

In our empirical analysis, we collect data from 29 provinces in mainland China from 1988 to 2007. All provincial data are available in the China Statistical Yearbook. We select 29 of the 31 provinces under the administration of the central government: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. ChongQing and Tibet are excluded because ChongQing data have been separated from Sichuan data in 1996 or 1997 and Tibet data are not available in most years.

We use the provincial gross domestic product per capita (yuan) as the economic indicators, and the provincial industrial emissions per capita as the environmental indicators: waste water (ton), waste gas (cubic meter), and solid waste generated (ton). Industrial waste gas emissions per capita have three components: sulfur dioxide discharged (ton), soot discharged (ton), and dust discharged (ton). Considering that provincial GDP data included in the Yearbook are at current prices, they have to be converted into fixed prices. We adjusted all provincial GDP data by deflating the provincial Consumer Price Index in 2000.[1]

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[1] The data of waste gas are from 1988 to 2005. The population in 1994 is estimated by taking the arithmetic average of the population in 1993 and 1995 because the data in 1994 are not available.

3.2 Overview of the Time-series EK Curves in Sample Provinces

Figure 1 indicates the time-series relationships between per capita real GDP and environmental indices in main samples of Chinese provinces. It is in the case of waste water that the assembly of the provincial trajectories clearly creates inverted-U shape patterns. The locations of trajectories represent a clear contrast: the downward shifts from the higher income provinces to the lower income provinces are observed in the case of waste water, while upward shifts are seen in the cases of waste gas and solid waste. The GDP-emissions relationships described above may produce different implications among waste water, waste gas, and solid waste. This point will be statistically clarified through a panel estimation in the following section.

3.3 Regression Analysis Using Provincial Panel Data

We'll now move to a regression analysis using provincial panel data to examine the existence of the EK curve pattern and to see whether the latecomer's advantage or its disadvantage dominates in the environmental management of undeveloped Chinese provinces.

3.3.1 Methodology

We will first clarify some methodological points related to our analysis. To study the relationship between pollution and growth, there are two possible approaches to model construction. One is to estimate a reduced-form equation that relates the level of pollution to the level of income. The other is to model the structural equations relating environmental regulations, technology, and industrial composition to GDP, and then to link the level of pollution to the regulations, technology, and industrial composition. We here take the reduced-form approach for the following reasons. First, the reduced-form estimates give us the net effect of a nation's income on pollution. If the structural equations were to be estimated first, one would need to solve backward to find the net effect. Moreover, confidence in the implied estimates would depend on the precision and potential biases of the estimates at every stage. Second, the reduced-form approach spares us from having to collect data on pollution regulations and the state of the existent technology, which are not always available. Although a reduced-form relationship gives no indication of the direction of causality—namely, whether growth affects the environment or the other way around—we think that the reduced-form relationship between pollution and income is an important first step.[2]

We then specify the reduced-form equation in accordance with our analytical interests. Our specific concern regarding the EK curves for the sample provinces in China is whether the provincial EK-curve trajectories have shifted downward or upward, depending on the dominance of either the latecomer's advantage or its disadvantage[3]; in other words, whether the levels of environmental pollution have been affected not only by the level of per capita income following the EK curve, but also by the speed of development among the provinces. If a sample province reaches a certain level of development later among the provinces and then lowers its environmental pollutants, we speculate that the province does not repeat the EK-curve trajectories already experienced by the developed provinces; it should enjoy the latecomer's advantage by absorbing the progress in environmental know-how, skills, and technology. On the contrary, if the later development in sample provinces is linked with higher pollution, the provinces may suffer from the disadvantage caused by the "pollution heaven" scenario. Therefore, we will include a term representing the speed of development among the provinces into the ordinary regression model of the EK curve, to identify the regional latecomer's effects. The speed of development of a sample province in a certain year is specified as the ratio of the GDP level of that province relative to the maximum GDP level among provinces (equivalent to the GDP of Shanghai province) in that year.

Another variable that seems to be important in the time-series EK curve analysis is concerned with a nation-wide time effect in environmental management and technology. For example, the more recent, the more technological transfer China may have received as a developing country, or the more pollution China may have suffered from through the "pollution heaven" scenario in the world. The variable on a nation-wide time effect can be specified as a time-trend, which is simply represented by the number of year.

In a sense, the latecomer's effects in China's environmental management and technology appear to be divided into two effects: a *regional* latecomer's effect, depending on the speed of provincial development, and a *national* latecomer's effect, shown as a nation-wide time effect — because a nation-wide time effect is caused by the fact that China is a developing country.

Based on analytical interests mentioned above, we specify the modified EK curve

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[2] Grossman and Krueger (1995), and Selden and Son (1994), which we introduced in reviewing previous studies, also estimate a reduced-formed equation.

[3] As Dasgupta et al. (2002) showed, the revised EK curve that is actually dropping and *shifting to the left* as growth generates less pollution in the early stages of industrialization and pollution begins falling at lower income levels, the latecomer's effects may not always be tantamount to a simple up- and downward shifts of the EK curve. For example, price changes of emission abatement technology may have the EK curve shift to the right or left, rather than to the upper and lower. We here simplify the analysis by focusing on up- and downward shift of the EK curve.

model as follows.

$$\mathbf{EMS_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDP^2_{it} + \alpha_3 SPEED_{it} + \alpha_4 YEAR_{it} + \mathit{e}_{it}} \qquad (1)$$

where **i** is the province index, **t** is the time index, and ***e*** is the error term. The dependent variables **EMS** is measure of the per capita industrial emissions: waste water (**WWP**), waste gas (**WGP**), and solid waste generated (**SWP**). The per capita waste gas emissions has three components: sulfur dioxide discharged (**SUP**), soot discharged (**SOP**), and dust discharged (**DUP**). As for the independent variables, **GDP** is the real provincial GDP per capita. **SPEED** represents the speed of provincial development, specifically the ratio of the GDP level of a certain province relative to the maximum GDP level among provinces in a certain year. **YEAR,** a nation-wide time effect in environmental management and technology, is indicated by number of year as a time trend.[4]

To verify the inverted-U shapes of the EK curves, the signs and magnitudes of $\boldsymbol{\alpha_1}$ and $\boldsymbol{\alpha_2}$, the coefficient of **GDP** should be examined. Environmental emissions can be said to exhibit a meaningful EK curve with the real GDP per capita, if $\boldsymbol{\alpha_1 > 0}$ and $\boldsymbol{\alpha_2 < 0}$, and if the turning point, $\boldsymbol{-\alpha_1/2\alpha_2}$ is a reasonably low number. Of particular importance is the coefficient of **SPEED**, $\boldsymbol{\alpha_3}$, which is useful for identifying the dominance of the latecomer's advantage or its disadvantage at the provincial level. The positive sign of $\boldsymbol{\alpha_3}$, the downward shift of the trajectories, indicates that the latecomer's advantage surpass its disadvantage, while the negative sign of $\boldsymbol{\alpha_3}$, the upward shift of the curve, reveals the dominance of the latecomer's disadvantage. The coefficient of **YEAR,** $\boldsymbol{\alpha_4}$ would have negative sign in case that China, as a nation, enjoys the nation-wide technological progress and positive sign when she suffers from the "pollution heaven" effect in the world.

Apart from real GDP per capita, speed of development, and nation-wide technological progress, there are also likely to be exogenous factors that affect emissions. For instance, climate and geography vary widely among provinces and may well be correlated with emissions. Insofar as these factors cause the error term ***e*** to be correlated among provinces for a given period, pooled cross-section estimates that ignore this correlation will be inefficient. To address this issue, we must specify an error-components model, in which:

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[4] The EK curve equation often includes the variable of population density as a regional effect (Selden and Song (1994) etc.). Our model, however, does not include population density, because population density and SPEED were proven to be linearly dependent.

$$\boldsymbol{e}_{\mathbf{it}} = \boldsymbol{r}_{\mathbf{i}} + \boldsymbol{u}_{\mathbf{it}} \qquad (2)$$

where $\boldsymbol{r}_{\mathbf{i}}$ is the province effect, and $\boldsymbol{u}_{\mathbf{it}}$ is the remaining error term. In choosing between fixed-effects and random-effects estimation, an important issue is whether the province effect is correlated with the explanatory variables. In the absence of such a correlation, random-effects estimation is consistent and efficient. In contrast, if such a correlation exists, there may be omitted-variable bias, necessitating fixed-effects estimation. According to the statistics of the Wu-Hausman test (Hausman 1978), which is used to help choose between these two approaches, we use a random-effects estimation on all emissions (see Table 1-1).

3.3.2 Estimation Results and Interpretations

Table 1 lists the results of the estimation on the per capita industrial emissions of waste water, waste gas, and solid waste generated. First, we must verify the shape of the EK curve of each emission index. In all the cases, the estimates for the coefficients $\boldsymbol{\alpha}_1$ and $\boldsymbol{\alpha}_2$ have the signs of the inverted-U shapes, which are different from zero as high levels of significance, and the turning point indicates a feasible number around 30,000 yuan per capita. All the indices for the industrial emissions can, therefore, be said to reflect a meaningful, inverted-U shaped EK curve with the real GDP per capita in sample provinces. Second, we must see if the trajectories show a downward shift or an upward shift, namely whether the regional latecomer’s advantage or its disadvantage dominates in the environmental management of latecomer’s provinces. In the case of waste water, the estimate for the coefficient of **SPEED**, $\boldsymbol{\alpha}_3$, is positive and discernable, thereby representing the downward shift of the trajectories and the dominance of the regional latecomer’s advantage. On the other hand, the case of total waste gas and solid waste generated has the negative and discernable coefficient of $\boldsymbol{\alpha}_3$, showing the upward shift of the trajectories, the dominance of the regional latecomer’s disadvantage. Third, we must identify a nation-wide time effect in environmental management and technology. In the case of waste water, sulfur dioxide discharged and soot discharged, the coefficient of **YEAR**, $\boldsymbol{\alpha}_4$, is negative and discernable, thereby representing the nation-wide technological progress – national latecomer’s advantage.

The estimation results above can be interpreted as follows. First, the provincial panel data proved the validity of the EK curve hypothesis in all the industrial emissions in China.

Second, the regional latecomer’s advantage was verified in the case of waste water discharged, while its disadvantage was identified in waste gas emissions and solid waste generated. The contrasting result appears to come from two backgrounds concerning environmental policy performances against each emission. One is about the difference in the timing of when the regulatory legal framework was formulated. The water pollution prevention and control law was promulgated in 1984 at the earliest stage in the series of environmental policy actions, while the air pollution prevention and control law and the solid waste pollution prevention and control law were promulgated later in 1987 and 1995 respectively (World Bank, 2001) . The other is concerned with the difference in the effectiveness of policy actions. The pollution levy system, covering the pollution charges for water, air and solid waste, is one of the most representative pollution control policies. However, the system is often criticized for having design deficiencies: pollution fees are often lower than the marginal cost of abatement required to meet emission standards, and pollution levies are assessed only on above-standard emissions. Industrial enterprises choose to remain noncompliant and pay the levy only on their excess pollution (World Bank, 2001). As far as the levy on water pollution is concerned, however, its level is reported to be higher than the marginal abatement costs in many cases (Wang and Wheeler, 1996), and also to have been assessed not on above-standard emission but on total volume of emissions since 1993 (Matsuoka, 2000). In these senses, water pollution control may have been mature and well-designed compared with the air and solid waste pollution control. This difference in policy performances may have created the contrasting result on regional latecomer's effects between the case of waste water and that of waste gas and solid waste. Regional latecomers may have enjoyed the dissemination effects of nation-wide progress in water pollution control, while the latecomers may have stayed behind from the progress or even suffered from the "pollution heaven" effect in air and solid waste pollution. In cases where pollution leakage among provinces occurs in the area of waste gas emission and solid waste, the estimated EK curve with inverted-U shapes may be unsustainable, namely a "historical artifact."

Third, nation-wide technological progress—the latecomer's advantage in environmental management and technology at a national level—was identified in the case of waste water, sulfur dioxide discharged, and soot discharged. The effect seems to reflect the fact that China, as a developing country, is obtaining the technological transfer in water and air pollution control from advanced countries through governmental cooperation and private direct investment. For example, the Japanese government has provided official development aid (ODA) in the area of environmental protection, including air and water pollution control, as a top priority. Especially, the "Environmental Development Model City Project," which has been promoted since 1997 based on Japan-China governmental agreement, has contributed to the enhancement of acid rain preventive measures and the measures for effective use of desulfurized by-products (OECC, 2001).

4. Concluding Remarks

In this study, using the analytical framework of the EK curve, we set out to examine, with a focus on regional environmental states in China, whether regional latecomers enjoy the spillover effects of nation-wide progress in environmental management and technology, or stay behind from environmental progress, or even suffer the "pollution heaven" effects through the relocation of polluters toward those regions. The analysis focused on such industrial emissions as waste water, waste gas (sulfur dioxide discharged, soot discharged, and dust discharged as its components) and solid waste in Chinese provinces. We carried out a regression analysis using provincial panel data to examine the existence of the EK curve pattern and to see whether the latecomer's advantage or its disadvantage dominates in the environmental management of undeveloped Chinese provinces.

The study's main findings are as follows. First, the provincial panel data proved the validity of the EK curve hypothesis in all the industrial emissions in China. Second, the regional latecomer's advantage was verified in the case of waste water, while its disadvantage was identified in waste gas and solid waste. Third, a nation-wide technological progress—the national latecomer's advantage—was identified in the case of waste water, sulfur dioxide, and soot. We speculate that the contrasting result on regional latecomer's effects between waste water, waste gas, and solid waste comes from the difference in policy performances: the mature and well-designed water pollution control may have regional latecomers enjoy the spillover effects of nation-wide progress, while the premature and ineffective control of air and solid waste pollution may cause the pollution leakage on regional latecomers. We also presume that nation-wide technological progress in waste and air pollution control may reflect the fact that China, as a developing country, is obtaining technological transfers from advanced countries. The results imply the urgent necessity to enhance the policy performances on the air and solid waste pollution control to make the EK curve pattern sustainable.

However, this study may only be an initial step in the analysis of the environmental latecomer's effects in Chinese provinces. Analytical issues still remain that need to be addressed. First, the EK curve estimation model might be more sophisticated in terms of adopting dynamic panel modeling with the semi-parametric generalized additive model framework (see Auffhammer and Carson, 2008). Second, another challenge is to have our analysis focus on environmental policy performances. We can insert policy variables into the EK curve estimation model and conduct policy simulation in terms of shifting the EK curve (see Panayotou , 1997).

Figure 1. The EK curve on waste water, waste gas, and solid waste in main provinces

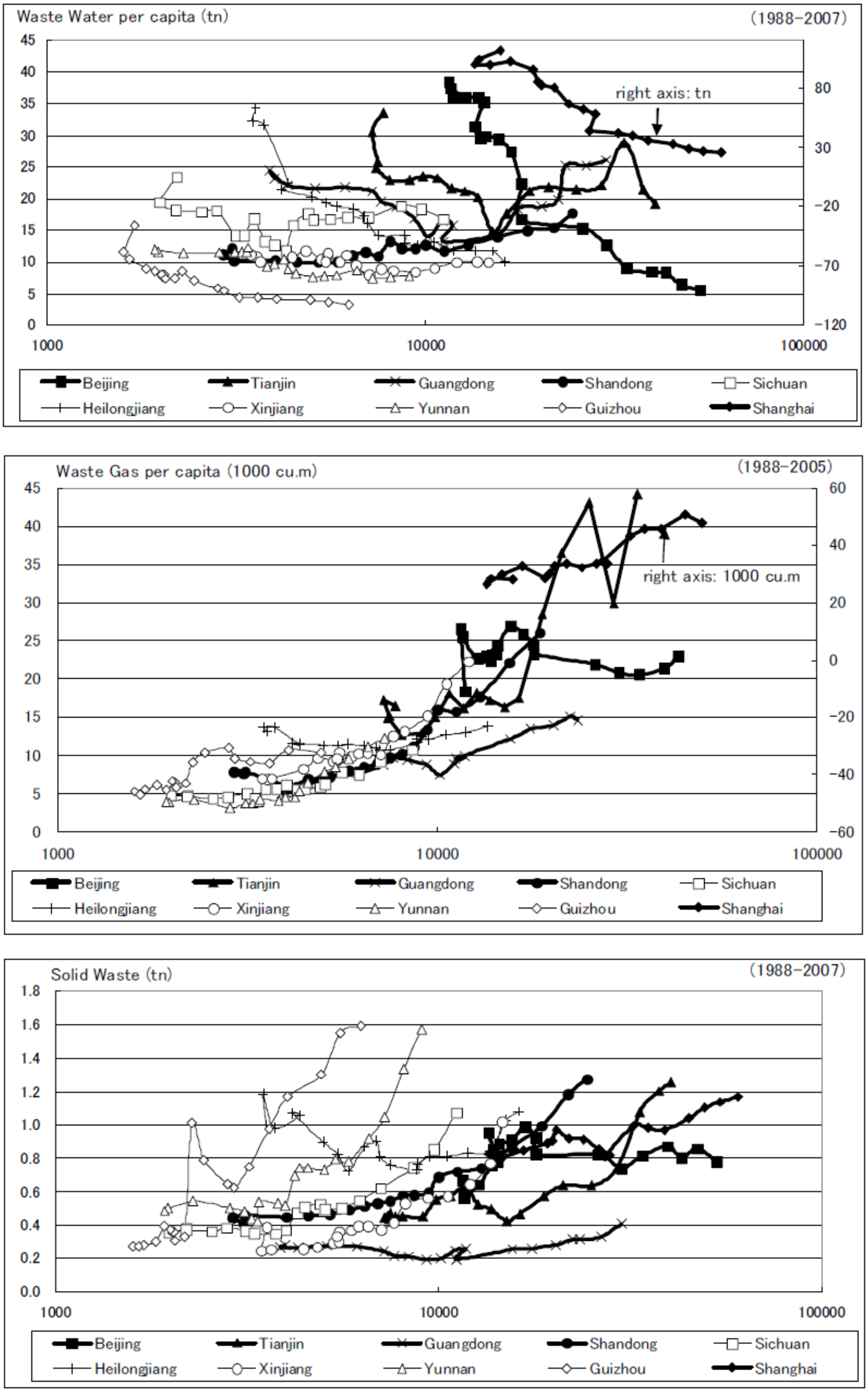

Table 1-1. Estimation results using provincial panel data

Variables	Waste Water (ton)	Waste Gas (1000 cubic meter)	Solid Waste (ton)	Among Waste Gas		
				Sulfur (ton)	Soot (ton)	Dust (ton)
Const.	$1.96*10^{3***}$	$1.25*10^{2}$	-2.41	0.29	0.32^{**}	0.08
	(10.12)	(0.80)	(-0.25)	(1.87)	(2.34)	(0.63)
GDP	$1.63*10^{-3***}$	$1.95*10^{-3***}$	$8.94*10^{-5***}$	$9.76*10^{-7***}$	$2.59*10^{-7*}$	$1.75*10^{-7}$
	(7.71)	(9.56)	(8.31)	(5.75)	(1.76)	(1.23)
GDP^2	$-3.66*10^{-8***}$	$-2.53*10^{-8***}$	$-1.24*10^{-9***}$	$-1.81*10^{-11***}$	$-5.56*10^{-12***}$	$-4.54*10^{-12**}$
	(-12.33)	(-7.63)	(-8.23)	(-7.64)	(-2.68)	(-2.26)
SPEED	31.5^{***}	$-1.28*10^{***}$	-1.12^{***}	$2.17*10^{-3}$	$-4.85*10^{-3}$	$-5.67*10^{-3}$
	(5.02)	(-2.63)	(-3.21)	(0.39)	(-1.13)	(-1.58)
YEAR	-0.98^{***}	-0.06	$1.45*10^{-3}$	$-1.41*10^{-4*}$	$-1.55*10^{-4**}$	$-3.81*10^{-5}$
	(-10.10)	(-0.77)	(0.30)	(-1.82)	(-2.28)	(-0.57)
Adj R^{**2}	0.46	0.57	0.44	0.18	0.04	0.02
Turning Point	$2.23*10^{4}$	$3.85*10^{4}$	$3.6*10^{4}$	$2.7*10^{4}$	$2.33*10^{4}$	$1.93*10^{4}$
<the Wu-Hausman Test>						
Chi-Sq. Statistic	7.65	0.00	1.01	4.12	0.1	0.12
Chi-Sq. d.f.	4	4	4	4	4	4
Prob.	0.11	1.00	0.90	0.39	1.00	1.00
Estimation Type	Random	Random	Random	Random	Random	Random

Table 1-2. Summary of estimation results

Variables	Waste Water	Waste Gas	Solid Waste	Sulfur	Soot	Dust
EK curve	Inverted-U	Inverted-U	Inverted-U	Inverted-U	Inverted-U	Inverted-U
Latecomer's Effect						
Regional	Advantage	Disadvantage	Disadvantage	-	-	-
National	Advantage	-	-	Advantage	Advantage	-

Note:

The T-value is shown in parenthese.

One, two, or three asterisks indicate that a coefficient estimate is significantly different from zero at 10, 5, or 1% percent level, respectively.

Sources: China Statiscal Yearbook(1889-2008)

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