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Economic Growth and Environmental Quality:

A Case Study from Industrial Sulfur Dioxide Provincial Panel Data in China

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Ⅰ. Introduction

Since the late 1970s, China's transformation from command-and-control to a market-based economy and open policy has accelerated the economic development. During the last two decades, the annual economic

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growth rate is averagely close to 10%. In 2005 China's gross domestic product (GDP) is 18,232 billion RMB (US$2,120 billion), while it was only 362,410 million RMB in 1978, and GDP per capita (GDPPC) has been US$ 1,703, which means China has become one of the most important world economic powers.

Meanwhile, the rapid economic growth in China has brought about large energy consumption and environmental problems (Qu, 1995). In 2005, China consumed 12% of the world's energy, second only to the U.S. which consumed 25%. As is reported, to produce US$1 of GDP, China expends 3 times the world average of energy, 4.5 times of the OECD level and 10 times of the Japanese level (Dai, 2002; Zhao, 2005; Ni, 2002). According to Bulletin of Chinese Environment Condition 2005, more than 50% alongshore water quality was at bank Ⅲ or even worse; nearly 40% cities air quality did not meet the standard Ⅱ and the main rivers were mostly polluted; total emission of SO_2 was up to 22.50 million ton, of which industrial SO_2 discharge accounted for 85.06%, and acid rain had become one of the most severe environmental problems in China. The area of acid rain control zone and SO_2 control zone is up to more than 11% of the whole country.[1)]

The Environmental Kuznets Curve (EKC) hypothesis-an inverted U-shape relation between various indicators of environmental degradation and income per capita-has become one of the 'stylized facts' of environmental

1) The acid rain control zone covers the areas where the pH value of precipitation is lower than 4.5, sulfur deposition exceeds the critical load and the SO_2 emissions are large. The SO_2 control zone ph<5.6 acid rain control zone. The SO_2 control zone includes areas whose average sulfur dioxide concentration exceeds the standard level. The SO_2 control zone is mainly located in the north and the acid rain control zone is mostly in the south.

and resource economics (Stokey, 1998). Although a large body of literature on the EKC phenomenon for many countries and for many environmental quality indices, little is known about China (Jordi, 2001; Dinda, 2004).

This paper will take industrial sulfur dioxide as example, and statistically analyze relationship between industrial sulfur dioxide emission and economic growth by using EKC model with 28 provincial data. The paper will also explore the potential solutions that will help achieve harmonious development between economic growth and environmental quality.

Ⅱ. Methodology

1. The Model

Based on the existing research of China's SO_2 pollution, the paper chose the classic EKC model. The authors take industrial sulfur dioxide emission data as dependent variable and GDPPC as independent variable to establish model. As the research covers almost all the provinces in China mainland, fixed effects regression model is preferred to the random effects regression model. And through the Hausman Test, an entity fixed effects regression model is finally chosen to reflect the general situation. The model is as follows:

$$S_{it} = a_0 + a_1 Y_{it} + a_2 Y_{it}^2 + \delta_{it} \quad (1)$$

where subscript i denotes province and t year. S denotes industrial sulfur dioxide in year t for province i. Y is GDPPC. a_0, a_1, a_2 are coefficients, and δ denotes stochastic error term.

2. Data

We compile a panel data set for the twenty-eight provinces of China inland(see the <Appendix>); as lack of data, it does not include Tibet and Hannan, and takes Sichuan and Chongqing as just one province.[2] The data comes from different sources, including the China Environment Yearbooks from 1990 to 2005, Chinese Statistical Yearbook from 1990 to 2005, China City Statistical Yearbook and some local statistical yearbooks. The max possible error of the data is proved to be less than 5%. All the provincial GDPPC is calculated at 1978 price.

Ⅲ. Results and Discussion

The result is shown in <Table 1>. From it, we can find that weighted F-statistic and t-statistics are all significant, and the adjusted R^2 shows it fits well. For a_2 (coefficient of Y_{it}^2) is negative, while a_1 (coefficient of Y_{it}) is positive, the EKC hypothesis is possibly conforming to China

2) Before 1997, Chongqing was one of cities in Sichuan province, while since 1997 Chongqing has become municipality directly under the Central Government. To ensure dada consistency from 1989 to 2004, the authors take Sichuan and Chongqing as a province in this paper.

in the study of industrial sulfur dioxide.

From <Table 1>, we can calculate the turning point $(-a_2/2a_1)$ is about RMB13, 548 (at 1978 price). Compared with other countries' research results, this turning point (about US$6,230, at 1985 US dollars price) in China is some what lower, they may partly because China central and local government have learned lessons from other countries experiences and emphasis environmental management to some extent. In 2004, the GDP per capital of 28 provinces are from RMB 1,198 to 24,129 (at 1978 price), and the average is 4,642. Only the city of Shanghai has passed the turning point, which means most provincial industrial sulfur dioxide emission will be still increasing in the near future.

The groupings of GDPPC in the 28 provinces in 2004 were shown in <Table 2>. Only the GDPPC of Shanghai, Beijing and Tianjin have been up to 10,000 or higher (at 1978 price). By contrast, 50% of these 28 provinces' GDPPC are less than 3,000 (at 1978 price). Just think about reaching the turning point, there is still a long way to go. Meanwhile, these provinces lower than 3,000 are mainly located in min-western China. So to control the industrial sulfur dioxide emission in the economic promotion in these areas is a urgent and serious task. If the increasing trend of sulfur dioxide emission in mid-western provinces could be well controlled, the total amount of industrial sulfur dioxide emission in whole mainland would be less considerably. Thus China can surmount the peak of industrial sulfur dioxide emission with much lower predicted amount.

〈Table 1〉 Regression Results of Industrial Sulfur Dioxide Omission and GDP Per Capita

Variable	Coefficient	Std. Error	t-Statistic
Y	0.006530	0.000405	16.12895***
Y2	-2.42E-07	2.22E-08	-10.91845***
Fixed Effects- a_0			
ANHUI	26.68592	BEIJING	-12.52860
FUJIAN	3.796249	SHANDONG	132.9956
GANSU	24.25160	SHANGHAI	-0.837689
GUANGDONG	47.96326	SHANXI	67.60293
GUANGXI	55.69146	SICHUAN	118.6599
GUIZHOU	51.77813	TIANJIN	-6.470626
HEBEI	86.68369	XINJIANG	9.510372
HEILONGJIANG	11.56030	YUNNAN	20.14296
HENAN	54.13612	ZHEJIANG	32.31443
HUBEI	35.80957	MONGOLIA	51.68372
HUNAN	48.38623	NINGXIA	8.938429
JIANGSU	82.61929	QINGHAI	-4.980621
JIANGXI	21.00517	SHAANXI	46.67797
JILIN	9.117401	LIAONING	57.70623
Weighted Statistics		Unweighted Statistics	
Adjusted R-squared	0.933820	Adjusted R-squared	0.897917
F-statistic	6336.318***	F-statistic	4000.602***

Note : *** denotes 1% significance level.

〈Table 2〉 The Groupings of GDP Per Capital in the 28 Provinces in 2004 (at 1978 price)

GDP Groupings	< RMB3,000	RMB3,000-6,000	RMB6,000-10,000	> RMB10,000
Provinces	Anhui, Jiangxi Henan, Hunan Shanxi, Shaanxi Ningxia, Gansu Guangxi, Qinghai Guizhou, Yunnan Sichuan, Neimenggu	Hebei, Liaoning Jilin, Heilongjiang Fujian, Shandong Hubei, Xinjiang	Jiangsu, Guangdong, Zhejiang	Beijing, Tianjin Shanghai

Ⅳ. Conclusions and Suggestions

In this paper, the authors select the classic EKC model to examine the relationship industrial sulfur dioxide emission and economic growth using province-panel data set from 1989 to 2004 in 28 provinces of China inland. The regression result shows that industrial sulfur dioxide maybe confirm to the EKC hypothesis, while the turning point in term of GDPPC is RMB 13,548 (at 1978 price). Because the GDPPC of all provinces except for Shanghai is lower than that, it denotes that industrial sulfur dioxide emission will keep increasing in the near future.

To achieve the harmonious development between economic growth and environment protection, reduce the industrial sulfur dioxide emission, there is still a long way to go for China government. Increasing environmental

protection investment, which is only 1.31% in 2005, to 2% or even higher of GDP in China, adjusting industrial structure and changing traditional development pattern which is characteristic of high investment, high consumption of resources and energy, wasteful processing operations, serious environmental pollution and low profit, implementing circular economy and cleaner production, raising environmental protection awareness by propagandizing and education, adopt advanced technical matters and equipments are all the key points the decision maker should consider seriously.

〈Appendix〉 Province in the Study

1. Beijing	2. Heilongjiang	3. Jilin	4. Liaoning
5. Zhejiang	6. Hebei	7. Henan	8. Tianjin
9. Shandong	10. Jiangsu	11. Anhui	12. Shanghai
13. Neimenggu	14. Jiangxi	15. Fujian	16. Gansu
17. Guangxi	18. Hunan	19. Shaanxi	20. Guizhou
21. Yunnan	22. Qinghai	23. Shanxi	24. Ningxia
25. Xinjiang	26. Sichuan (Chongqing)	27. Guangdong	28. Hubei

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The Environmental Kuznets Curve Hypothesis postulates an inverted-U shaped relationship between GDP per capita and various pollutants. Pollutants emission increases up to a certain level as income goes up; after that, it decreases. This paper investigates the relationship between industry pollutants taking industrial sulfur dioxide omission as example, and economic growth by using province-panel data set from 1989 to 2004 in 28 provinces of P. R. China. The result shows that the EKC hypothesis may be supported in the case of industrial sulfur dioxide, and the GDP per capital of turning point is about RMB 13,548 (at 1978 price). Except Shanghai, all the provinces GDP per capital in this study are less than RMB 13,548, indicating the amount of industrial sulfur dioxide emission will be increasing in the near future. To realize sustainable development and pollutants abatement, the central and local government should adopt an integrated strategy to protect environment.

Keywords : Environmental Kuznets Curve, economic growth, environmental quality, sulfur dioxide, China