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## Pollution Across Chinese Provinces

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**Pollution Across  
Chinese Provinces**

**Catherine Yap Co  
Fanying Kong  
Shuanglin Lin**

**September 2008**



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## Foreword

This paper was presented at the Conference on “India and China’s Role in International Trade and Finance and Global Economic Governance” organised by ICRIER, Konrad-Adenauer-Stiftung (KAS) and the International Monetary Fund (IMF) at New Delhi, India on December 6-7, 2007. It is being published shortly in a book titled “Emerging Giants: China and India in the World Economy” edited by Barry Eichengreen, Poonam Gupta and Rajiv Kumar.

This paper which compares off-sample (1996-2004) predictions to actual emissions across Chinese provinces finds that pollution levels in some provinces, which the study identifies, remain high. Therefore, more stringent rules are needed to fight industrial pollution. We are bringing this out as a Working Paper to reach a wider interested audience and invite further collaboration on trade and environment and climate change and role of developing economics.



**(Rajiv Kumar)**  
Director & Chief Executive

September 16, 2008

## Abstract

We revisit the environmental Kuznets curve (EKC) hypothesis using 1987-1995 data for Chinese provinces. A comparison of off-sample (1996-2004) predictions to actual emissions indicates that more stringent rules are still needed to fight industrial (waste water and dust) pollution. Auxiliary regressions show that conditional on income, northern provinces have lower industrial waste water pollution; non-coastal and provinces with smaller secondary industry shares have lower industrial (waste water, COD, and dust) pollution; provinces with smaller state-owned enterprises share have lower industrial COD pollution; and, commitment to control industrial dust pollution is correlated with local governments' budget balance.

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**Keywords:** environmental Kuznets curves; Chinese provinces; pollution  
**JEL Classifications:** Q53; O13

# Pollution Across Chinese Provinces

Catherine Yap Co, Fanying Kong and Shuanglin Lin\*

## 1. Introduction

The market-oriented economic reforms that started in 1978 have greatly transformed the Chinese economy. State-owned enterprises (SOEs) were allowed to operate and compete on free market principles, rather than under the direction and guidance of state planning; special economic zones were established along the coast for the purpose of attracting foreign direct investments, boosting exports, and importing high technology products; and, private enterprises were legalized and promoted. With these reforms, the average annual growth rate of China's real GDP was close to 10 percent from 1979 to 2007, compared to a pre-reform growth rate of around 5 percent from 1960 to 1978. No country has ever lifted more people out of poverty faster than China since the adoption of these reforms. However, economic growth in China has been accompanied by severe environmental deterioration.

According to *The Economist* (2004), the World Bank estimates that direct damages from pollution (e.g., medical bills) are 8-12 percent of China's annual GDP. The World Bank has identified 16 of the 20 most polluted cities in the world to be located in China. And, close to two-thirds of the 300 cities tested by China's environmental protection agency failed to meet the air quality standards set by the World Health Organization. With negligent environmental protection, some areas have such high levels of toxins in the air and groundwater that cancer levels are 15 to 30 times higher than the national figure (see Lynch 2005).<sup>1</sup> Unsustainable environmental practices also pose increasing threats to China's water, forests, biodiversity, and food and energy supplies. Since China is a huge country, its pollution problems undoubtedly have serious negative effects on the global environment.<sup>2</sup>

Currently, forces that oppose more stringent rules and regulations in the name of free markets and economic growth are battling forces that favor greater environmental protection. It appears that the latter group is losing the battle. The general public and the central government tend to favor more stringent environmental rules while local governments do not.<sup>3</sup> The current central and local government tax revenue sharing scheme is one reason why local governments in China have little incentive to call for

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<sup>1</sup> Economy (2004) also provides a description of the health effects of pollution in China.

<sup>2</sup> See *The Economist* (2007) for a popular account of how China's pollution problems affect the rest of the world.

<sup>3</sup> According to Cheng et al. (2007), a recent survey indicates that 86 percent of the people are not satisfied with China's environmental protection; 70 percent of the people blame local governments for the environmental problems; and, 78 percent of the people indicate willingness to sacrifice the speed of growth for a better environment.

more stringent environmental policies. Since 1994, local governments have experienced budget deficits every year, and they have come to rely heavily on central government transfers.<sup>4</sup> These transfers are largely dependent on value-added tax rebates. Since value-added tax rebates are related to local output increases, local governments in China have strong incentives to increase production (thereby increasing revenue transfers),<sup>5</sup> but have little incentive to protect the environment.

In this paper, we revisit the environmental Kuznets curve (EKC) hypothesis. According to the EKC hypothesis, an inverted-U characterizes the income-emission relationship.<sup>6</sup> However, a number of studies (e.g., Millimet et al. 2003) have shown that a cubic relationship may exist between income and emissions. In particular, they may again be positively correlated at still higher income levels.

Our strategy is to first estimate income-emissions regressions using fixed effects panel regression using data for 30 Chinese provinces from 1987 to 1995.<sup>7</sup> We end the data coverage of the estimations in 1995 since a number of amendments to pollution laws were introduced after this year. This allows us to determine the trajectory of selected pollutants relative to income after 1995 if no changes to pollution policy occur (or, if no changes to the structure of the economy occur). In other words, we make off-sample predictions of pollution discharges using the estimated income-emissions regressions. We then compare these off-sample predictions to actual pollution discharges in 1996 to 2004 to partly quantify any effect pollution policy changes may have had on emissions.

A comparison of the off-sample predictions to actual pollution discharges in 1996 to 2004 indicates that actual industrial chemical oxygen demand (COD) pollution per capita discharge rates in 1996-2004 have leveled off and do not increase with income as the estimated income-emission regression predicts. Thus, environmental policies enacted by the Chinese government to control industrial COD pollution may have been partly successful. However, actual industrial waste water per capita discharge rates in 1996-2004 increase with income; this is opposite the prediction of the estimated income-emission regression. Also, actual industrial dust per capita discharge rates in 1996-2004 are larger than the predicted per capita discharge rates for most of the provinces. This is inconsistent with the notion that given the adoption of stricter environmental regulations, actual emissions should be lower than the predictions because the latter assumes no changes in environmental regulations.

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<sup>4</sup> Even rich provinces largely depend on transfers from the central government to cover their budget deficits. For example in 2004, 42 percent of Shanghai's budgetary revenues are rebates from the central government; the rate for Jiangsu province is 48 percent.

<sup>5</sup> Another reason is that Chinese local government officials are appointed by their superiors based mainly on local economic performance.

<sup>6</sup> See Grossman and Krueger (1995) for an early contribution. One of the explanations for the inverted-U EKC is that when regions reach a sufficiently high income level, people living in these regions will demand cleaner environments (and, these regions also have the necessary institutions to enforce extant environmental rules); thus, emissions decline as income increases beyond this point. See De Bruyn and Heintz (1999) for a review.

<sup>7</sup> To be precise, Beijing, Tianjin, and Shanghai are municipalities while Inner Mongolia, Guangxi, Tibet, Ningxia, and Xinjiang are Minority Autonomous Regions. We refer to all of these areas as provinces for convenience. Chongqing became a municipality in 1997 (it is part of Sichuan province in our data).

Auxiliary regressions of the estimated province-specific fixed effects against several province characteristics show that conditional on income, northern provinces have lower levels of industrial waste water pollution (thus, may have been more willing to regulate this type of pollution); non-coastal provinces and provinces with smaller secondary industry shares have lower levels of three types of pollutants; provinces with smaller state-owned enterprises share have lower levels of industrial COD pollution; finally, there is some evidence that a province's industrial dust pollution level (thus, its commitment to control pollution) is related to its budget balance.

To put the current study in perspective, the environmental consequences of economic growth and policy responses to environmental problems since the establishment of the People's Republic of China are briefly described in the next section. In Section 3, a detailed description of the data and empirical methodology used are provided. The results are analyzed in section 4. Concluding remarks are presented in the last section.

## **2. Pollution and Environmental Policy in China**

Since the founding of the People's Republic of China, environmental degradation has accompanied economic growth. During the Great Leap Forward (1958-1960), people's communes were established in rural China. Trees were cut and used as fuel to make steel, causing a reduction in forest coverage. During the Cultural Revolution (1966-1976), farmers in the communes were mobilized to build terra fields in mountains to increase arable farmland, damaging the green coverage of mountains.<sup>8</sup> During the period of economic reforms that started in 1978, communes were dissolved and farmers and herdsmen were given freedom to engage in industrial production. SOEs became profit-oriented and private enterprises emerged. Using mostly outdated technologies, the emergence of these enterprises increased pollution in China substantially.

It was only in 1995 that the central government fully realized the urgency of environmental problems in China. A number of environmental laws were amended to signal their strong commitment to protect the environment. For example, the *Law on the Prevention and Control of Water Pollution* was amended in 1996; the *Law on the Prevention and Control of Atmospheric Pollution* was amended in 1995 and 2000.<sup>9</sup> According to the *Law on Prevention and Control of Water Pollution*, all activities of any person or unit polluting surface and underground water shall be punished with a fine. The *Law on the Prevention and Control of Atmospheric Pollution* sets standards for air pollution from burning coal, automobiles, and dust; it also specifies measures to punish violators.

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<sup>8</sup> Also see Edmonds (1999).

<sup>9</sup> National People's Congress of the People's Republic of China, *Amendment to the Law on the Prevention and Control of Water Pollution*, May 15, 1995; and, National People's Congress of the People's Republic of China, *The Law on Prevention of Air Pollution*, April 29, 2000. English translations of these laws are available from the State Environmental Protection Administration's (SEPA) website at [www.zhb.gov.cn/english/](http://www.zhb.gov.cn/english/). According to Wang and Wheeler (2005), China's water pollution standards are stricter than those pertaining to air pollution. Muldavin (2000) provides an overview of China's environmental policy after 1949. Also see Ma and Ortolano (2000) for a detailed description of environmental regulations in China.



Environmental policymaking devolved from the central government to local governments in the 1980s. This has introduced some amount of heterogeneity in environmental policy and enforcement across China's provinces.<sup>10</sup> For example, in 1998 Jiangsu passed the *Regulations on Protection of Agricultural Ecology and Environment* making dumping polluted water in agricultural areas illegal.<sup>11</sup> In 1998, Guangdong province passed the *Regulations on Zhujiang Triangle Water Protection*. This regulation set strict measures to punish water polluters.<sup>12</sup>

**Table 1: Summary Statistics, 30 Chinese Provinces from 1987 to 2004**

	Mean	Standard Deviation	Coefficient of Variation	Obs.
<i>A. 1987 to 1995</i>				
Real Income Per Capita (RGRPPC) <sup>1/</sup>	696.634 <sup>a/</sup>	470.984	67.609	270
Total Industrial Waste Water (IWATER) <sup>2/</sup>	22.549 <sup>a/</sup>	17.504	77.624	269
Industrial COD (COD) <sup>3/</sup>	0.007 <sup>a/</sup>	0.004	65.006	237
Waste Gas (GAS) <sup>4/</sup>	10359.320	7372.472	71.168	268
Sulfur Dioxide (SO <sub>2</sub> ) <sup>3/</sup>	0.016	0.010	63.752	267
Total Smoke (SMOKE) <sup>3/</sup>	0.014 <sup>a/</sup>	0.010	69.780	266
Industrial Dust (IDUST) <sup>3/</sup>	0.007	0.005	73.178	267
<i>B. 1996 to 2004</i>				
Real Income Per Capita (RGRPPC) <sup>1/</sup>	1421.518	1105.391	77.761	270
Total Industrial Waste Water (IWATER) <sup>2/</sup>	16.307	10.905	66.876	270
Industrial COD (COD) <sup>3/</sup>	0.005	0.004	70.309	270
Waste Gas (GAS) <sup>4/</sup>	NA	NA	NA	NA
Sulfur Dioxide (SO <sub>2</sub> ) <sup>3/</sup>	0.017	0.011	65.965	120
Total Smoke (SMOKE) <sup>3/</sup>	0.009	0.007	71.197	120
Industrial Dust (IDUST) <sup>3/</sup>	0.007	0.004	62.155	269

Notes: <sup>1/</sup> 1950 yuan; <sup>2/</sup> Metric ton per capita; <sup>3/</sup> Ton per capita; <sup>4/</sup> Cubic meter per capita. <sup>a/</sup> Means test indicates that means in 1987-1995 and 1996-2004 are significantly different at the 99 percent confidence level.

<sup>10</sup> See MacBean (2007), Economy (2004), Muldavin (2000), and Ma and Ortolano (2000) for details.

<sup>11</sup> See the 9<sup>th</sup> Standing Committee of Jiangsu People's Congress, 7<sup>th</sup> session, the *Regulations on Protection of Agricultural Ecology and Environment*, December 29, 1998 (Revised June 7, 2004).

<sup>12</sup> See the 9<sup>th</sup> Standing Committee of Guangdong People's Congress, 6<sup>th</sup> session, the *Regulations on Zhujiang Triangle Water Protection*, November 27, 1998.

The passage of the *Cleaner Production Promotion Law* in 2002 is another signal of China's commitment to a path of sustainable development.<sup>13</sup> This has been preceded by a number of other environmental legislations with cleaner production provisions such as the *Law on the Prevention and Control of Water Pollution* amended in 1996 (Article 22) and by the *Law on the Prevention and Control of Atmospheric Pollution* amended in 2000 (Article 19). Both legislations contain provisions encouraging firms to adopt cleaner production technologies to reduce pollution discharge.

Since a number of environmental laws were amended after 1995, we study the time path of various pollutants in two periods: 1987-1995 and 1996-2004. Table 1 presents summary statistics for per capita emissions across 30 Chinese provinces for various pollutants.<sup>14</sup> Means tests of the per capita emissions data show that the mean per capita discharge for three of the pollutants considered (industrial waste water, industrial COD, and smoke) declined between these two periods. Can this partly be attributed to changes in environmental laws enacted after 1995? Also, conditional on provinces' income levels, what other factors correlate with pollution discharges? These, and other, questions are tackled in the succeeding sections.

### 3. Data and Empirical Methodology

#### Data

Pollution discharge data for 1987 to 1995 are obtained from the *Economics of Industrial Pollution Control* research team of Development Research Group (DECRG) at the World Bank. Data are downloadable at [www.worldbank.org/nipr/data/china/status.htm](http://www.worldbank.org/nipr/data/china/status.htm). The data compiled by the World Bank are from two sources: *China Environmental Quality Report* and *China Environment Yearbook*. Pollution discharge data for 1996 to 2004 are obtained from various editions of the *China Environment Yearbook*. From Table 1, it is evident that pollution data for 1996-2004 are sparse. Waste gas data are no longer available and data for sulfur dioxide and smoke are incomplete.

Gross regional product (in current yuan) and the general consumer price index (1950=100) data are obtained from the China National Bureau of Statistics, *China Compendium of Statistics 1949-2004*. In 2004, China conducted its first national economic census, a major piece of the comprehensive reform of the country's economic accounting system. For the most part, the new economic accounting system fixes the significant undercounting of activities in the tertiary sector (services) in China. The undercounting is a legacy of China's use of the Material Product System, commonly used by centrally-planned economies. When economic reforms started in 1978, the number of private and individually-run services increased, and these have

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<sup>13</sup> Cleaner production (CP) is referred to as pollution prevention (P2) in the United States. In 1990, the United States passed the Pollution Prevention Act. Prior to this legislation, pollution control efforts were focused at the "end-of-the-pipe." P2 refocuses pollution control efforts to the early stages of production whereby firms are encouraged to use production techniques that prevent pollution at the source.

<sup>14</sup> Industrial COD is the most important water pollutant in China (Wang and Wheeler 2003), and is commonly used as a measure of water quality. Sulfur dioxide is of concern because it contributes to acid rain. It is released primarily from burning fuels that contain sulfur (e.g., coal). Smoke and industrial dust pollution are also important concerns in China as a number of the provisions (e.g., Article 30) in the Prevention and Control of Atmospheric Pollution Law address these pollutants.

been missed by an economic accounting system geared towards industrial production. In fact, for 2004, 93% of the upward revision in China's GDP can be attributed to the undercounting of the value added of tertiary industries under the old economic accounting system (see Deshui 2005). The methodological change necessitated the issuance of revised gross domestic product figures for earlier years and revised data are available back to 1993. The revised figures are based on the 2004 GDP data using a trend deviation method.<sup>15</sup> Because the revised values only go as far back as 1993, we are not able to use them in our analysis.<sup>16</sup> More importantly, for our purposes, the unrevised gross product values are more appropriate. This is because tertiary industries are less polluting and using the revised GDP figures would "overestimate" income (for most provinces) in our EKC estimations.<sup>17</sup>

Each province's ranking (from cleanest to dirtiest) in 1987-1995 for all pollution media appear in Table 2. For the most part, Tibet is the cleanest province while Liaoning is the dirtiest province. The Southwest region is the cleanest region while the Northeast region is the dirtiest one.<sup>18</sup> Coastal provinces are dirtier—in four of the six pollution media, the mean rank of coastal provinces range from 17 (waste gas) to 22 (industrial COD) while the mean rank of non-coastal provinces range from 11 (industrial COD) to 14 (SO<sub>2</sub>). Non-coastal provinces ranked higher (dirtier) on average for smoke and industrial dust. Northern provinces ranked higher (dirtier) in all pollution media except industrial waste water. The mean ranks for Northern provinces range from 14 (industrial waste water) to 22 (smoke). For Southern provinces, the mean ranks range from 9 (smoke) to 17 (industrial waste water).

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<sup>15</sup> According to China National Bureau of Statistics (2007, p.56), "historical trend values were first calculated with data from the census; next, the ratio between the actual value of the historical data and the trend value of historical data was calculated; and finally the ratio was applied to the historical trend values obtained from the census data to obtain the revised series of historical data."

<sup>16</sup> It is not appropriate to use the estimated income-emissions regressions (based on unrevised 1987-1995 income data) to make off-sample predictions of pollution discharges (based on revised 1996-2004 income data).

<sup>17</sup> Using revised output data from the 2007 Statistical Yearbooks of each of the provinces, for 1995-2004, the mean revised GDP-to-unrevised GDP ratio for 12 provinces (six Northern and five coastal provinces) are less than one. The mean ratio for Hubei is 0.85, followed by Anhui at 0.94, and Heilongjiang at 0.96. Beijing experienced the largest upward revision with a 1.25 mean ratio, followed by Shanxi at 1.11, and Guangdong at 1.10. Combining these ratios with information on Table 2, no clear pattern emerges as to a province's pollution ranking and the amount of upward or downward revision it experiences. For example, Liaoning is the dirtiest province, it experienced an average of 0.29 percent downward revision; Shanghai, another dirty region, experienced an average upward revision of 4.43 percent.

<sup>18</sup> Shanghai is the dirtiest province (municipality) and the Central and South region is the cleanest region if median ranks are used instead of mean ranks.

**Table 2: Provincial Unconditional Rankings (Cleanest=1 to Dirtiest=30) in Various Pollutants, 1987-1995**

Province	IWATER	COD	GAS	SO <sub>2</sub>	SMOKE	IDUST
<b>NORTH</b>						
Beijing <sup>1/2/</sup>	28	24	29	28	25	17
Tianjin <sup>1/2/</sup>	24	29	25	26	23	9
Hebei <sup>1/2/</sup>	11	7	20	17	16	23
Shanxi <sup>2/</sup>	13	10	26	27	27	24
Inner Mongolia <sup>2/</sup>	9	22	24	25	30	26
<b>NORTHEAST</b>						
Liaoning <sup>1/2/</sup>	29	27	28	24	26	30
Jilin <sup>2/</sup>	17	28	23	13	28	16
Heilongjiang <sup>2/</sup>	23	23	22	11	29	18
<b>EAST</b>						
Shanghai <sup>1/</sup>	30	30	30	29	20	11
Jiangsu <sup>1/</sup>	27	19	16	19	15	10
Zhejiang <sup>1/</sup>	21	20	15	14	6	19
Anhui	14	16	7	5	12	4
Fujian <sup>1/</sup>	19	18	8	3	4	5
Jiangxi	16	6	6	10	11	21
Shandong <sup>1/2/</sup>	3	21	17	23	19	8
<b>CENTRAL AND SOUTH</b>						
Henan <sup>2/</sup>	5	8	9	4	9	3
Hubei	26	11	12	12	8	13
Hunan	25	12	5	9	5	12
Guangdong <sup>1/</sup>	18	15	13	7	3	22
Guangxi <sup>1/</sup>	20	26	3	15	10	28
Hainan <sup>1/</sup>	8	25	2	2	2	1
<b>SOUTHWEST</b>						
Sichuan	22	14	14	22	17	15
Guizhou	2	3	11	21	13	14
Yunnan	6	9	4	8	7	2
Tibet	1	1	1	1	1	6
<b>NORTHWEST</b>						
Shaanxi <sup>2/</sup>	7	4	10	20	21	7
Gansu <sup>2/</sup>	12	5	21	18	14	25
Qinghai <sup>2/</sup>	10	2	18	6	22	27
Ningxia <sup>2/</sup>	15	13	27	30	24	29
Xinjiang <sup>2/</sup>	4	17	19	16	18	20

Notes: <sup>1/</sup> Coastal province. <sup>2/</sup> Northern province. Classifications adopted from De Groot et al. (2004).

Table 3 contains the Spearman rank correlation coefficients of the various pollutants for 1987-1995. The rank correlations range from 0.02 (industrial COD and industrial dust) to 0.83 (waste gas and smoke). Not surprisingly, the rank correlations are high among the various types of gas pollutants but low between water and gas pollutants. Also, although provinces with high water quality also tend to have high air quality, this relationship is not that strong (the rank correlation between industrial waste water and waste gas is 0.38).<sup>19</sup>

**Table 3: Spearman Rank Correlation Coefficients, 30 Chinese Provinces from 1987 to 1995**

	IWATER	COD	GAS	SO <sub>2</sub>	SMOKE	IDUST
IWATER	1.000					
COD	0.564 <sup>a/</sup>	1.000				
GAS	0.383 <sup>b/</sup>	0.404 <sup>b/</sup>	1.000			
SO <sub>2</sub>	0.298	0.318 <sup>c/</sup>	0.774 <sup>a/</sup>	1.000		
SMOKE	0.180	0.321 <sup>c/</sup>	0.825 <sup>a/</sup>	0.705 <sup>a/</sup>	1.000	
IDUST	0.212	0.022	0.518 <sup>a/</sup>	0.428 <sup>b/</sup>	0.467 <sup>a/</sup>	1.000

Notes: <sup>a/ b/ c/</sup> Significant at the 99 percent, 95 percent, and 90 percent confidence levels, respectively.

### Empirical Methodology

The following one-way fixed effects panel model is estimated:

$$poll_{it} = \alpha_i + \beta income_{it} + \gamma income_{it}^2 + \delta income_{it}^3 + \varepsilon_{it},$$

$$i = 1, \dots, 30; t = 1, \dots, 9 \quad (1)$$

where  $i$  indexes provinces and  $t$  indexes time;  $poll_{it}$  is one of the six pollutants measured in per capita terms in 1987 to 1995;  $income$  is real per capita gross regional product for province  $i$  at time  $t$ ;  $\beta$ ,  $\gamma$ , and  $\delta$  are coefficient parameters;  $\alpha_i$  are province-specific fixed effects;<sup>20</sup> and,  $\varepsilon_{ij}$  is a well-behaved error term. We also estimate a quadratic specification for comparison.

We do realize that besides income, a number of other factors, such as environmental regulations, output composition, and the relative importance of state-owned

<sup>19</sup> Gas pollution in China is mostly from the use of coal and wood as fuels and from automobiles, while water pollution is mainly from pulp and paper, metallurgical, and chemical factories (see Naughton 2007). In the late 1980s and the early 1990s, the environmental issue had not been emphasized. Thus, provinces with more water polluting industries might have higher levels of water pollution, while provinces with more air polluting industries might have more air pollution. In addition, the water distribution in China is largely uneven. There is a shortage of surface and underground water in the northern part of China. For example, in Beijing, we will only see air pollution not much water pollution, since the Yongding River in Beijing has dried up. However, if we just look at the southern part, we may find a closer correlation between air and water pollution, i.e., less developed areas have less water and air pollution, while developed areas such as Shanghai have both high water and air pollution.

<sup>20</sup> The province-specific fixed effects capture unmeasured locational attributes or attributes that are non-time varying (e.g., north/south or coast/non-coast location) during the period of analysis.

enterprises, may affect pollution emissions across provinces.<sup>21</sup> However, these factors are somewhat related to income; thus, following standard practice (see e.g., List and McHone 2000; Millimet et al. 2003) we exclude these other factors from equation (1) to focus on the total effect of income on emissions.<sup>22</sup> This is one of the limitations of the environmental Kuznets curve: the model *per se* does not explain why an income-emission relationship exists. De Bruyn and Heintz (1999) review some explanations for the EKC found in the literature. One explanation is that when people's income increases beyond a certain level, they start to demand a cleaner environment. Thus, emissions decline as income increases beyond this level. Likewise, a number of institutional changes occur as a country's income increases. For example, stricter environmental policies are enacted and enforced thereby leading to lower emissions. Third, economies generally transition to a service-oriented economy as incomes increase. And since services are less polluting than manufacturing, emissions decline. Thus, institutional and structural changes that occur as income increases can also explain the EKC.

Because equation (1) provides only reduced-form estimates, another limitation of the EKC is what its policy implications are. For example, if an inverted-U income-emissions relationship is found, it is not clear how this information could be used by policymakers. As Dasgupta et al. (2002, p.147) observe, “[i]n developing countries, some policymakers have interpreted such results as conveying the message about priorities: Grow first, then clean up.”

To address the above limitations, auxiliary regressions are estimated whereby the estimated province-specific fixed effects from equation (1) are regressed against a number of provincial characteristics such as industrial structure (see equation (2) in the next section). Thus, conditional on income, do emissions increase with the share of secondary industries in total output? Equation (2) below answers this (and related) question(s).

#### 4. Analysis of Results

Table 4 contains the empirical results.<sup>23</sup> F-tests indicate that the inclusion of province-specific fixed effects is appropriate as the null hypothesis that the province-specific

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<sup>21</sup> See Dasgupta et al. (2002) for a review.

<sup>22</sup> We are aware of the limitations of using equation (1) to estimate income-emissions regressions, see e.g., Stern (2004). In particular, equation (1) assumes that the slopes are homogenous across the Chinese provinces. Using cross-country (e.g., Dijkgraaf and Vollegergh 2005) and cross-state panel data (e.g., List and Gallet 1999), studies have shown parameter heterogeneity across the cross-sectional units for selected pollutants. We do not implement slope heterogeneity in this paper. Equation (1) is less likely to provide biased and inconsistent estimates since our cross-section units belong to a single country and not a cross-section of countries observed over time. The assumption of a common slope among cross-section units is more believable within than between countries. Also, given China's political set-up (that is, local government officials being basically appointed by the central government), pollution policies across Chinese provinces are expected to be less heterogeneous than pollution policies across US states.

<sup>23</sup> The province-specific fixed effects are available upon request. An unbalanced panel is estimated for all six models as pollution data are not available for selected provinces in selected years. Since missing data are at most only 12 percent (for industrial COD) of the 270 possible observations (30 provinces by 9 years), we do not think the results obtained are biased and inefficient. As a robustness check, we also omit observations whose standardized residuals are greater than 4. The results are qualitatively similar to those in Table 4.

fixed effects are the same is rejected at the one percent significance level (the F statistic range from 4.56 to 137.71 for the cubic specification). Hausman tests of the null hypothesis that province characteristics are uncorrelated with income are also rejected in four of the models at the one percent significance level (for the cubic model, the Hausman test statistic range from 3.12 to 93.02). This is indicative of the appropriateness of using the fixed effects model (versus the random effects model). The one-way fixed effects model controls for unmeasured province characteristics whereas the one-way random effects model treats these unmeasured characteristics as a component of the error term (see Greene 2000, for details). We focus on the results for four pollutants below: total industrial waste water, industrial COD, waste gas, and industrial dust. This is because at least one of the income terms is statistically significant in all models dealing with these four pollutants. We also focus on the results from the cubic regressions (column (2) in Table 4) as the cubic term is statistically significant in the regressions for these four pollutants. The (within group) R-square values of these models range from 0.10 to 0.41.<sup>24</sup>

**Table 4: Fixed effects panel regression estimates**<sup>1/</sup>

	IWATER		COD		GAS	
	(1)	(2)	(1)	(2)	(1)	(2)
Income	-1.14E-02 <sup>a/</sup>	-3.23E-02 <sup>a/</sup>	-8.56E-07	8.86E-06	8.49 <sup>a/</sup>	15.90 <sup>a/</sup>
	(2.34E-03)	(5.15E-03)	(2.03E-06)	(5.39E-06)	(1.17)	(3.97)
Income <sup>2</sup>	-1.20E-07	1.69E-05 <sup>a/</sup>	-1.38E-09 <sup>a/</sup>	-9.29E-09 <sup>b/</sup>	-6.25E-04	-6.65E-03 <sup>b/</sup>
	(9.40E-07)	(3.90E-06)	(5.09E-10)	(3.67E-09)	(4.35E-04)	(3.32E-03)
Income <sup>3</sup>	-	-3.40E-09 <sup>a/</sup>	-	1.58E-12 <sup>b/</sup>	-	1.20E-06 <sup>c/</sup>
		(7.65E-10)		(6.81E-13)		(6.71E-07)
Constant	30.57 <sup>a/</sup>	36.75 <sup>a/</sup>	0.01 <sup>a/</sup>	0.01 <sup>a/</sup>	4871.76 <sup>a/</sup>	2684.47 <sup>b/</sup>
	(1.10)	(1.74)	0.00	(0.00)	(561.86)	(1188.92)
F-statistic <sup>2/</sup>	138.93 <sup>a/</sup>	137.71 <sup>a/</sup>	8.12 <sup>a/</sup>	8.32 <sup>a/</sup>	84.30 <sup>a/</sup>	86.34 <sup>a/</sup>
Hausman test statistic <sup>3/</sup>	92.74 <sup>a/</sup>	93.02 <sup>a/</sup>	40.34 <sup>a/</sup>	45.99 <sup>a/</sup>	8.40 <sup>b/</sup>	10.55 <sup>b/</sup>
R-sq.--within	0.349	0.393	0.113	0.128	0.389	0.408
R-sq.--between	0.710	0.618	0.457	0.370	0.585	0.558
Obs.	269	269	237	237	268	268

<sup>24</sup> A two-way fixed effects panel is also estimated. In three of the models (industrial waste water, waste gas, and industrial dust), results indicate the appropriateness of including the time-specific fixed effects. These time effects capture unmeasured macroeconomic factors (e.g., change in environmental laws emanating from the central government) that all provinces experience. However, when the time effects are included, the income variables (linear, square, and cubic terms) lose their significance. This suggests that the effects of changes in macroeconomic factors dominate those of changes in income as far as these types of emissions are concerned. With this result in mind, we focus on the one-way fixed effects panel results since income is an important variable in the EKC regressions.

**Table 4: continued. Fixed effects panel regression estimates**<sup>1/</sup>

	SO2		SMOKE		IDUST	
	(1)	(2)	(1)	(2)	(1)	(2)
Income	8.88E-06 <sup>a/</sup> (1.83E-06)	1.52E-05 <sup>b/</sup> (6.35E-06)	7.52E-07 (1.96E-06)	3.92E-06 (7.41E-06)	-1.35E-05 <sup>a/</sup> (2.75E-06)	-3.59E-05 <sup>a/</sup> (9.19E-06)
Income <sup>2</sup>	-1.39E-09 <sup>a/</sup> (4.79E-10)	-6.53E-09 (5.10E-09)	-6.22E-10 (4.45E-10)	-3.20E-09 (6.02E-09)	2.74E-09 <sup>a/</sup> (6.68E-10)	2.09E-08 <sup>a/</sup> (6.37E-09)
Income <sup>3</sup>	-	1.03E-12 (9.92E-13)	-	5.15E-13 (1.16E-12)	-	-3.64E-12 <sup>a/</sup> (1.19E-12)
Constant	1.09E-02 <sup>a/</sup> (1.02E-03)	9.02E-03 <sup>a/</sup> (1.94E-03)	1.43E-02 <sup>a/</sup> (1.16E-03)	1.33E-02 <sup>a/</sup> (2.22E-03)	1.48E-02 <sup>a/</sup> (1.63E-03)	2.14E-02 <sup>a/</sup> (3.40E-03)
F-statistic <sup>2/</sup>	65.75 <sup>a/</sup>	64.09 <sup>a/</sup>	64.61 <sup>a/</sup>	63.81 <sup>a/</sup>	4.22 <sup>a/</sup>	4.56 <sup>a/</sup>
Hausman test statistic <sup>3/</sup>	2.53	4.15	2.81	3.12	9.92 <sup>a/</sup>	12.31 <sup>a/</sup>
R-sq.--within	0.081	0.085	0.006	0.007	0.074	0.103
R-sq.--between	0.192	0.159	0.010	0.003	0.004	0.000
Obs.	267	267	266	266	267	267

Notes: The numbers in parentheses are robust standard errors. <sup>a/ b/ c/</sup> Significant at the 99 percent, 95 percent, and 90 percent confidence levels, respectively. <sup>1/</sup> The province-specific fixed effects estimates are available upon request. <sup>2/</sup> This tests the null hypothesis that the province-specific fixed effects are the same. <sup>3/</sup> The Hausman test is used to test the fixed effects model against the random effects model. A significant Hausman test statistic favors the fixed effects model.

### Estimated Income-Emissions Regressions

Substituting the estimated coefficients into equation (1), the estimated per capita emission values can be determined. Figure 1a contains the actual and estimated values of the industrial waste water per capita discharges from 1987 to 1995.<sup>25</sup> Although the cubic term is statistically significant, the coefficient estimate of the linear term for income dominates both the coefficient estimates of the square and cubic income terms. That is, the estimated industrial waste water per capita discharge declines with a rise in real income.

The actual and estimated values of the industrial COD per capita discharge appear in Figure 1b. A turning point in the estimated income-emissions relationship is evident here. A per capita discharge peak is observed at per capita income 556 yuan (in 1950

<sup>25</sup> To focus on the relationship between income and emissions, unless indicated otherwise, all estimated values referred to in the paper exclude the estimated province-specific fixed effects.

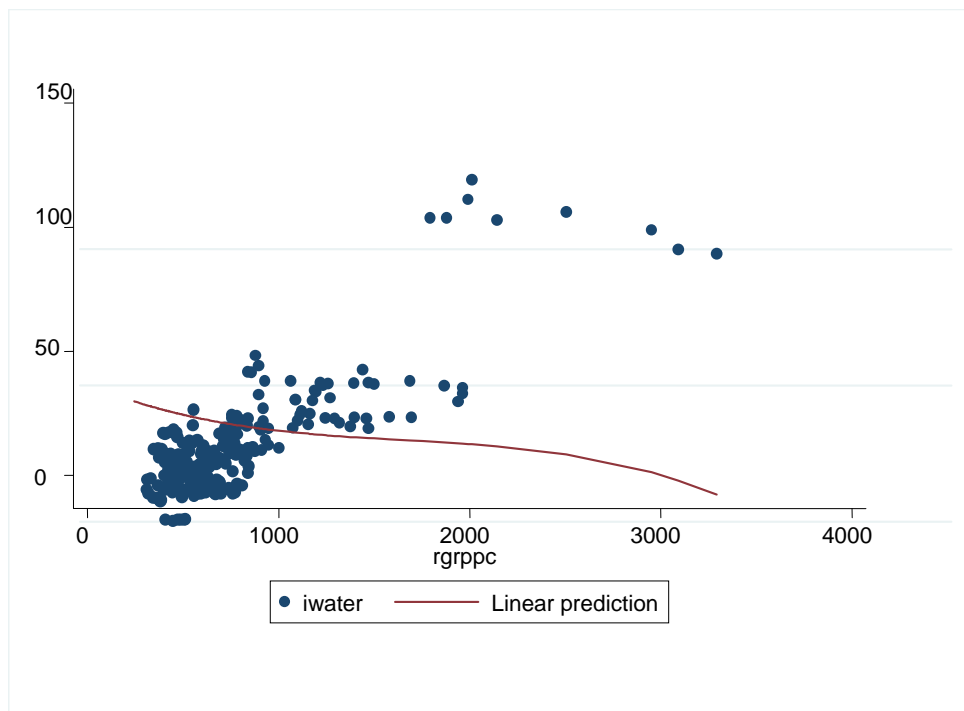


prices). According to the estimated income-emissions regression, industrial COD per capita emission is expected to decline as per capita income increases up to 3,291 yuan (the maximum real per capita income observed during the period). This is consistent with Wang and Wheeler’s (2003) finding that COD pollution intensity across China’s provinces declined between 1987-89 and 1992-1995. The authors attribute this to increases in the pollution levy rates as incomes increase. As they suggest, “[t]he locally enforced price of pollution rises steadily with development because enforcement capacity and community valuation of damage both increase.” (p. 466)

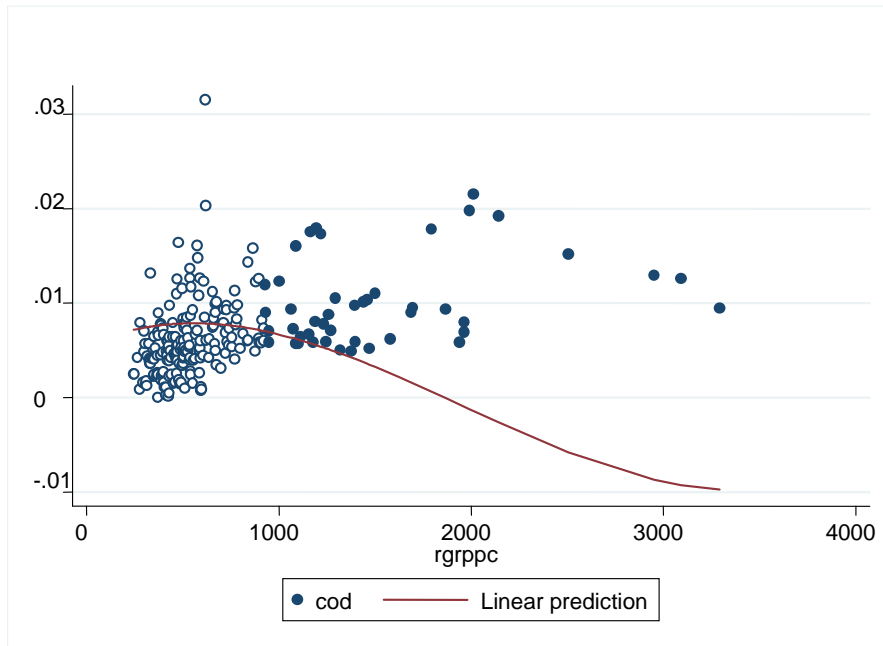
The coefficient estimate of the linear term for income once again dominates those of the square and cubic terms in the waste gas per capita discharge regression. From Figure 1c, we observe that emission per capita is expected to increase with real income. This result is consistent with those found by De Groot et al. (2004) who use a slightly longer data series (1982-1997) for Chinese provinces. They also find that waste gas increase monotonically with per capita income.

Two turning points are evident in the estimated industrial dust per capita discharge regression, see Figure 1d. For the per capita income (at the 1950 constant price) range observed between 1987 and 1995, we see per capita emission at first decreases as per capita income increases up to 1,295 yuan; emission then increases with income up to an income level of 2,505 yuan; and, emission is expected to decrease as income increases up to the observe maximum per capita income of 3,291 yuan.

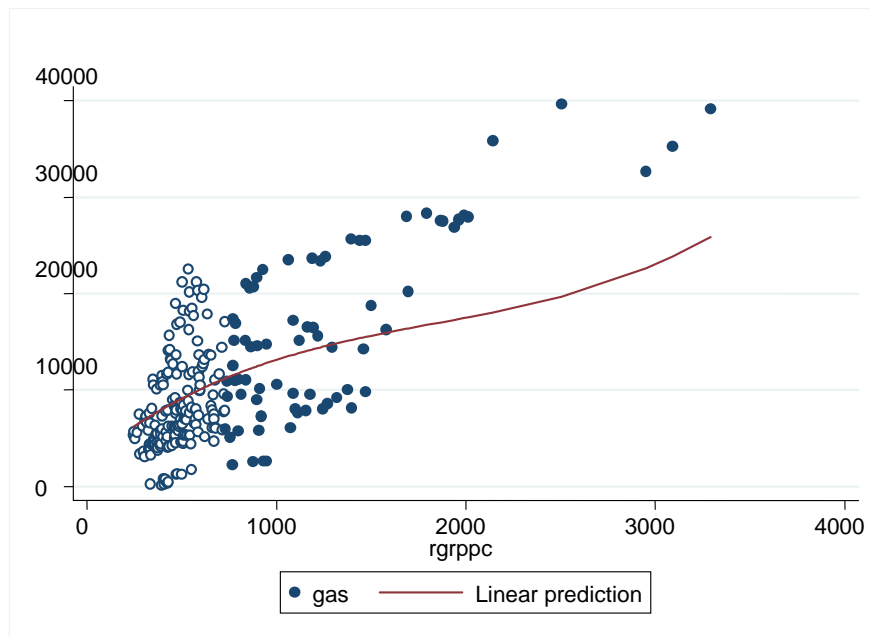
**Figure 1a : Total Industrial Waste Water Per Capita Discharge (Actual and Estimated, 1987-1995)**



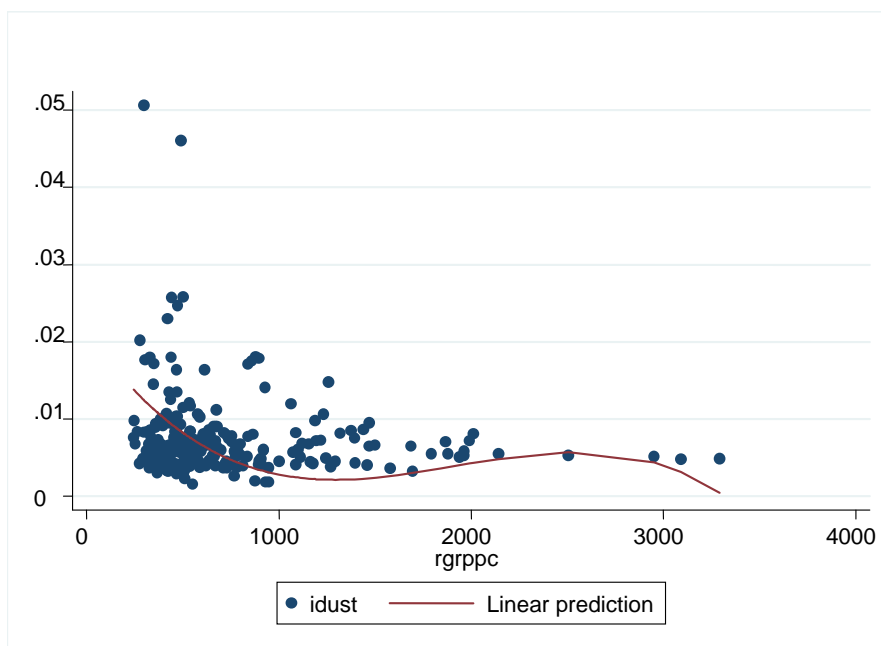
**Figure 1b : Industrial COD Per Capita Discharge  
(Actual and Estimated, 1987-1995)**



**Figure 1c : Waste Gas Per Capita Discharge  
(Actual and Estimated, 1987-1995)**



**Figure 1d : Industrial Dust Per Capita Discharge  
(Actual and Estimated, 1987-1995)**



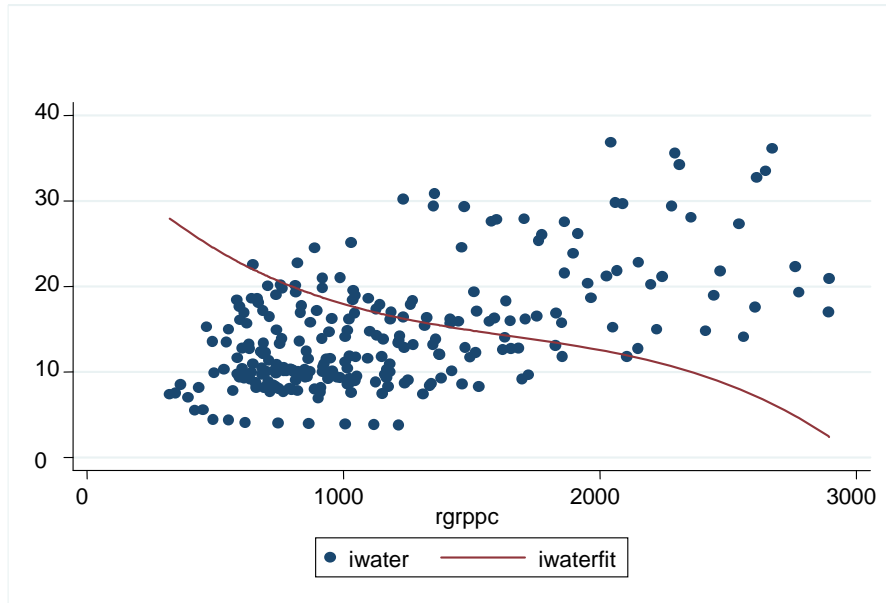
Using the estimated income-emissions relationships, off-sample (1996 to 2004) predictions of per capita emission values are calculated. In other words, if the estimated income-emissions relationship remained the same after 1995, what are the expected per capita emission levels for each of these four pollutants? How do these compare with the actual per capita emission levels in 1996 to 2004? Since data for waste gas are no longer available after 1995, we can make such comparisons only for three pollutants.<sup>26</sup>

The estimated cubic income-emissions regression for industrial waste water predicts a decline in per capita emission as income increases up to the observed maximum real per capita income level of 8,343 yuan. In fact, the model predicts negative per capita emissions when income reaches around 3,000 yuan. Practically, this result suggests that if no changes occur (in the income-emission relationship), industrial waste water emissions per capita is expected to be negligible at around 3,000 yuan.<sup>27</sup> Figure 2a contains the actual and off-sample predictions (using the average province-specific fixed effects) excluding 22 observations with negative predicted values.

<sup>26</sup> By limiting our sample to 1987 to 1995, it is possible that we are not capturing the entire range of the income-emissions relationship. For example, if a cubic relationship exists between income and emissions, it is possible that we capture only the first increasing (decreasing) portion of the relationship and completely miss the subsequent declining (increasing) portion by limiting the data period to 1987 to 1995. To address this issue, we also estimate income-emissions regressions for these three pollutants using data for the entire 1987-2004 period. The results are qualitatively similar to those using the shorter sample—industrial waste water pollution increases then declines with an increase in income; industrial COD pollution declines and increases with an increase in income; and, the industrial dust estimated income-emission relationship flattens; however, it still predicts a decline in emissions as income increases.

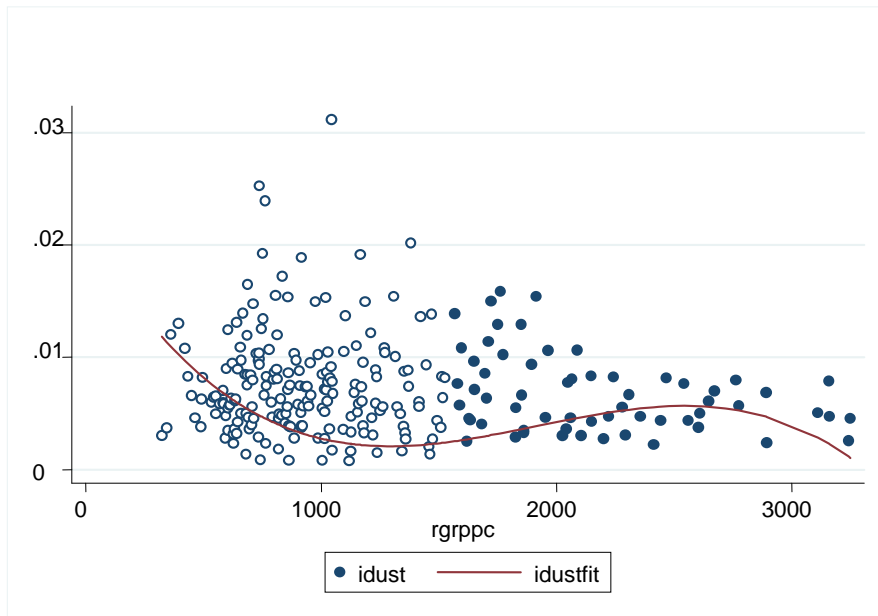
<sup>27</sup> This translates to 19,809 yuan in 2004 prices; this is roughly US \$2,390 at an exchange rate of 8.2768 yuan per US dollar.

**Figure 2a : Total Industrial Waste Water Per Capita Discharge  
(Actual and Predicted, 1996-2004)**



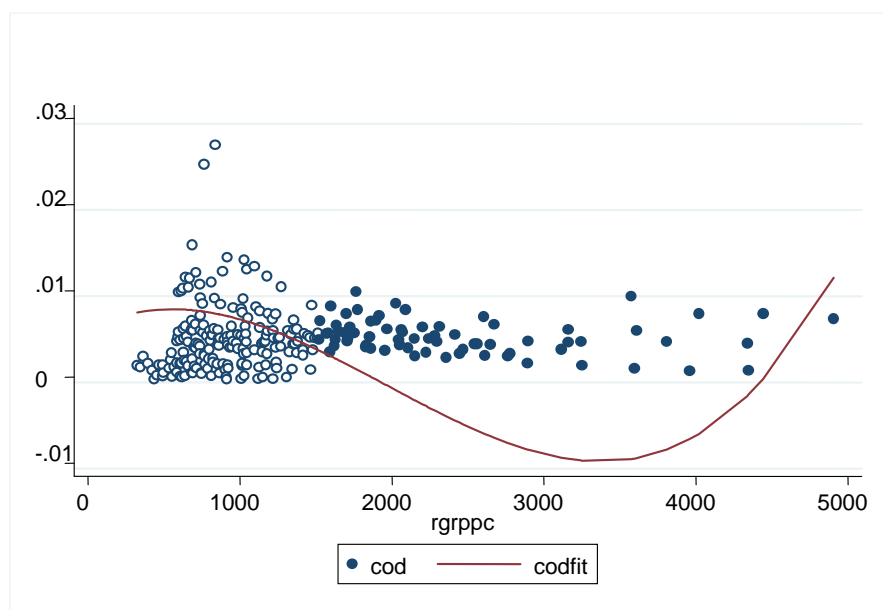
*Note: Excludes 22 observations with negative predicted values.*

**Figure 2b : Total Industrial Dust Per Capita Discharge  
(Actual and Predicted, 1996-2004)**



*Note: Excludes 15 observations with negative predictive values.*

**Figure 2c : Industrial COD Per Capita Discharge  
(Actual and Predicted, 1996-2004)**



*Note. Excludes 5 observations with RGRPPC > 5000 yuan*

The estimated cubic income-emissions regression (using the average province-specific fixed effects) for industrial dust also predicts a decline in per capita industrial dust discharge as income increases beyond 3,291 yuan; and, per capita industrial dust discharge is also expected to be insignificant at around 3,280 yuan. Observations with negative predicted values are excluded in Figure 2b.

Although the estimated income-emissions regression for industrial COD indicates that per capita industrial COD discharge declines as income increases up to 3,291 yuan (see Figure 1b), we see from Figure 2c that the estimates for industrial COD (using the average province-specific fixed effects) show a rise in per capita discharge as income increases beyond 3,291 yuan (the observed maximum per capita income in the 1987-1995 period).<sup>28</sup>

Note that the estimates in Figures 2a to 2c also assume that the province-specific fixed effects remain the same between 1996 and 2004. Recall that the province-specific fixed effects for the most part capture the effect of unmeasured locational attributes; the effect of other factors that either did not or changed very little during the period of analysis (e.g., north/south location; local authorities' attitude towards pollution) are also subsumed in the province-specific fixed effects. Thus, the predicted values in Figures 2a to 2c are calculated also assuming that the province-specific fixed effects remain the same between 1996 and 2004. That is, the off-sample predictions are based on a counter-factual—the relationship between income and emissions and the factors

<sup>28</sup> We exclude observations with real income per capita greater than 5,000 yuan in Figure 2c to highlight the curvature in the estimated income-emissions regression. Actual data for these five observations are significantly lower than the predicted values.

that are subsumed in the province-specific fixed effects remain the same (or changed very little) after 1995.

It is evident from Figure 2a that actual industrial waste water per capita discharge increases with income—this is opposite of the prediction of the estimated income-emission regression. This suggests that despite policies enacted by the Chinese government after 1995,<sup>29</sup> perhaps these have not been stringent enough to bring the per capita discharge levels down to the level provided by the estimates.

Besides the adoption of stricter environmental rules, structural changes (e.g., sectoral changes in output) experienced by the Chinese economy between 1996 and 2004 could have contributed to the observed emission pattern.<sup>30</sup> The income-emissions relationships observed here is less likely due to structural changes. This is because large structural changes in the overall Chinese economy (i.e., shift to secondary industries) occurred in the early 1990s not after 1995. In particular, the share of secondary industries to total output in 1990 was 41.6 percent; this increased to 48.5 percent in 1995; by 2004, the share increased to 52.9 percent (see China National Bureau of Statistics 2005).<sup>31</sup>

Output growth (scale effect) could have also contributed to the observed income-emissions relationships. Once again, it is not likely that the observed patterns after 1995 are due to significant growth in output. This is because between 1980 and 2004, China experienced its highest annual GDP growth prior to 1996. For example, annual GDP growth reached a high of 15 percent in 1984 and 14 percent in 1992. Annual growth rates after 1995 ranged from 7 percent to 10 percent (see World Bank 2005).

Actual industrial dust per capita discharge rates are larger than the predicted per capita discharge rates for most of the provinces between 1996 and 2004, see Figure 2b. This is inconsistent with the notion that given the adoption of stricter environmental regulations, actual emissions should be lower than the predictions because the latter assumes no changes in environmental regulations. Although, it should be noted that actual per capita emissions are closer to the predicted per capita emission values at income levels beyond 2,000 yuan. And, a negative income-emission relationship is observed in the actual data.

Policies enacted to lower industrial COD pollution discharge appear to have been partly successful.<sup>32</sup> That is, although actual per capita industrial COD pollution

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<sup>29</sup> For example, Article 16 of the amended *Law on the Prevention and Control of Water Pollution* authorized “national and provincial agencies to employ mass-based pollution control systems for water bodies that would not meet ambient standards even if all discharges met concentration-based effluent standards.” (Ma and Ortolano, 2000, p. 28) Prior to the amendment in 1996, China did not limit the mass (concentration and volume) flowrate of pollutants. Rather, concern was mostly over pollutant concentration.

<sup>30</sup> According to Dasgupta et al. (2002), “observed changes in pollution as per capita income rises could come from several different sources: shifts in the scale and sectoral composition of output, changes in technology within sectors, or the impact of regulation on pollution abatement.” (p. 152)

<sup>31</sup> Using the revised GDP values in fact would strengthen our argument. The share of secondary industries to total output in 1990 was 41.3 percent increasing to 47.2 percent in 1995; the share dropped to 46.2 percent by 2004 (see China National Bureau of Statistics 2007).

<sup>32</sup> A World Bank study (2006) arrives at a similar conclusion and partly attributes the reduction to improved industrial processes.

discharge rates are higher than the predicted discharge rates (see Figure 2c), the differences are for the most part not large and actual emission rates have not increased with income as the estimated income-emission regression model predicts. According to Wang and Wheeler (2005), industrial COD pollution is considered the most important water pollutant in China and has been monitored very closely by the Chinese environmental regulators. In fact, mass-based limits on industrial COD was included in the *Ninth Five Year Plan for Environmental Protection and Long Term Targets for the Year 2010* passed in 1996 (see Ma and Ortolano 2000).

The above conclusions though need to be qualified. This is because the off-sample predictions were calculated assuming that the effect of factors that are subsumed in the province-specific fixed effects on emissions remain the same (or changed very little) after 1995. If these are not the case, then the above conclusions may not be correct. To partly address this concern, we also estimate a cubic income-emissions regression for the three pollutants using 1996-2004 data. We find that the structures of the fixed effects in the first (1987-1995) and second (1996-2004) periods are similar for industrial waste water and industrial COD—the Spearman (Pearson) correlations of the first and second period province-specific fixed effects are 0.91 (0.96) for industrial waste water, 0.72 (0.69) for industrial COD, and 0.26 (0.27) for industrial dust. This increases confidence in the results presented above.

### Auxiliary Regressions

Although China’s State Environmental Protection Administration (SEPA) sets effluent standards, local governments have the right to set stricter standards.<sup>33</sup> Thus, local conditions will have an influence on how stringent pollution prevention and control policies are. It was suggested earlier that the province-specific fixed effects could be related to provincial authorities’ attitudes towards pollution control independent of income levels. Since the estimated fixed effects are parametric shifts, larger values indicate higher pollution discharge rates which could have resulted from less willingness to control pollution.

We test a number of additional hypotheses using the estimated province-specific fixed effects. In particular, we ask if the estimated province-specific fixed effects (which we take to be related to a province’s commitment to control pollution) are related to a number of characteristics such as a province’s north/south and coast/non-coast location, unemployment rate, urbanization rate, and industrial structure. These fixed effects may also be related to the relative importance of state-owned enterprises and foreign direct investment (FDI) in a province’s economy; and, whether the provincial government is running a budget surplus/deficit. The following auxiliary regression model is estimated:

$$\alpha_i = \phi + \theta' \mathbf{Z}_i + v_i, \quad (2)$$

where  $\alpha_i$  are the estimated province-specific fixed effects from equation (1), regressors included in  $\mathbf{Z}_i$  are province attributes hypothesized to be related to emission levels and commitment to pollution control; and,  $v_i$  is a well-behaved error term.

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<sup>33</sup> See Muldavin (2000), Ma and Ortolano (2000), and Economy (2004) for details.

The raw data clearly show that northern and coastal provinces are dirtier, thus we include a province's location in the auxiliary regression. Since the problems caused by unemployment are immediate and visible while the problems caused by pollution may not be immediate and are less visible, provinces with higher unemployment rates are expected to be dirtier and may be less willing to enforce environmental protection laws. Urbanization may reduce pollution since urban areas have better sanitary facilities and people in urban areas usually use gas instead of coal. However, urbanization normally is accompanied by industrialization. More industries imply higher industrial pollution. Therefore, the correlation between the urbanization rate (proxied by population density) and emissions is ambiguous.

Provinces with a larger share of their output originating from secondary industries which includes manufacturing are expected to be more polluted than provinces with a smaller output share from secondary industries. The managers of China's SOEs are appointed by the central government. Thus, they may be more willing to follow pollution control rules. These enterprises also tend to have access to better pollution control technologies than other types of enterprises. Therefore, provinces with a larger share of their output coming from the SOEs are expected to have lower emissions. Since most foreign enterprises in China are from developed countries and these firms tend to have superior and cleaner technologies, provinces receiving relatively more FDI are expected to be cleaner.

Lester and Lombard (1990) argue that administrative units with greater fiscal resources may be more inclined to regulate pollution. This is because they are less dependent on polluters for tax revenues. In China, fiscal revenue shortage is the major obstacle for local government enforcement of environmental protection laws. Thus, provinces experiencing relatively large budget deficits are expected to be more polluted and may be less willing to control pollution.

To mitigate potential endogeneity between the estimated province-specific fixed effects and the above mentioned regressors, we use the average values of these regressors in 1982-1986. In other words, since the effects of these factors may also be subsumed in the estimated province-specific fixed effects, these variables are measured in periods prior to 1987. Also, since the province-specific fixed effects capture unmeasured province characteristics that either did not or changed very little, these variables should also not vary too much in each province. Some of these variables did not vary too much in each province. For example, the coefficients of variation for population density range from 1.3 percent (Jilin) to 4.5 percent (Beijing). The share of secondary industries to total regional output and the share of state-owned enterprises to total industrial output are also quite stable in most of the provinces. The provinces, however, experienced large changes in the rate of unemployment, the size of the budget surplus/deficit, and FDI relative to total regional output. For example, the coefficients of variation for the rate of unemployment range from 4.5 percent (Guangdong) to 69.4 percent (Beijing).

The estimates for the full model appear in column (1) of Table 5. There is no indication of a misspecification, multicollinearity, or heteroskedasticity problem. The fit of the models are quite good and ranges from 59 percent to 62 percent. Controlling for income, northern provinces, provinces with lower population densities, and provinces with smaller secondary industries shares have lower per capita industrial



**Table 5: Correlates of the Estimated Province-Specific Fixed Effects in 1987-1995**

	Industrial Waste Water			Industrial COD <sup>1/</sup>			Industrial Dust <sup>1/</sup>		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
North	-13.13 <sup>a/</sup>	-9.41 <sup>b/</sup>	-9.66 <sup>b/</sup>	-0.09	-0.10	-0.08	-0.18	0.24	0.21
	(4.14)	(3.43)	(3.55)	(0.20)	(0.14)	(0.14)	(0.17)	(0.17)	(0.14)
Coast	4.696	7.432 <sup>b/</sup>	8.398 <sup>b/</sup>	0.363	0.501 <sup>a/</sup>	0.450 <sup>a/</sup>	0.658 <sup>a/</sup>	0.388 <sup>b/</sup>	0.532 <sup>a/</sup>
	(4.33)	(3.11)	(3.43)	(0.21)	(0.12)	(0.13)	(0.18)	(0.15)	(0.13)
Unemployment	0.477	--	--	0.019	--	--	0.079	--	--
	(1.69)			(0.08)			(0.07)		
Population density	0.005 <sup>a/</sup>	0.005 <sup>a/</sup>	-0.003	0.000 <sup>b/</sup>	0.000 <sup>a/</sup>	0.001	0.000	0.000	-0.001 <sup>a/</sup>
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Secondary share	1.180 <sup>a/</sup>	0.835 <sup>a/</sup>	0.885 <sup>a/</sup>	0.013	0.016 <sup>b/</sup>	0.013 <sup>c/</sup>	0.035 <sup>a/</sup>	0.011	0.018 <sup>b/</sup>
	(0.28)	(0.16)	(0.17)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
State enterprises share	0.130	0.125	0.070	0.010	0.012 <sup>b/</sup>	0.015 <sup>b/</sup>	0.001	0.002	-0.007
	(0.18)	(0.15)	(0.17)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
FDI share	2.006	--	--	0.045	--	--	0.062	--	--
	(2.91)			(0.14)			(0.12)		
Budget balance share	-0.053	--	--	0.007	--	--	-0.031 <sup>b/</sup>	--	--
	(0.35)			(0.02)			(0.01)		
Constant	-58.84 <sup>a/</sup>	-46.22 <sup>a/</sup>	-42.59 <sup>a/</sup>	-1.50 <sup>c/</sup>	-1.78 <sup>a/</sup>	-1.97 <sup>a/</sup>	-2.03 <sup>a/</sup>	-0.83	-0.29
	(15.71)	(13.39)	(14.64)	(0.75)	(0.53)	(0.57)	(0.64)	(0.65)	(0.56)
N	23	30	28	23	30	28	23	30	29
F-statistic <sup>2/</sup>	34.34 <sup>a/</sup>	54.60 <sup>a/</sup>	10.64 <sup>a/</sup>	7.58 <sup>a/</sup>	20.35 <sup>a/</sup>	7.13 <sup>a/</sup>	4.93 <sup>a/</sup>	4.59 <sup>a/</sup>	9.02 <sup>a/</sup>
Adj R	0.92	0.90	0.64	0.71	0.77	0.53	0.59	0.38	0.59
Ramsey Reset <sup>3/</sup>	2.28	0.70	2.72 <sup>c/</sup>	0.65	1.78	1.29	0.59	0.73	1.76
Breusch-Pagan <sup>4/</sup>	0.43	0.01	0.85	0.85	0.66	0.95	1.80	1.80	0.74
Mean VIF	3.50	1.94	1.97	3.50	1.94	1.97	3.50	1.94	1.98

Notes: The numbers in parentheses are standard errors. <sup>a/ b/ c/</sup> Significant at the 99 percent, 95 percent, and 90 percent confidence levels, respectively. <sup>1/</sup> Coefficients and standard errors are multiplied by 100. <sup>2/</sup> Model significance test. <sup>3/</sup> Specification test. <sup>4/</sup> Heteroskedasticity test.

waste water pollution; industrial COD emissions per capita are lower in less urbanized areas; and, coastal provinces, provinces with larger secondary industries shares, and provinces experiencing smaller budget surpluses (or larger budget deficits) have larger industrial dust emissions per capita.

Since the rate of unemployment, the size of the budget balance and FDI relative to total output experienced large changes in most provinces, we exclude them from equation (2). The results appear in column (2) of Table 5. For the most part, the results for the remaining variables are qualitatively similar to those in column (1) for industrial waste water and industrial dust. Coast, secondary industries share, and SOEs share are now statistically significant in the industrial COD regression. Non-coastal provinces and provinces with smaller secondary industries shares and smaller SOEs shares have lower industrial COD pollution per capita discharge rates. The latter is consistent with Wang and Wheeler's (2003) finding that state-owned plants are more pollution intensive. As a robustness check, we also test for the presence of influential observations using DFITS, Cook's distance, and Welsch Distance. We exclude observations (Shanghai and Guangdong for the first two pollutants; and only Shanghai in industrial dust) when at least two of these tests identify them as influential observations. The estimates appear in column (3). Population density loses significance in the industrial waste water and industrial COD regressions but become significant in the industrial dust regression. The results for the remaining variables are qualitatively similar.

Overall, the results indicate that provinces in the north have lower levels of industrial waste water pollution, after controlling for income. Northern provinces do not have much water resources, i.e., water is much more precious for them compared to the southern provinces, and therefore, they may be more interested in controlling water pollution. Non-coastal provinces and provinces with smaller secondary industries shares have lower levels of all three types of pollutants. Contrary to expectations, provinces with higher state-owned enterprises shares have higher levels of industrial COD pollution. Finally, there is also some evidence that a province's industrial dust pollution level is related to its budget balance. Industrial dust is a local public "bad;" thus, local governments may have more incentives to regulate this pollutant. Therefore, administrative units with greater fiscal resources may be more inclined to regulate industrial dust pollution.

## **5. Conclusion**

This paper estimated income-emissions regressions using 1987-1995 data for Chinese provinces. Six pollutants were considered. We find no evidence consistent with an inverted-U relationship between income and emissions. In fact, the estimated EKC's show no relationship between income and emissions (e.g., smoke pollution), a monotonically decreasing relationship (e.g., industrial waste water pollution), and a cubic relationship between income and emissions (e.g., industrial COD). Off-sample predicted values of selected pollutants for the period of 1996-2004 were compared with actual emission levels during this period. We find that actual industrial COD pollution per capita discharge rates in 1996-2004 have leveled off and do not increase with income as the estimated income-emissions regression predicts, indicating that environmental policies enacted by the Chinese government may have been partly successful. However, we also find that the actual industrial waste water and industrial

dust per capita discharge rates in 1996-2004 were higher than the predictions. And, contrary to the predictions of the estimated income-emission regression model, actual industrial waste water emissions increase with income. Clearly, more stringent rules are needed to fight industrial waste water pollution.

Auxiliary regressions show that conditional on income, northern provinces have lower industrial waste water pollution; non-coastal and provinces with smaller secondary industry shares have lower industrial (waste water, COD, and dust) pollution; provinces with smaller SOEs shares have lower industrial COD pollution; and, commitment to control industrial dust pollution is correlated with local governments' budget balance.

Policymakers in China now admit that costs (e.g., health costs, ecological destruction) associated with pollution can no longer be ignored, and serious actions need to be undertaken to enforce extant pollution laws. China simply cannot continue to grow at 10 percent per year and ignore the associated harm to the environment. This line of thinking is clearly evident in a white paper on environmental protection issued by the China State Council Information Office in 2006. The white paper recognizes the trade-off between economic growth and a clean environment; and, admits that a damaged environment may hinder China's future development, see China State Council Information Office (2006). The white paper also summarizes what China has done to protect its environment in the last decade—from the passage of new environmental laws to closing firms that have caused serious environmental damage. China has also increased investments on environmental protection. According to *The Economist* (2004), in 2001-2005 environmental spending is about 1.3% of GDP; it was only 0.8% of GDP in the early 1990s. In 2006, environmental protection expenditure formally became a government budgetary expenditure item (see State Council Information Office 2006).<sup>34</sup>

Despite these positive developments, a number of outstanding issues remain. First, enforcement of extant environmental laws is quite weak. There have been numerous reports of some administrators accepting bribes from violators and failing to enforce established laws on environmental protection.<sup>35</sup> Second, the role of local governments in environmental protection is crucial. Thus, appropriate incentives need to be constructed to bring them in-line with the public's demand for a cleaner environment (see Cheng et al. 2007). Since fiscal resources are extremely limited, local governments in China simply do not have much incentive for environmental protection. Thus, one way to put pressure on local governments to regulate pollution is to create a mechanism whereby central government transfers are tied not only to local output growth but to improvements in environmental outcomes as well. If appropriately constructed, this may prove popular with local government officials.

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<sup>34</sup> The Standing Committee of China's National People's Congress passed *Energy Conservation Law of the People's Republic of China* on October 28, 2007. This law requires households and enterprises to meet energy-conservation targets and requires governments above the county level to annually report their energy saving achievements to the People's Congress of the corresponding level and requires provincial governments to report energy saving achievements to the State Council. The law also allows the central government to use policy tools to encourage energy savings. It is expected that local government officials will be evaluated based on their energy savings achievements, in addition to their growth achievements. This law certainly is another step in tackling China's environmental problems (see China Daily 2007a).

<sup>35</sup> See e.g., China Daily (2007b).

There has been an attempt to control pollution by using green GDP. Green GDP accounts for pollution costs in GDP calculations. A recent official estimate puts the cost of pollution at 3 percent of GDP in 2004 (see *The Economist* 2007). Green GDP, however, is a controversial measure—both in how it is calculated and in its potential use in evaluating the performance of local government officials. It is so controversial and unpopular that a report due in March 2007 has not been issued (see Kahn and Yardley 2007). Perhaps rather than using green GDP to measure local government officials' performance, a system rewarding those able to achieve targeted emission reductions would be more acceptable. Finally, the appearance of 16 Chinese cities in the World Bank's list of the 20 most polluted cities in the world suggests that China has a long way to go in cleaning up its environment. This is a concern for the rest of the world as pollution in China affects other countries as well. In 2001 for example, dust from China reached the United States (See *The Economist*, 2004). Thus, China's participation in the international coordination of environmental protection is necessary.

## Appendix

Data used in equation (2) are collected from *China Compendium of Statistics 1949-2004*. **Unemployment rate** is the ratio of the number of the registered unemployed persons to the labor force in urban areas. **Population density** is the number of people per square kilometer. **Secondary share** (in percent) is the share of secondary industry output to the total regional product. Secondary industry includes mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction. **State enterprises share** (in percent) is the size of the gross industrial output of state-owned enterprises to gross industrial output of all enterprises in the province. **FDI share** (in percent) is the size of actually used foreign direct investment to the region's total output. **Budget balance share** (in percent) is the size of the budget balance relative to the region's total output. Budget balance is the difference between the local government general revenue and expenditure.

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