Economic Growth and the Environment in China[1]

——An Empirical Test of the Environmental Kuznets Curve Using Provincial Panel Data

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Abstract: Environmental pollution is an important issue in the process of economic growth. This paper is to test the availability of the Environmental Kuznets Curve in China using reduced form model based on provincial panel data. By analyzing the relationship between GDP per capita and the emissions of five kinds of industrial pollutants (solid wastes, waste water, so_2, soot and smoke), we conclude that the relationship varies on the types of pollutants and regions. In order to make the harmonized development, environmental regulation needs to be strengthened.

Key words: Environmental Kuznets Curve, Economic Growth, Environmental Pollution

1 Background

Environmental pollution is an important issue in the process of economic growth. Since the adoption of reform and open policies in 1978, the People's Republic of China (hereinafter, China) has obtained remarkable economic growth with an average annual growth rate of 9.6%[2] in gross domestic product (GDP) from 1979 to 2004. Despite the impressive economic performance, the environment qualities have become worse and worse during the past two decades. The deterioration of environment begins to have direct impact on the quality of human life, or even a threat to the survival of mankind. More and more attentions have been brought to environmental issues in China in recent years. People began to think about the following questions: Will the high economic growth be able to sustain within environmental constraints or without exceeding ecological threshold? What is the effect of economic growth on environment quality? Are there any tradeoffs between attaining high economic growth and protecting environment? And will the environment conditions become improved automatically at higher income levels? If so, what is the turning point in China? What should the government do to the environmental degradation?

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[2] The figure is based on amended GDP figures, from http://www.stats.gov.cn/zgjjpc/cgfb/t20060307_402309437.htm.

In 1991, Grossman and Krueger (1991) found that the long-term relationship between economic growth and environment quality was an inverted U-shaped curve. The phenomenon has been labeled as Environmental Kuznets Curve (EKC) by Panayotou (1993) later. The EKC hypothesizes that environment quality deteriorates with the increase of per capita income at the early stage of economic growth and gradually improves when the country reaches to a certain level of affluence. Since then, extensive empirical studies have been conducted to test the EKC hypothesis and the effect of economic growth on environmental quality is much under dispute. [①]

And most of the empirical studies are based on multi-countries. Actually "EKC hypothesis is fundamentally a within-country story"[②] , but cross-countries analysis assumes that all cross-section countries react identically no matter how difference in income, geographical conditions, culture and history (Dijkgraaf and Vollebergh, 1998). Only recently, some researchers have begun to use individual country to test the EKC hypothesis (De Bruyn, 2000; Unruh and Moomaw, 1998; Lekakis, 2000; Stern and Common, 2001; Cole, 2003 and so on). In fact, besides the income factor, environmental quality is also affected by other factors, such as economic structure, international trade, FDI, environmental regulation and so on, while most the empirical studies just focused on income level. Little consideration has been paid to issues of model adequacy such as the possibility of omitted variables bias (Stein, 2004). Although some researchers began to consider other factors in recent years, they just took one or two other variables into consideration[③]. Regarding these drawbacks, this paper intends to put several factors together, using panel data analysis to test whether EKC exists in China based on provincial data.

Based on provincial data of China from 1992 to 2005, this paper is aimed to test the availability of the Environmental Kuznets Curve (EKC) in China. By analyzing the relations between the GDP per capita and the emissions of five kinds of industrial pollutants (solid wastes, waste water, so_2, soot and smoke), the author intends to answer the above questions raised relative to China. In addition, this paper will study the effect of economic structural change, international trade, FDI and governmental abatement effort on environmental pollutions in China. What's more, the geographic location will also be studied in the paper, to see whether exists any difference when all provinces are considered as a whole or grouped

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[①] Some papers supported the existence of EKC (see page 5), while some other papers did not support EKC hypothesis, like Shafik (1994), Holtz-Eakin and Selden (1995), Harbaugh et al. (2000), Heil and Selden (2001), and Taskin and Zaim(2000).

[②] Deacon, R.T. and C.S.Norman, 2004. "Does the Environmental Kuznets Curve Describe How Individual Countries Behave?", Working paper, downloaded from *http://ideas.repec.org/p/cdl/ucsbec/1182.html*.

[③] See Panayotou (1997), Suri and Chapman (1998), Kaufmann *et al.* (1998), Torras and Boyce (1998), López and Mitra (2000), Bhattarai and Hamming (2000) and Merlevede *et al*. (2006).

into two regions, the east and the middle and west. Of course, some policy options concerning the principles government should insist on and measures government should take to make the harmonized and sustainable development will also be recommended at the end of paper.

2 Theoretical Framework

Theoretical explanations of the EKC hypothesis are generally based on three effects: the scale of economic activity (scale effect), the composition of economic activity or economic structure (structure effect), and pollution abatement efforts (abatement effect). The impacts of different factors, such as economic growth, technological change, international trade, FDI, environmental regulations *et al.* actually can be decomposed into the above three effects.

Along with the economic growth, the scale of an economy tends to become larger and larger. As mentioned by Grossman (1995), a growing world needs more inputs to expand outputs, which implies that wastes and emissions as by-products of the economic activities will increase. This is the so-called scale effect. Obviously, the scale of economy is a monotonically increasing function of income, when the other two effects are controlled. Meanwhile, with the economic growth, the production structure will change, from clean agrarian economies to polluting industrial economies and further to clean service economies (Arrow, *et al*., 1995). As Panayotou (1993) points out, when the production of an economy shifted mainly from agriculture to industry, pollution intensity increases. It is because more and more resources are exploited and the exhaustion rate of resources begins to exceed the regeneration speed of resources. When the industrial structure enhances further, from energy-intensive heavy industry to service and technology-intensive industries, pollution falls as income grows. This is the structure effect. It is probably to be a non-monotonic function of income, like inverted U-shape curve. Actually, technology effect goes with the structure effect. The upgrading of industrial structure needs the support from technology. Technical progress makes it possible to replace the heavily polluting technology with cleaner technology. It is the tradeoff between scale effect and technology effect that the environment deteriorates at the first industrial structural change and improves at the second industrial structural change. So the relationship between environment and economic growth looks like inversed-U curve. The downward sloping portion of the environment and economic growth may be facilitated by advanced economies exporting their pollution intensive production processes to less-developed countries (Suri and Chapman, 1998).

Some researchers try to explain the EKC hypothesis from the perspective of the stringency of environmental regulations. At the early stage of economic growth, the command of environmental pollution by the government is still very poor due to limited governmental revenue and weak environmental awareness of the whole society. Environmental quality becomes worse and worse with the economic growth because of the scale effect and structure effect. However, when the economy grows to a certain level, environmental pollution will decrease, because a series of environmental regulations are issued and implemented with the buildup of the government's financial resources and management capacities. If we simply consider the environmental management capabilities, Pollution is a monotonic decreasing function of income. This is the so-called abatement effect.

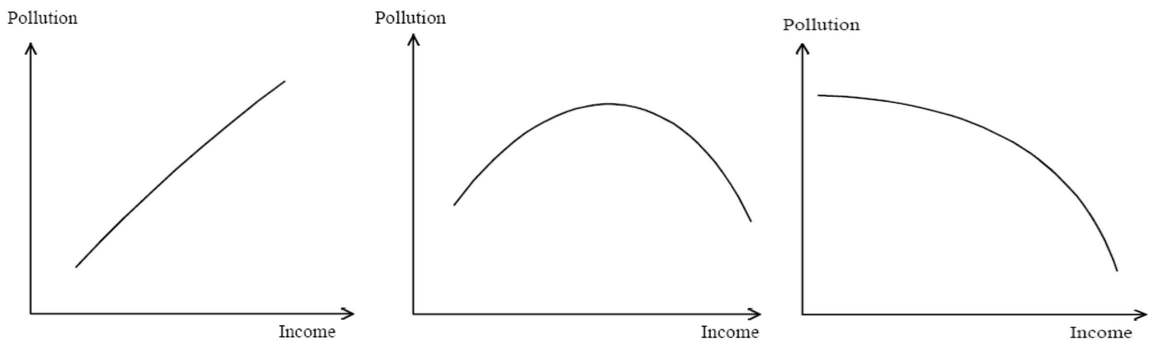
Another theoretical explanation is from the perspective of the properties of preferences and especially the income elasticity of demand for environmental quality (McConnell, 1997; Kriström and Riera, 1996). In the early stage of economic growth, to those countries that are struggling against poverty or are at the take-off stage of economic development, the GDP per capita is low. People are more focused on how to shake off poverty and access to rapid economic growth. Besides the less polluted environment at the early stage, the environment quality degrades because people ignore the importance of environmental protection due to low income elasticity of demand for environmental quality. It can be said that environmental quality is a "luxury goods" for people at this time (Dinda, 2004). Along with the increase of income, industrial structure as well as consumption structure begins to change. Environmental quality becomes "normal goods". The demand for good environmental quality increases. People begin to pay more attention to the protection of the environment. Rising income levels are associated with a falling income elasticity of demand for pollution intensive products (Cole, 2000a, b). So, environmental degradation gradually slows down.

An alternative explanation for the EKC hypothesis is from the perspective of international trade and FDI. International trade and FDI have contradictory impacts on environment. International trade, especially export and inflow FDI lead to increased use of land and natural resources, as well as encouraging consumption, which will cause more pollution due to more production and/or consumption (this is the scale effect), while international trade and FDI also have positive effects on environment via composition effect and/or technology effect which are attributed to *Displacement Hypothesis* and *Pollution Haven Hypothesis* (Dinda, 2004)[①]. To developing countries, FDI might bring in improved efficiency and cleaner technology, which offers opportunities to leapfrog the most damaging phases of industrialization (Goldemberg, 1998). Pollution emissions may drop due to trade openness, since the economies become more environment awareness under greater competitive pressure. But trade and FDI might facilitate advanced economies to export their pollution intensive

[①] As for the explanation of Displacement Hypothesis and Pollution Haven Hypothesis, please refer to the paper of Dinda (2004).

production processes to less-developed countries due to different environmental stringent policies (Suri and Chapman, 1998). This will speed up the pollution level of less-developed countries. As Arrow *et al.* (1995) and Stern *et al.* (1996) pointed out, “if there was an EKC type relationship, it might be partly or largely a result of the effects of trade on the distribution of polluting industries”[①].

To the end, the impact of income on environment can be decomposed of three effects, scale effect, structure effect and abatement effect. The relations between the three effects and income are as Figure 1.



a. scale effect b. structure effect c. abatement effect

Figure 1 Different Effects of Income on Environment

Source: Islam, N., J.Vincent and T.Panayotou, 1999.

3 Empirical Review

Since the pathbreaking studies of Grossman and Krueger (1991, 1993) and Shafik and Bandyopadhyay (1992), extensive studies have been conducted to test the EKC hypothesis. There are two main purposes for those studies, one is to see whether the EKC exists or not, and the other one is to find the turning point if the EKC does exist.

In the early surveys, reduced form model was commonly used to test the EKC and the empirical findings were incompatible. Some papers supported the existence of EKC, such as Shafik and Bandyopadhyay (1992), Panayotou (1993), Selden and Song (1994), Cropper and Griffith (1994), Grossman and Krueger (1995), de Bruyn *et al.* (1998), Suri and Chapman (1998), Schmalensee *et al.* (1998), Galeotti and Lanze (1999) and Sachs *et al.* (1999). They conducted analyses on the relationship between income and different pollutants. Shafik and Bandyopadhyay (1992) used three different functional forms (log-linear, log quadratic and logarithmic cubic polynomial forms) to

① Stern (2004), p.1426.

estimate the EKCs for different pollutants and found that the emission of SO_2 and suspended particulate matter (SPM) increased first and declined later with growing incomes. The turning points for these two pollutants lie between \$3000 and \$4000 per capita. Panayotou (1993) and Copper and Griffith (1994) also found that the relations between deforestation and income conform to the EKC hypothesis. Selden and Song (1994) conducted a survey on SO_2, NO_X, CO and SPM four pollutants and the results support the EKC hypothesis. Schmalensee *et al.* (1998), Galeotti and Lanze (1999) have studied the interactions between CO_2 and GDP per capita. Their findings show that inverted U-shaped curve exists for CO_2.

Although the above research results show that EKC does exist for some pollutants, there are some other papers do not support the EKC hypothesis. According to Kaufmann *et al.* (1998) paper, the relationship between SO_2 and income is U-shaped curve. Even in Shafik and Bandyopadhyay' study (1992), the lack of clean water and sanitation decline uniformly with increasing incomes and over time; water pollution, municipal waste and carbon emissions become worse and worse; and deforestation is independent of income levels. Recently, Meyer *et al.* (2003) conducted a survey on deforestation based on the data of 117 countries and the time span from 1990 to 2000. The finding is a U-shaped curve.

So, not all environmental pollutants follow the same EKC process. Conflicting results exist even for the same pollutant among various studies. Besides the different shape, the turning points of the curves are also different to some extent. The empirical tests are inconsistent due to different samples and different pollutants. Actually EKC is only a phenomenon, not an inevitable result.

The above papers mentioned use cross-section or panel data analysis based on multi countries[①]. Some people question this. Even some empirical results support EKC hypothesis, they cannot ensure that EKC exists in individual countries or regions. Stern et al. (1996) suggested that other factors existing in data from different countries might affect the relations between pollution and income. Coondoo and Dinda (2002) advised that the pollution-income relations might differ from one group of countries to another. While De Bruyn (1997) pointed out that the structural changes among countries may affect the pattern of causality between pollution and income. Within-country approach minimizes the influence of unobserved factors.

① Most of the data are from GEMS data sets. It is the Global Environmental Monitoring System sponsored by the United States that gathers pollution data from various countries.

Actually, the EKC hypothesis is a story about a country's pollution process on the way of economic development (Deacon and Norman, 2004). Some researchers have begun to see the relationship between income and environment within one country. For examples, Giles and Mosk (2003) exhibited that relations between CH_4 emission and income per capita in New Zealand is inverted-U shaped curve. Huang and Shaw (2002) also showed that EKC exists for N_2O and CO in Taiwan during the period between 1988 and 1997. But Rica *et al.* (2001) analyze six atmospheric pollutants in Spain and find that there doesn't exist EKC hypothesis, except for SO_2.

In addition to the effect of income on environment, some researchers have taken other factors into consideration, such as structural change of production or consumption (Panayotou *et al.*, 2000;Cole, 2000a,b), international trade and FDI (Suri and Chapman, 1998; Antweiler *et al.*,2001), political freedom and pollution (Panayotou, 1997; López and Mitra, 2000; Torras and Boyce, 1998; Deacon, 1999; Bhattarai and Hammig, 2001), environmental policy (De Bruyn, 1997; Panayotou, 1997; Mani *et al.*, 2000) and inequality (Torras and Boyce, 1998; Magnani, 2000; Ravallion *et al.*, 2000).

In 1993, Panayotou pointed out that EKC is an inevitable result of structural change accompanying economic growth. Later on, Panayotou *et al.* (2000) demonstrated that pollution emissions rise at the process of one country's industrialization and decrease in the post-industrial stage. Cole (2000a) found that EKC could be the result of a falling share of manufacturing and the shifting of the manufacturing to "clean" sectors away from "dirty" sectors. But Cole (2000b) also pointed out that a falling income elasticity of demand for pollution intensive products is associated with rising income level.

Some authors insist that trade factor cannot be omitted when study the EKC hypothesis due to the so called "pollution heaven" or "environmental dumping" or "race to the bottom" hypothesis. As for trade factor, Antweiler et al (2001), Chintrakarn and Millimet (2006) found that international trade has positive effect on environment. Suri and Chapman (1998) divided trade factor into two parts, i.e., share of export in GDP and share of import in GDP. Their findings are that higher export share generates more emissions and higher import share generates lower emissions.

Panayotou (1997) tried to incorporate policy variables into model. He found that improvements in policy institutions result less pollution emission and the emission elasticity is smaller with respect to economic growth and the density of population.[①] So, he argued to protect the environment via improving the quality of institutions and policies. While Deacon (1999) pointed out that the relations

[①] A set of five indicators is used in this paper. They are respect for and enforcement of contracts, efficiency of the bureaucracy, the rule of law, the extent of government corruption, and the risk of appropriation.

between income and environment vary across political systems and environmental quality is worse in non-democratic regimes. Besides, López and Mitra (2000) took corruption into consideration. His result shows that corruption makes environmental quality lower and the turning point of income per capita is higher. Bhattarai and Hammig (2001) found that government institutions are negative related with the extent of deforestation.

Environmental policies such as stricter environmental regulation play a role in decreasing pollution. De Bruyn (1997) found that environmental policy has an important impact on the changes in sulfur dioxide pollutant. Panayotou (1997) argued that effective environmental policies could reduce environmental degradation at lower income levels and speed up improvement at higher level for sulfur dioxide. Mani et al. (2000) showed that the main factor for the improvement in water quality with increasing of income is stricter environmental regulation.

Torras and Boyce (1998) showed that income inequality reduces environmental quality in low-income countries and equality improves environmental quality. Magnani (2000) confirmed the findings. Ravallion (2000) offered some evidence that the income elasticity of pollution emission is a positive function of inequality.

Merlevede *et al.* (2006) even adds firm size to the standard EKC reduced form to see whether firm size matters once income and composition variables are controlled. Their finding is that countries with larger average firm are initially associated with higher levels of environmental damage. But as economies develop, environmental damage decrease is much larger compared to countries with smaller average firm.

4 Methodology and Hypothesis

Based on the drawback of analyses using cross-country data, this paper is to analyze the relationship between pollution and income in China using provincial data. Compared with cross-country data, there are two major advantages of using within country data. First, it ensures consistent measurement of pollution, income and policy. Second, although there are some differences among Chinese provinces, the samples are more homogeneous in political freedom, legal institution, cultural norms and corruption compared to cross country data (Chintrakarn and Millimet, 2006).

Reduced form model is commonly used to test the EKC. This paper also exploits the reduced form model. Concerning the possible impacts of trade, FDI, population, composition of production and environmental policy on the relations, all these factors are to be included in this model. As the trade impact is inexplicit, trade is divided into two parts, import and export in this model, to see what the different effects played by import and export respectively. The model is as the following:

$$\ln E_{it} = \alpha_i + \gamma_t + \beta_1 \ln Y_{it} + \beta_2 (\ln Y_{it})^2 + \beta_3 (\ln Y_{it})^3 + \beta_4 ind_{it} + \beta_5 ex_{it} + \beta_6 im_{it} + \beta_7 \ln FDI_{it} + \beta_8 \ln POP_{it} + \beta_9 \ln R_{it} + \varepsilon_{it}$$

Here: i: province

t: year

α_i : the country specific effects

γ_t : the time specific effects

Y_{it} : real GDP per capita

E_{it} : annual emissions/discharge of industrial pollutants

ind_{it} : share of industry in GDP

ex_{it}: share of export in GDP

im_{it}: share of import in GDP

FDI_{it}: realized FDI inflow

POP_{it}: population

R_{it}: proxy of the stringency of environmental regulation for different pollutant

ε_{it} : disturbance term..

Panel data analysis will be employed in this paper. The fixed-effect model treats the α_i and γ_t as regression parameters. It helps us to capture province specific time invariant factors affecting pollution intensity. The random-effect model treats the α_i and γ_t as components of the random disturbance. If there is correlation between α_i, γ_t and the explanatory variables, the random-effect model cannot be estimated consistently (Hsiao, 1986). Only the fixed-effect model can be estimated consistently. So Hausman test will be used to determine whether the fixed effect or random effect model is preferred. After that, several hypothesis tests will be adopted, such as omitted variable test and redundant test.

There are several hypotheses assumed in this model. First, technological change is considered exogenous. A second aspect is that homogeneity exists in the income coefficients across provinces. Third, governments regulate pollution with full information about the benefits and costs of pollution control. Fourth, this model also implies that there is no feedback effect from the environment to economic growth, as income is assumed to be an exogenous variable. This is an important shortage for reduced form model. And fifth, the pollution externality is within-province, not cross-border.

There are several kinds of relations between pollution and income:

If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, the relations between pollution and income is inverted U-shaped curve;

If $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$, the relations is U-shaped curve;

If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, the relations is N-shaped curve;

If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 < 0$, the relations is inverted N-shaped curve;

If $\beta_1 \neq 0$, $\beta_2 = 0$ and $\beta_3 = 0$, the relations is linear curve.

If the relationship between pollution and income is U-shaped, the turning point is exp(- $\beta_1 / 2\beta_2$).

5 Data

The sample is composed of 29 provinces/municipality/autonomous regions over the period of 1992-2005. Tibet and Chongqing are excluded from the sample, because there are not enough data for Tibet and Chongqing became a municipality directly under the jurisdiction of central government in 1996. In order to keep consistency, the relevant data for Chongqing are added to those for province of Sichuan. Based on available data, the relations between five emissions/discharges of industrial pollutants and income per capita are tested in this paper. They are industrial waste water (FS), industrial solid waste (FW), industrial sulphur dioxide (SO_2), industrial dust (FC) and industrial soot (YC).

Population is the figure at the year-end. Y_{it} is provincial real GDP per capita. It is GDP per capita at constant 1991 price divided by population figure at the end of the year. The real GDP per capita is chosen because it is a better index for income level. Regarding the share of export or import in GDP, we use current GDP. Since the unit of current GDP is in 100 million RMB, we have to transfer it into 100 million US dollar first.

As for the stringency of environmental policy for the five industrial pollutants, some authors in China used current investment completed in the treatment of industrial pollution, such as Zhao (2003). But we think it is not a good proxy. First, it cannot reflect the extent of policy stringency. Because usually the more production, the higher realized abatement investment. Second, it does not show how efficiency the government environmental regulation is. So, this paper uses the shares of industrial SO_2/dust/soot removed as proxies for the intensity of government regulation in industrial SO_2, dust and soot. For the intensity of government regulation in industrial waste water, the share of industrial waste water meeting discharge standards is exploited. Regarding industrial solid waste, the ratio of industrial solid waste treated is used.

All the original data are from the database of Chinese Economic Information Network. Table 1 provides the statistic descriptions of the variables used in this paper.

Table 1 Statistic Description of Variables

Variables	Unit	Obs.	Mean	Median	Std. Dev.	Min.	Max.
FS	10,000 ton	406	76065.96	61713.00	57784.76	4093.00	296318.00
FW	10,000 ton	384	50568.09	40.63	402306.00	0.00	6288789.00
SO_2	10,000 ton	406	55.65	48.44	38.96	1.67	182.42
FC	10,000 ton	406	29.31	22.88	22.36	1.06	100.58
YC	10,000 ton	406	31.50	26.60	22.67	1.00	156.19
Y_{it}	10,000 ¥	406	4766.41	3649.48	3576.01	951.70	26290.43
ind_{it}	%	406	43.43	42.74	6.91	20.92	60.79
ex_{it}	%	406	14.60	6.42	17.53	2.07	93.67
im_{it}	%	406	13.75	4.48	22.70	0.49	157.52
FDI_{it}	10,000 $	405	154581.6	52340.00	252863.00	0.00	1318020.00
POP_{it}	10,000 persons	406	4440.75	3966.00	2731.17	461.00	11847.00
FSQD	%	406	66.42	65.53	19.59	27.04	99.84
FWQD	%	384	17.64	12.82	20.69	0.12	82.46
SO_2QD	%	398	22.02	15.57	16.42	0.00	68.36
FCQD	%	406	80.60	82.46	10.78	23.11	99.51
YCQD	%	406	91.89	93.06	5.33	62.30	99.30

Empirical Results

We begin by estimating the reduced form model of the relations between pollution and income per capita. Fix effect model is used in this paper according to Hausman test. Given the sample covers 29 provinces and the period of 1992-2005, there are two potential estimation biases that we need to pay attention to, the time-invariant specific effect and potential serial correlation within province. So GLS estimation with cross section weights and AR(1) is exploited to correct both cross-section heteroskedasticity and contemporaneous correlation. Then omitted variable tests and redundant tests are used to evaluate the models. From the adjusted R square, F statistic and *D.W. h* test, we can see all the models are well fit. And most of the coefficients show expected signs and high significance.

The empirical results for the data based on 29 provinces are summarized in Table 2. The table shows that the relationship between different pollutants and GDP per capita at national level is mixed. From the results, we find that EKC does not exist in China when we use the panel data based on 29 provinces over the period of 1992-2006. The relationships between industrial SO_2/soot/dust/solid waste and income per capita are inverted N-shaped curve, while the relationship between industrial waste water and GDP per capita is U-shaped curve. For industrial SO_2, only Beijing, Tianjin, Shanghai and Zhejiang are currently locating at the falling part of curve, others are locating at the rising part of curve. And for industrial waste water, the emissions in all 29 provinces are still increasing with the rise of GDP per capita.

(Please insert Table 2 here)

Concerning the big gap in income per capita between the eastern region and non-eastern region, this paper also divided 29 provinces into two regions, the east[①], and the middle and west[②]. Reduced form models are also used to test the relations between pollution and income in the eastern region, and the middle and west region respectively. The empirical results are demonstrated in Table 3 and Table 4.The main reason is to see whether the geographic factor has an impact on the relations between pollutions and GDP per capita.

For the eastern region, we find that EKC exists in the relations between industrial SO_2 and GDP per capita, with turning point at RMB 11244 per capita. The relations between industrial waste water and income per capita is U-shaped curve with the turning point at RMB 5045 per capita. But the relationship between industrial solid wastes and GDP per capita is linear, which means that discharge of industrial solid wastes monotonically increase with income. The relations between industrial dust/soot and income per capita are inverted N-shaped curve. If we take the 11 provinces/municipalities as a whole group, the emissions of industrial waste water and solid wastes are becoming more and more severe.

① The east has 11 provinces and municipalities directly under the jurisdiction of central government. They are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan.

② The middle and west has 18 provinces/municipality/autonomous regions. They are Shanxi, Neimenggu, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

(Please insert Table 3 here)

For the middle and western region, EKC exists in industrial dust with turning point at RMB 9259 per capita, while the relations between industrial SO_2 and income is U-shaped curve with turning point at RMB 1057. But the relationship between industrial waste water and income is linear. The relations between industrial soot/solid waste and income are inverted N-shaped curves. So, in the middle and western region, the emissions of industrial waste water and SO_2 still keep rising, which is a serious problem that we need to pay attention to.

(Please insert Table 4 here)

In general, we can see that FDI has no clear impact on pollutants except for industrial solid wastes. The effect of FDI on the emission of industrial solid wastes is negative, i.e. FDI decreases the emission of industrial solid wastes. From the empirical results, environmental policies play a role in reducing the emission of pollutants except for industrial solid wastes. General speaking, the more industrial share in GDP and the more population the society has, the higher pollution the society is,[①] which is mainly due to the scale effects. As for the function of international trade, it is complicated. Import decreases emissions of certain pollutants, while export increases the emissions of industrial SO_2 and soot. To industrial solid wastes, export decreases the emission. What's more, geographic location has an impact on environmental quality.

Conclusion, Implication and Further Studies

From the empirical results, we find that the EKC hypothesis is not clear in China, since the relationship between environmental quality and income varies on the types of pollutants and regions. The inverted U-shaped curve cannot be generalized for all emissions. The relationship between economic growth and environment in China is complicated. So, EKC is actually a phenomenon, not a necessary rule. Generally speaking, environment cannot be improved at higher income levels automatically in China. Governmental abatement effort to against pollution is good to the environment. So, environmental friendly governments are needed and more stringent environmental regulations should be adopted by Chinese governments at all levels. And different abatement effort should be made by the central government to different pollutants and regions. For industrial solid wastes, current environmental policies almost have no impact in reducing the discharge. Chinese governments at all levels should make greater efforts to reducing the discharge of industrial solid wastes, waste water and SO_2.

[①] There are some exceptions. For the details, please look at Table 3 to Table 5.

Our results show that empirical results are dependent on the sample used when estimating the EKC. Differences occur in the relations as well as the turning points. So those studies based on multi countries cannot describe the real situation of individual country. When we try to explain the relations between pollution and income, the effect of sample choice should be considered.

There are two major shortages for this paper. For one thing, this paper does not conduct a more thorough checking of the statistical robustness of the model. There are some empirical tests to have a better investigation on the relationship between environmental quality and income. So, panel unit root test and panel cointegration estimating can be used for further studies. Regarding that the time span is only 14 years, non-parametric bootstrap inference might be used. For the other, this paper only considers the effect of income on environment, and omits the function of environment on economic growth. Therefore, simultaneous equations can be used, which is better to describe the relationship between environment and economic growth.

In order to see the contributions of the determinants to pollution, structural form model can be used for decomposing analysis, to see which effect is the critical factor to pollution, scale effect, structural effect, technical effect or abatement effect. Actually, structural nonparametric modeling incorporates potential endogeneity problems.

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Table 2 Estimates for 29 Provinces

Dependent variable	FS	FW	SO_2	FC	YC
c	19.4442 (3.0704)*	214.3910 (1.1364)	82.9334 (3.3333)*	76.6555 (1.8837)***	150.2739 (5.4285)*
lnY_{it}	-3.8009 (-3.3711)*	-119.9141 (-1.6145)****	-31.5505 (-3.5116)*	-30.1168 (-2.0289)**	-46.2946 (-4.8111)*
$(lnY_{it})^2$	0.2419 (3.7462)*	15.1057 (1.7092)***	3.8025 (3.6251)*	4.0161 (2.2978)**	5.6374 (5.0558)*
$(lnY_{it})^3$		-0.6297 (-1.7949)***	-0.1502 (-3.6837)*	-0.1739 (-2.5392)**	-0.2272 (-5.2837)*
ind_{it}			0.0146 (4.0113)*	0.01499 (2.4432)**	0.0147 (3.4364)*
ex_{it}		-0.0447 (-1.8455)***	0.0065 (2.7154)*		0.0042 (1.9869)**
im_{it}			-0.0030 (-2.3635)**		
$lnFDI_{it}$		-0.4693 (-2.6178)*			
$lnPOP_{it}$	0.7626 (1.8794)***	13.4528 (2.7998)*	0.7702 (2.33.7)**	1.1392 (1.8671)***	
lnR_{it}	-0.1803 (-4.2131)*		-0.1554 (-7.8914)*	-2.4481 (-19.3156)*	-4.8766 (-17.8574)*
AR(1)	0.9673 (44.5595)*	-0.2667 (-5.5688)*	0.5796 (12.2835)*	0.5152 (11.2847)*	0.5499 (13.3662)*
Adjusted R-squared	0.9917	0.8676	0.9856	0.9568	0.9721
F statistic	1360.536	65.7803	684.0447	238.6831	375.7000
Hausman	111.5277	13.2003	13.9630	7.7371	16.1747
Turning point (P)	-	6361	13900	7601	7841
Turning point (L)	2578	1420	1543	639	1947
No. of observations	406	384	398	406	406
Provinces	29	29	29	29	29
Shape of curve	**U**	**Inverted N**	**Inverted N**	**Inverted N**	**Inverted N**

Note: * indicates significant at 1% confidence level; ** indicates significant at 5% confidence level; *** indicates significant at 10% confidence level; **** indicates significant at 15% confidence level.

Table 3 Estimates for Provinces in the Eastern Region

Dependent variable	**FS**	**FW**	**SO_2**	**FC**	**YC**
c	34.1937	0.7156	-22.2158	341.0971	238.7542
	(5.3524)*	(0.1502)	(-2.3058)**	(2.1521)**	(6.7.71)*
LnY_{it}	-5.2039	1.4656	3.4700	-114.5228	-64.4451
	(-3.6057)*	(2.3481)**	(2.0082)**	(-2.1716)**	(-5.4527)*
$(lnY_{it})^2$	0.3052		-0.1860	13.5464	7.5916
	(3.5409)*		(-1.9129)***	(2.3153)**	(5.7077)*
$(lnY_{it})^3$				-0.5301	-0.2965
				(-2.4523)**	(-5.9504)*
ind_{it}			0.0239		0.0163
			(3.8543)*		(4.0129)*
ex_{it}		-0.0751	0.0056		0.0130
		(-3.5084)*	(2.1831)**		(5.3350)*
im_{it}			-0.0030		-0.0045
			(-2.2812)**		(-2.7836)*
$lnFDI_{it}$		-0.6774			
		(-1.8287)***			
$lnPOP_{it}$			1.0983		
			(2.2999)**		
lnR_{it}	-0.1173		-0.1026	-4.0901	-12.2129
	(-1.5988)****		(-2.8751)*	(-14.5220)*	(-18.5424)
AR(1)	1.0157	-0.2970	0.6193	0.5611	0.0392
	(42.5783)*	(-3.7039)*	(7,8725)*	(10.5588)*	(1.9164)**
Adjusted R-squared	0.9925	0.7828	0.9917	0.9729	0.9936
F statistic	1337.861	32.4034	927.4205	340.4891	1223.933
Hausman	0.9929	4.9952	15.7157	5.5747	20.7056
Turning point (P)	-	-	11244	10435	9428
Turning point (L)	5045	-	-	2397	2740
No. of observations	154	138	152	154	154
Provinces	11	11	11	11	11
Shape of curve	**U**	**Linear(rising)**	**Inverted U**	**Inverted N**	**Inverted N**

Note: Turning points in Table 3-Table 5 refer to income per capita at 1991 constant price (RMB).

Table 4 Estimates for Provinces in the Middle and Western Region

Dependent variable	FS	FW	SO_2	FC	YC
c	9.2157 (8.1878)*	701.7845 (-1.1040)	15.3912 (2.8959)*	-29.8026 (-3.5321)*	286.1128 (2.5433)**
lnY_{it}	0.2629 (2.1873)**	-317.4960 (-1.3267)^	-3.4265 (-2.6417)*	4.1343 (2.0851)**	-91.2307 (-2.2523)**
$(lnY_{it})^2$		40.7192 (1.3565)^	0.2460 (3.0765)*	-0.2263 (-1.8682)***	10.5348 (2.1626)**
$(lnY_{it})^3$		-1.7349 (-1.3837)^			-0.4027 (-2.0619)**
ind_{it}		0.1105 (1.5265)^	0.0084 (1.7670)***	0.0200 (-1.8682)***	
ex_{it}			0.0165 (2.7801)*		
im_{it}			-0.0143 (-2.0134)**		
$lnFDI_{it}$		-0.5823 (-2.0817)****			
$lnPOP_{it}$		15.4621 (2.1951)**		2.8113 (3.5986)*	
lnR_{it}	-0.2135 (-3.9439)*		-0.1550 (-6.5541)*	-2.1467 (-16.4532)*	-4.6662 (-17.1256)*
AR(1)	0.8837 (25.5291)*	-0.2489 (-3.4577)*	0.5083 (8.2713)*	0.4874 (8.1013)*	0.7100 (19.4971)*
Adjusted R-squared	0.9889	0.2950	0.9760	0.9387	0.9614
F statistic	1040.674	4.8876	385.9126	156.0944	264.7664
Hausman	4.8272	8.6619	17.7037	8.2366	3.9520
Turning point (P)	-	3935	-	9259	12633
Turning point (L)	-	1586	1057	-	2969
No. of observations	252	246	246	252	252
Provinces	18	18	18	18	18
Shape of curve	**Linear(rising)**	**Inverted N**	**U**	**Inverted U**	**Inverted N**

Note: ^ indicates significant at 20% confidence level.