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Growth, Foreign Direct Investment and the Environment: Evidence from Chinese Cities

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Abstract

In this paper we investigate the relationship between economic growth and industrial pollution emissions in China using data for 112 major cities between 2001 and 2004. Using disaggregated data we separate FDI inflows from Hong Kong, Macao and Taiwan from those of other foreign economies. We examine four industrial water pollution indicators (wastewater, chemical oxygen demand, hexavalent chromium compounds, and petroleum-like matter) and four industrial air pollution indicators (waste gas, sulphur dioxide, soot and dust). Our results suggest that most air and water emissions rise with increases in economic growth at current income levels. The share of total output produced by firms from Hong Kong, Macao and Taiwan has a positive effect on emissions although this effect is only significant for three industrial water pollution emissions. The share of total output produced by firms from other foreign economies can be beneficial, detrimental or neutral, depending on the pollutants considered.

JEL Classification: O13, O18, Q25, O53, R1, F23

Key words: FDI; economic growth; pollution; cities.

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Introduction

In recent years China has experienced rapid export driven economic growth enhanced by large investment flows from abroad. Since 2000, economic growth rates have consistently exceeded 8% (World Bank 2007), while China now receives more FDI than any other developing economy and by 2005 ranked among the world's top 3 recipients with inflows of $72 billion (UNCTAD 2007). However, these economic gains have come at a cost. Seventeen of the 25 most polluted cities in the world can be found in China and an estimated 300,0000 people die prematurely each year as a result of air pollution.[1] If China is to alleviate its environmental degradation and the health impacts that result from it, particularly in urban areas, a detailed understanding of the economic forces influencing industrial pollution is required.

In this paper we examine the relationship between economic growth, foreign direct investment (FDI) and the environment in China. We make three specific contributions to the growth-environment literature. First, we focus specifically on China given the undeniable strain such a large and rapidly growing economy is placing on the natural environment. Studies investigating these issues in China are relatively scarce. Second, since the majority of industrial emissions are released in urban areas, we concentrate our analysis on Chinese cities and examine the city-level characteristics that influence industrial emissions. We believe the use of city-level variables provides more potential explanatory power than the use of highly aggregated variables reported at the national level. Third, given the vast FDI flows into China in recent years we analyse the contribution of FDI to China's industrial pollution emissions and also take the additional step of identifying FDI by source country.

A large literature has examined the impact of economic growth on the environment using panels of country-level data over time, with mixed results. [2] Early studies such as Shafik (1994), Seldon and Song (1994) and Grossman and Krueger (1995) claimed to find an inverted-U shaped relationship between income and pollution, since known as an environmental Kuznets curve (EKC). More recent studies have subjected the EKC to

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[1] Wang (2007) and China Environment Yearbook (2000).

[2] Some studies use site-specific pollution concentrations as the dependent variable instead of national emissions, but still use explanatory variables measured at the country-level (e.g. Grossman and Krueger 1995).

ever-greater levels of scrutiny and generally urge caution when interpreting EKC results, not least because many have been shown to lack robustness (Harbaugh *et al.* 2002, Stern 2001).

Of the various growth-environment studies, there are few that investigate the role played by FDI, particularly in a developing country context. He (2006) is one exception and constructs a five-equation simultaneous system to study the FDI-emission relationship in China. The system incorporates the FDI location decision with respect to environmental regulation stringency and the impact of FDI on pollution through scale, composition and technique effects. The simultaneous system is estimated on a dynamic panel of 29 Chinese provinces' SO_2 emissions during the period from 1994 to 2001. The results show that the total impact of FDI on industrial SO_2 emissions is small. A 1 per cent increase in FDI capital stock contributes a 0.098 per cent increase in industrial SO_2 emissions. Zeng and Eastin (2007) examine the effects of trade openness and FDI on industrial pollution levels across China's provinces over the period 1996-2004. They find that increased trade openness and FDI is positively associated with environmental protection in China.

Other studies have investigated the environmental impact of FDI by suggesting that a 'pollution halo' may exist around multinational firms if those firms are less pollution intensive than domestic firms. Studies such as Eskeland and Harrison (2003) and Cole *et al.* (2008) do indeed find evidence to suggest that multinational firms in developing economies are less pollution intensive than their domestic counterparts, although no such evidence was found for Indonesia by Pargal and Wheeler (1996). Explanations of why multinationals may be cleaner than domestic firms include the suggestion that they may utilise more advanced technologies, cleaner production methods, and possess more developed environmental management systems (EMS). Also, they may have large export markets in OECD countries where they have to meet the requirements of environmentally aware consumers. Seemingly at odds with the pollution halo concept is the idea that FDI may be attracted to developing economies by less stringent environmental regulations, the so-called pollution haven hypothesis. If true, it may suggest that multinationals are damaging the environment in developing countries, although that still does not preclude them from being cleaner than domestic firms.

However, evidence for the pollution haven hypothesis is limited (Eskeland and Harrison 2003, Cole and Elliott 2005).

The previous literature therefore provides little by way of clear guidance as to the impact of China's significant FDI inflows on the environment. This lack of guidance is compounded by the absence of previous studies examining the city-level characteristics that influence a city's pollution emissions. This paper therefore aims to at least partially fill this gap in the literature by examining the extent to which FDI and economic growth influence industrial pollution emissions in China using data for 112 major cities between 2001 and 2004. Additionally, our dataset allows us to separate FDI inflows from Hong Kong, Macao and Taiwan from those of other foreign economies. We examine four industrial water pollution indicators (wastewater, chemical oxygen demand, hexavalent chromium compounds, and petroleum-like matter) and four industrial air pollution indicators (waste gas, sulphur dioxide, soot and dust). Our results suggest that all of our air and water emissions increase with income. Turning points, where estimated, are at income levels that are significantly beyond the sample income range. The share of total output produced by firms from Hong Kong, Macao and Taiwan has a positive effect on emissions although this effect is only significant for three industrial water pollution emissions. The share of total output produced by firms from other foreign economies can be beneficial, detrimental or neutral, depending on the pollutants considered.

The remainder of the paper is organised as follows. Section two provides background information on Chinese cities, section three provides the model specification and a description of the data. Section five presents the empirical results and section six concludes.

2. Pollution and Economic Change in Chinese Cities

To illustrate the economic development of Chinese cities, Table 1 compares the population, income and FDI inflows for a number of the largest Chinese cities in 2004. Cities in coastal provinces generally have higher income levels than inland cities (15 of the 17 cities with income above $3,000 are located in eastern regions), especially in some southeast coastal provinces, for example, Zhuhai, Shenzhen and Guangzhou in Guangdong province; Xiamen in Fujian province; and Ningbo and Hangzhou in

Zhejiang province. In terms of the per capita GDP growth, some inland cities have higher rates than the eastern cities, possibly as a result of a recent Western Development Programme. However, the gap between east and west remains considerable.

The geographical distribution of FDI is also unbalanced. In terms of total FDI inflows, Shanghai, Qingdao, Shenzhen and Beijing are the four largest recipients of foreign capital accounting for more than 28 per cent of FDI inflows in 2004. Among the cities with the total FDI inflows above $1,000 million, only Wuhan, the capital of Hubei province, is located in central China, the others are all eastern cities. Similarly, among the cities with a share of FDI/GDP above 5 per cent, the majority are located in eastern regions, except Wuhan and Nanchang (the capital of Jiangxi province).

Table 1: Population, Income and FDI for Some Cities in China, 2004

City	Population (million)	GDP per capita ($)	GDP per capita growth rate (%)	FDI (million $)	FDI/GDP (%)
Zhuhai	0.86	7848	3.32	510	7.73
Shenzhen	1.65	7161	1.62	3612	8.73
Guangzhou	7.38	6799	8.82	2401	4.83
Shanghai	13.52	6682	11.21	6541	7.27
Xiamen	1.47	4850	5.60	570	5.34
Ningbo	5.53	4733	12.84	2103	8.07
Hangzhou	6.52	4695	11.10	1410	4.64
Beijing	11.63	4477	8.64	3084	5.96
Dalian	5.62	4226	12.72	2203	9.30
Nanjing	5.84	3993	11.73	2566	11.12
Tianjin	9.33	3812	11.86	2472	6.98
Qingdao	7.31	3401	12.66	3799	14.53
Jinan	5.90	3336	10.09	483	2.47
Shenyang	6.94	3321	10.72	2423	10.55
Huhhot*	2.15	3180	18.12	239	3.87
Yantai	6.47	3043	16.37	1857	9.42
Wuhan*	7.86	3016	10.01	1520	6.43
Fuzhou	6.09	2832	7.25	1360	7.27
Urumuchi*	1.86	2757	8.81	15	0.26
Changchun*	7.24	2572	7.03	902	4.86
Zhengzhou*	6.71	2565	15.79	242	1.45
Chengdu*	10.60	2510	8.28	332	1.26
Wenzhou	7.46	2277	6.99	209	1.23
Taiyuan*	3.32	2272	15.20	143	1.84
Kunming*	5.03	2268	8.65	62	0.55
Changsha*	6.10	2179	13.11	501	3.66
Haikou	1.43	2166	1.15	320	10.47
Shijiazhuang	9.18	2159	10.63	352	1.78
Yinchuan*	1.38	2135	9.42	64	2.79
Harbin*	9.70	2110	9.87	405	1.99
Nanchang*	4.61	2083	10.58	730	7.85
Qinhuangdao	2.76	1995	9.17	202	3.68
Lanzhou*	3.08	1991	6.53	-	-
Nantong	7.74	1910	15.10	1104	7.46
Xi'an *	7.25	1701	8.18	276	2.08
Hefei*	4.45	1616	17.42	316	4.43
Guiyang*	3.48	1532	8.60	78	1.46
Shantou	4.88	1501	7.11	78	1.07
Beihai*	1.48	1328	7.83	20	1.01
Zhanjiang	7.16	1176	9.48	71	0.97
Chongqing*	31.44	1161	10.88	405	1.26
Nanning*	6.49	1103	4.40	78	1.09
Lianyungang	4.69	1074	13.29	247	4.90
Xining*	2.07	1025	12.37	9	0.44

*Source: China City Statistical Yearbook, 2004, 2005. * indicates cities in inland provinces.*

Note: Cities reported in this table include:

1) 4 municipalities: Beijing, Tianjin, Shanghai, and Chongqing;

2) 26 province capital cities: Shijiazhuang, Taiyuan, Huhhot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chengdu, Guiyang, Kunming, Xi'an, Lanzhou, Xining, Yinchuan, and Urumuchi (Lasa is not included due to lack of data)

3) 15 sub-provincial cities: Shenyang, Dalian, Changchun, Harbin, Nanjing, Hangzhou, Ningbo, Xiamen, Jinan, Qingdao, Wuhan, Guangzhou, Shenzhen, Chengdu, and Xi'an;

4) 5 special economic zones: Shenzhen, Zhuhai, Shantou, Xiamen, Hainan

5) 14 coastal open cities: Tianjin, Shanghai, Dalian, Qinhuangdao, Yantai, Qingdao, Lianyungang, Nantong, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai.

Some cities appear in several categories, for example, Guangzhou, the capital of Guangdong province, is also a sub-provincial city and a coastal open city.

Turning to environmental considerations, in 2002, the State Environmental Protection Agency (SEPA) found that close to two-thirds of the 300 cities tested failed to meet the air quality standards set by the World Health Organisation (WHO). Furthermore, the World Bank announced that pollution is costing China an annual 8-12% of GDP in direct damage, such as the impact on crops by acid rain, medical bills, lost work from illness, money spent on disaster relief following floods and the implied costs of resource depletion (The Economist, 21/08/2004).[3]

In this paper we concentrate on water and air pollutants. We therefore consider each in turn. Table 2 provides general information about city drinking water quality, groundwater quality and groundwater levels. The proportion of cities reaching the drinking water quality standard of 80% or above has decreased from 83% in 2002 to 70% in 2004, while correspondingly, the proportion in the less than 60% group increased from 2% to 23% illustrating a deterioration in the quality of drinking water. Turning to the level of groundwater, the number of cities that show a drop in the level of groundwater has fallen. However, in more than half of the monitored cities in 2004 groundwater quality worsened. SEPA reported that the groundwater quality was mainly affected by human activities. The major pollutants in the groundwater are nitrates, nitrogen-ammonia, and chloride. Domestic sewage is another major source of water pollution.

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[3] To monitor environmental quality, China has, since 1980, established 2389 environmental monitoring stations, including 1 general station, 41 provincial central stations, 401 prefecture-level stations, 1914 county-level stations and 32 nuclear monitoring stations.

Table 2: Drinking Water Quality, Groundwater Level and Quality in Cities

	Rate of Reaching Drinking Water Quality Standard				
	100%	99.9% ~ 80%	79.9% ~ 60%	59.9% ~ 0	Total
2002	26 (55%)	13 (28%)	7 (15%)	1 (2%)	47
2003	22 (47%)	9 (19%)	8 (17%)	8 (17%)	47
2004	25 (53%)	8 (17%)	3 (6%)	11 (23%)	47

	Groundwater Level			
	Raise	Stable	Drop	Total
2001	63 (34%)	8 (4%)	115 (62%)	186
2002	75 (34%)	34 (16%)	109 (50%)	218
2003	61 (31%)	73 (38%)	60 (31%)	194
2004	53 (28%)	78 (41%)	61 (32%)	192

	Groundwater Quality			
	Improve	Stable	Worsen	Total
2004	39 (21%)	52 (28%)	96 (51%)	187

Note: # of cities reported in the table; and proportion in brackets.
Source: *China Environment Yearbook 2002-2005.*

For air pollution, monitoring stations observe concentrations of SO_2, NO_2 and PM_{10} every day in a number of key cities. Tables 3 to 5 present the 20 most polluted cities and the 20 cleanest cities according to the annual average concentrations of SO_2, NO_2 and PM_{10} (fine particulate matter) in 2004. In terms of SO_2 and PM_{10}, the most polluted cities are mostly located in northern and central regions, for example, Linfen, Yangquan, Datong, Changzhi, and Taiyuan in Shanxi province; Jiaozuo, Kaifeng, Anyang, Luoyang, Sanmenxia and Pingdingshan in Henan province; Chifeng and Baotou in Inner Mongolia; Zhuzhou and Xiangtan in Hunan province; and Yibin, Panzhihua, and Zigong in Sichuan province. The major industrial sectors in these cities are mining and the washing of coal, mining and procession of ores, processing of coking, and smelting of ferrous and non-ferrous metals, etc. In terms of NO_2, some eastern cities enter the most polluted group, such as Beijing, Guangzhou, Shenzhen, Shanghai, Wenzhou and Ningbo.

SEPA reported that in 2004, of 342 monitored cities, 132 (38.6%) achieved the national ambient air quality standard II (living standard), 141 (41.2%) reached standard III and 69 (20.2%) were lower than standard III. Furthermore, 66.1% of citizens live in cities below the air quality standard II.

Table 3: Annual Average SO_2 Concentration in Some Cities in China, 2004

The Most Polluted Cities	SO_2 Concentration (mg/m^3)	The Cleanest Cities	SO_2 Concentration (mg/m^3)
Yangquan	0.231	Lasa	0.003
Linfen	0.224	Beihai	0.005
Jinchang	0.198	Haikou	0.007
Yibin	0.155	Karamay	0.007
Datong	0.149	Fuzhou	0.010
Zunyi	0.135	Zhanjiang	0.012
Sanmenxia	0.132	Changchun	0.013
Jiaozuo	0.127	Hefei	0.013
Zhuzhou	0.123	Wuhu	0.017
Handan	0.121	Qiqiharr	0.019
Yichang	0.120	Maanshan	0.019
Chongqing	0.113	Shenzhen	0.023
Liuzhou	0.109	Zhuhai	0.024
Urumuchi	0.102	Changzhou	0.024
Chifeng	0.099	Xining	0.024
Anyang	0.094	Rizhao	0.024
Guiyang	0.094	Quanzhou	0.025
Changzhi	0.093	Xiamen	0.025
Luoyang	0.093	Huzhou	0.026
Shizuishan	0.090	Mudanjiang	0.027

Source: China Environment Yearbook 2005.

Table 4: Annual Average NO_2 Concentration in Some Cities in China, 2004

The Most Polluted Cities	NO_2 Concentration (mg/m^3)	The Cleanest Cities	NO_2 Concentration (mg/m^3)
Guangzhou	0.073	Beihai	0.007
Shenzhen	0.072	Yuxi	0.011
Beijing	0.071	Zhanjiang	0.012
Chongqing	0.067	Haikou	0.013
Shanghai	0.062	Hefei	0.017
Wenzhou	0.062	Quanzhou	0.018
Ningbo	0.060	Lasa	0.020
Harbin	0.060	Jinchang	0.020
Urumuchi	0.058	Lianyungang	0.020
Jiaozhuo	0.056	Taiyuan	0.022
Changzhi	0.056	Qinhuangdao	0.023
Yangquan	0.055	Qujing	0.023
Linfen	0.055	Deyang	0.023
Nanjing	0.055	Changde	0.023
Hangzhou	0.055	Guiyang	0.024
Huzhou	0.054	Zhangjiajie	0.024
Wuhan	0.054	Maanshan	0.024
Tianjin	0.052	Qingdao	0.024
Suzhou	0.051	Mianyang	0.025
Datong	0.050	Luzhou	0.025

Source: China Environment Yearbook 2005.

Table 5: Annual Average PM_{10} Concentration in Some Cities in China, 2004

The Most Polluted Cities	PM_{10} Concentration (mg/m^3)	The Cleanest Cities	PM_{10} Concentration (mg/m^3)
Panzhihua	0.256	Haikou	0.033
Linfen	0.219	Beihai	0.043
Kaifeng	0.198	Guilin	0.046
Baotou	0.186	Zhuhai	0.046
Datong	0.180	Zhanjiang	0.050
Weinan	0.175	Lasa	0.052
Taiyuan	0.175	Rizhao	0.058
Pingdingshan	0.174	Karamay	0.059
Changzhi	0.173	Shantou	0.059
Lanzhou	0.172	Xiamen	0.063
Zhuzhou	0.171	Wenzhou	0.068
Luoyang	0.165	Yantai	0.068
Yangquan	0.162	Shaoxing	0.072
Fushun	0.162	Fuzhou	0.074
Xuzhou	0.158	Mianyang	0.075
Xiangtan	0.153	Shenzhen	0.076
Zigong	0.151	Qinhuangdao	0.076
Tongchuan	0.151	Nanning	0.078
Beijing	0.149	Ningbo	0.079
Jinan	0.149	Huhhot	0.080

Source: China Environment Yearbook 2005.

Acid rain is another serious problem in Chinese cities. Table 6 compares the pH value and frequency of city acid rain in recent years. We find that the proportion of cities without acid rain decreased from 49.7% in 2002 to 43.5% in 2004, i.e. the number of cities suffered from acid rain increased. Of those cities showing an increase in acid rain, the proportion with a rainwater pH value of less than 5.6 increased from 36.9% in 2001 to 41.4% in 2004. The proportion of cities with frequency of acid rain more than 40% moved up as well, from 24.0 % to 30.1%. Acid rain tends to occur in south China due to the presence of low hills, abundant rainfall and a wet climate.

Table 6: City Acid Rain pH Value and Frequency

	Frequency of Acid Rain						
	0	0 ~ 20	20 ~ 40	40 ~ 60	60 ~ 80	80 ~ 100	Sub total > 40
2001	41.2	23.7	10.9	8.0	9.1	6.9	24.0
2002	49.7	18.6	10.5	5.8	7.7	7.7	21.2
2003	45.6	18.7	7.4	6.8	11.1	10.5	28.4
2004	43.5	18.2	8.2	8.5	9.5	12.1	30.1

	Average pH Value of Acid Rain					
	≤ 4.5	4.5 ~ 5.0	5.0 ~ 5.6	5.6 ~ 7.0	> 7.0	Sub total < 5.6
2001	3.3	18.3	15.3	63.1	-	36.9
2002	6.0	12.4	14.2	50.5	16.9	32.6
2003	8.8	15.6	12.9	48.9	13.8	37.3
2004	10.8	17.5	13.1	44.2	14.4	41.4

Note: proportion of cities reported in the table.
Sauce: China Environment Yearbook 2002-2005.

4. Data and Methodology

Using data for 112 cities between 2001 and 2004 we estimate the determinants of eight different environmental indicators. Our emissions data are collected from various years of the China Environment Yearbook (see Appendix A1 and A2) and are reported in terms of total emissions for a large selection of key enterprises in each city.[4] Unfortunately, the number and proportion of enterprises varies across cities. We therefore adjust total industrial pollution emissions using the following equation.

$$E = (e \times correction\, ratio) = \left[e \times \left(\frac{GIP}{gip} \right) \right] \quad (1)$$

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[4] Whilst city-level concentrations provide more information regarding the human health impact of a particular pollutant, emissions provide more information on wider environmental issues and may have a weak relationship with concentrations. For instance, if the government plans to tackle the detrimental health impact from air pollution, they could execute a policy of heightening the factory chimneys or encouraging firms to locate outside the city. These policies would reduce the city-level concentrations but would not reduce national emissions. Concentration data also tend to be "nosier" than emissions data and require the inclusion of some dummy variables to capture site-specific effects, for example, variables to control for the nature of the observation site, measuring equipment, the average temperature, and the level of rainfall (Cole and Elliott, 2003).

where *e* and *gip* are respectively the pollution emissions and gross industrial output from the investigated firms; and *E* and *GIP* are those for the city. We assume that the emissions per unit of industrial product are the same within each city. Total emissions are then scaled by population to form per capita emissions. Data for our explanatory variables are collected from China City Statistical Yearbook.

To examine the role played by FDI, we distinguish between 'Chinese sourced' investment (Hong Kong, Taiwan and Macau, hereafter HTM) and foreign sourced investment. Investment from different sources has tended to concentrate in different sectors. Although it is not possible to get data on foreign industrial output or FDI inflows/stocks by sector, the China Industrial Economy Statistical Yearbooks do provide the paid-in capital by industrial sector. HTM capital is relatively high in sectors such as leather, fur, feather and related products; textile wearing apparel, footwear and caps; articles for cultural, education and sport activity; furniture; plastics; metal products textiles; chemical fibres; and printing, reproduction of recoding media. Foreign capital is high in various kinds of machinery and equipment; foods; metal products; rubber; paper and paper products; beverages; processing of food from agricultural products; medicines; and raw chemical and chemical products.

Since the pollution intensity of these sectors varies according to pollutant, the environmental effect of Chinese-sourced and non-Chinese sourced firms are likely to differ by pollutant. However, any link found between foreign or HTM capital and a city's emissions may simply reflect the fact that different investors tend to concentrate in sectors of differing emissions intensities e.g. if foreign investors typically invest in industries which are inherently less emissions intensive than the average industry then we would expect to find a negative relationship between emissions and the share of output in a city that is produced by foreign-owned firms. However, this of course does not mean that foreign owned firms are inherently cleaner than Chinese owned firms within the same industry but simply reflects the nature of the industries that foreign owned firms invest in. One way to overcome this problem would be to include variables measuring each industry's share of total output within each city as determinants of the city's emissions. Unfortunately, industry level measures of output have proved to be unattainable at the city level. Instead, we include a measure of the capital-labour ratio within each city as an attempt to proxy the pollution intensity of the composition of industry within the city. Previous studies have found a clear link between an industry's capital intensity and its pollution intensity and it would seem highly likely that such a relationship would also hold within China (Antweiler *et al.* 2001 and Cole *et al.* 2005). However, we acknowledge that this is an imperfect solution to our problem and hence we accept that our results may be capturing the impact on emissions of the compositional pattern of FDI as much as (or more than) whether foreign firms are cleaner than domestic firms.

We now describe our econometric methodology. Following the previous literature on economic growth and the environment we begin by estimating the following reduced-form equation for the emissions of industrial pollutants using random and fixed effects.

$$Epc_{it} = \alpha + \gamma_i + \theta_t + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 (GIP/GDP)_{it} + \beta_4 (K/L)_{it} + \varepsilon_{it} \qquad (2)$$

where *Epc* denotes per capita emissions, γ is city-specific intercepts, θ is time-specific intercepts, *Y* represents per capita income, *GIP/GDP* refers to the gross industrial product (GIP) normalised by city GDP, *K/L* is the capital-labour ratio and ε is the error term. Subscripts *i* and *t* represent city and year, respectively.

Equation 1 is estimated for the above mentioned eight industrial water and air pollution indicators (*Wastewater*, *COD*, *CrVI*, *Petroluem*, *Waste Gas*, SO_2, *Soot* and *Dust*) over the period 2001 to 2004 for a sample of 112 major cities in China (See Appendix A3 for descriptive statistics and Appendix A4 for the cities in the sample).[5]

Per capita income captures the direct scale and technique effects of economic growth. The capital-labour ratio is included to capture the direct composition effect of growth given the likely correlation between capital intensity and pollution intensity. Year specific effects are included to pick up any effects that are common to all cities but which change over time; and the city specific effects pick up the effects specific to each city that do not change over time.

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[5] In order to check the efficiency of the random-effects estimator, a Hausman specification test is employed to examine whether there is a correlation between the explanatory variables and the error terms (the strict exogeniety assumption of the random-effects model). The results indicate that the random-effects specification is consistent and efficient. Therefore, we report random-effects results.

In order to separate the activities of foreign affiliates from those of domestic firms, we decompose *GIP* into three components: industrial output for domestic firms (*GIPd*), the industrial output for firms from Hong Kong, Taiwan and Macao (*GIPh*) (i.e. Chinese-sourced firms), and the industrial output for the firms funded by foreign countries (*GIPf*) (i.e. non-Chinese sourced firms). Thus equation (2) becomes:

$$\begin{aligned} Epc_{it} &= \alpha + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 (GIPd/GDP)_{it} + \\ &\beta_4 (GIPh/GDP)_{it} + \beta_5 (GIPf/GDP)_{it} + \beta_6 (K/L)_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

Income cubed was also included to allow for a possible cubic relationship as found, for instance, by Grossman and Krueger 1995), but was not found to be statistically significant and was hence omitted.

Given the previous evidence that domestic firms in developing economies may be more pollution intensive than foreign owned firms (Eskeland and Harrison 2003 and Cole *et al.* 2008), we expect a positive sign on *GIPd/GDP* in Equation 3. However, this effect will be influenced by the pollution intensity of domestically owned industry. The effects of foreign FDI may be positive or negative and, again, may depend on the sectors in which foreign capital has concentrated. The expected coefficient on *K/L* is positive since labour-intensive sectors are generally considered as cleaner than capital-intensive sectors (Cole *et al.* 2005).

Equations 2 and 3 are estimated in logs and levels. However, Cole *et al.* (1997) argue that the quadratic log function provides a more realistic income-environment relationship because of the symmetrical nature of the quadratic levels function. The symmetry of quadratic levels function implies, first, that pollution levels will fall at the same rate as they increase and, second, that these pollution levels will become negative, probably in a short space of time. In contrast, a quadratic log function falls away gradually once it passes the turning point, as the curve asymptotically approaches zero.

A possible methodological concern is whether per capita income can be considered to be is exogenous, given the possibility that causality could move from environmental degradation to income. A Davidson-MacKinnon test is employed to test the null of exogeneity of current income with lagged income used as an instrumental variable. The null hypothesis of exogeneity is not rejected suggesting that simultaneity bias is not present. An exception is the logged form of Equation 3 when using industrial soot as the dependent variable. Therefore, the logged Equation 3 for soot is estimated with lagged income as an instrumental variable.

Third, we test for heteroskedasticity and autocorrelation. Breusch-Pagan tests for heteroskedasticity reject the null hypothesis of homoskedasticity in all cases. We also estimate the following dynamic model for the residuals to test for first order autocorrelation.

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \nu_{it}, t = 2,\ldots,T \qquad (4)$$

where $|\rho| < 1$ and $\nu_{it} \sim \mathrm{IID}(0, \sigma_{\nu}^{2})$.

The results show that the estimated $\hat{\rho}$'s are significant in the logged CrVI model, indicating the existence of first order autocorrelations within the panel. No such evidence was found in the other estimations. We correct for heteroskedasticity and autocorrelation when necessary.

5. Empirical Results

We present our results in Tables 7 to 10 and now consider each in turn. Table 7 reports the results for industrial wastewater and chemical oxygen demand. Columns 1, 2, 5 and 6 are the linear and quadratic specifications from equation 2, while columns 3, 4, 7 and 8 are those from equation 3.[6] Columns 1, 3, 5 and 7 show a positive linear relationship between income and the emissions of industrial wastewater and COD. This relationship is statistically significant for wastewater and for column 7 for COD. To put these results in context, taking the example of column 1 for wastewater we find that a 10 per cent increase in per capita income will increase per capita emissions of industrial water by 4.2

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[6] The Dickson-MacKinnon test results suggest the exogeniety of current income. Hausman specification test results indicate that the random-effects estimator is appropriate. The autocorrelation test also suggests no correlation within panels.

per cent. With the quadratic specification we find a statistically significant inverted-U-shaped relationship between per capita income and wastewater emissions but these relationships are not statistically significant for COD. For wastewater in column 2, the estimated turning point is around RMB 35,122 in 1990 prices (US $7,348).[7] In our sample, only Karamay city passed this income level in 2003 and 2004, demonstrating that most Chinese cities are on the upward sloping side of the EKC curve. The estimated income elasticity in Column 2 is around 0.44 at the mean of per capita income and is similar to that for the linear Column 1. Where appropriate, the table also reports the estimated turning points from the fixed-effects results to enable comparison with the random-effects turning points. We find that they are broadly similar.

We find that industrial output has a constant significant and positive impact on wastewater and COD emissions. The capital-labour ratio is positive and generally insignificant. In columns 3, 4, 7 and 8 we decompose industrial output according to the ownership of enterprises. For wastewater and COD, the industrial output of domestic firms is found to have the strongest positive impact on emissions, while foreign ownership has a negative, but insignificant, impact for wastewater. For both pollutants, output from Hong-Kong, Taiwan and Macau-owned firms is a positive and significant determinant of emissions.

Table 8 provides the results for hexavalent chromium compounds and petroleum-like matter. With respect to *CrVI*, first order autocorrelation exists within our panel. We therefore estimate a random-effects GLS regression accounting for AR(1) disturbances. Results suggest a positive linear relationship between per capita income and emissions of such compounds. The income elasticity is relatively high, between 0.8 and 0.9 according to Columns 1 and 3. The results for petroleum-like matter provide evidence of a robust inverted-U-shaped-relationship between per capita income and emissions. The estimated turning point is around RMB 20,500 on average (about $4,289 at the 1990 exchange rate), which is slightly lower than for *Wastewater*.[8] In our sample, nine cities have passed this income level. Again, gross industrial output significantly increases the discharges of *both* pollutants with domestic firms being the main contributors to this effect. Turning to the

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[7] Annual average exchange rate is $1=RMB 4.78 in 1990. RMB 35,122 is equal to about RMB 70,813 in 2004 prices, which is approximately $ 8,552 at the 2004 exchange rate ($1=RMB 8.28).

[8] Equivalent to RMB 41,332 ($4,992) at 2004 prices and exchange rate.

activities of foreign affiliates, for *CrVI* Chinese-sourced firms increase the discharge of such compounds with an elasticity of 0.23, while foreign firms decrease the discharges with a rate of 0.16. For petroleum-like matter, foreign owned firms increase emissions, presumably because foreign funded enterprises have invested a large amount in the sectors discharging petroleum-like matter, e.g. raw chemical materials and chemical products, medicines, and transport equipment. Finally, it is notable that *K/L* is negative and statistically significant for *CrVI*, perhaps reflecting the fact that a key source of such emissions is the Leather, Fur, Feather and Related Products industry which has the lowest K/L ratio of all Chinese industries.

Table 9 provides the results for waste gas and sulphur dioxide. For both pollutants only a linear relationship is found to exist with per capita income. The share of industrial output in GDP is found to be a significant determinant of both pollutants, an effect that appears to be driven entirely by domestically owned firms. The share of HTM owned or foreign owned output does not influence emissions.

Table 10 provides the results for industrial soot and dust. In light of the Davidson-MacKinnon test results, current income should not be considered to be exogenous in Columns 3 and 4 hence we employ a generalised 2-stage least square (G2SLS) random-effects IV estimation in these two columns. Lagged income is used as the instrumental variable. In all but one estimation (Soot, column 3) no significant relationship is found between income and emissions of soot or dust. The share of industrial output in GDP is found to be a significant determinant of emissions and again this effect appears to be entirely driven by the output from domestically owned firms. The share of HTM owned output has a positive but insignificant coefficient while the share of foreign owned output has a negative but insignificant coefficient.

Table 7: Linear and Quadratic Log Estimation Results with Random-effects for Industrial Wastewater and COD

Variables	Wastewater				COD			
	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*	*Column 8*
Y	0.420	0.968	0.479	0.976	0.0925	-0.522	0.265	-0.298
	(4.16)***	(4.13)***	(4.80)***	(3.86)***	(0.53)	(0.86)	(1.67)*	(0.56)
Y^2		-0.136		-0.120		0.151		0.132
		(2.56)**		(2.11)**		(1.14)		(1.13)
GIP/GDP	0.519	0.518			0.667	0.657		
	(3.94)***	(4.06)***			(2.45)**	(2.43)**		
GIPd/GDP			0.461	0.440			0.320	0.338
			(3.89)***	(3.75)***			(1.39)	(1.51)
GIPh/GDP			0.0474	0.0442			0.110	0.116
			(1.71)*	(1.56)			(2.35)**	(2.44)**
GIPf/GDP			-0.0123	-0.0183			0.00816	0.0173
			(0.53)	(0.79)			(0.15)	(0.32)
K/L	0.0268	0.00891	0.0377	0.0223	-0.190	-0.182	-0.285	-0.272
	(0.50)	(0.15)	(0.70)	(0.40)	(1.30)	(1.24)	(1.86)*	(1.75)*
Constant	-0.166	-0.593	0.0900	-0.217	0.522	1.087	1.656	2.047
	(0.18)	(0.69)	(0.11)	(0.27)	(0.45)	(0.81)	(1.51)	(1.72)*
R^2 (overall)	0.62	0.63	0.65	0.65	0.38	0.37	0.44	0.44
DM	0.46	0.16	0.10	0.32	1.77	0.74	2.64	0.93
Hausman	0.75	1.17	4.75	5.43	1.31	4.60	4.14	4.29
AR(1)	None	None	None	None	None	None	None	None
Turning point RE (FE)		35,122 (32,697)		58,362 (33,525)				
Observations	423	423	398	398	431	431	407	407

Robust z-statistics in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level, respectively. Turning point is in RMB at 1990 price.

Table 8: Linear and Quadratic Log Estimation Results with Random-effects for Industrial CrVI and Petroleum-like matter

Variables		CrVI				Petroleum		
	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*	*Column 8*
Y	0.775	0.610	0.956	0.316	0.951	2.752	0.723	2.489
	(2.61)***	(0.63)	(3.13)***	(0.31)	(3.26)***	(3.13)***	(2.78)***	(2.91)***
Y^2		0.0413		0.155		-0.443		-0.425
		(0.18)		(0.66)		(2.32)**		(2.25)**
GIP/GDP	0.810	0.802			0.828	0.838		
	(1.98)**	(1.94)*			(1.89)*	(1.86)*		
GIPd/GDP			0.718	0.738			0.919	0.820
			(2.07)**	(2.13)**			(2.42)**	(2.11)**
GIPh/GDP			0.234	0.237			0.0673	0.0639
			(2.10)**	(2.12)**			(0.97)	(0.94)
GIPf/GDP			-0.157	-0.151			0.222	0.208
			(1.65)*	(1.58)			(3.05)***	(3.02)***
K/L	-0.732	-0.727	-0.823	-0.801	-0.109	-0.165	0.00857	-0.0514
	(2.54)**	(2.50)**	(2.74)***	(2.65)***	(0.82)	(1.23)	(0.05)	(0.33)
Constant	-5.869	-5.706	-5.389	-4.962	-2.365	-3.866	-2.832	-3.871
	(2.87)***	(2.53)**	(2.87)***	(2.49)**	(1.09)	(1.63)	(1.42)	(1.86)*
R^2 (overall)	0.50	0.50	0.50	0.51	0.45	0.47	0.46	0.46
DM	1.45	1.03	1.80	1.32	0.31	0.88	0.01	0.54
Hausman	9.06	4.53	7.27	5.57	2.06	7.49	5.66	3.11
AR(1)	Yes	Yes	Yes	Yes	None	None	None	None
Turning point RE (FE)						22,334 (23,866)		18,695 (17,233)
Observations	383	383	364	364	423	423	403	403

Robust z-statistics in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level, respectively. Turning point is in RMB at 1990 price.

Table 9: Linear and Quadratic Log Estimation Results with Random-effects for Industrial Waste Gas and SO$_2$

Variables		Waste Gas				SO$_2$		
	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*	*Column 8*
Y	0.407	0.711	0.470	0.704	0.525	0.494	0.536	0.430
	(2.72)***	(2.41)**	(3.88)***	(2.30)**	(4.43)***	(1.72)*	(5.43)***	(1.53)
Y^2		-0.0763		-0.0567		0.00754		0.0253
		(1.16)		(0.82)		(0.12)		(0.40)
GIP/GDP	0.770	0.775			0.625	0.625		
	(6.42)***	(6.47)***			(4.41)***	(4.40)***		
GIPd/GDP			0.619	0.613			0.535	0.538
			(5.73)***	(5.63)***			(4.74)***	(4.73)***
GIPh/GDP			0.0300	0.0290			0.0417	0.0421
			(1.07)	(1.02)			(1.27)	(1.28)
GIPf/GDP			0.0410	0.0389			0.0277	0.0293
			(1.64)	(1.53)			(0.91)	(0.95)
K/L	0.0135	0.00510	0.0886	0.0834	0.0285	0.0295	0.0703	0.0736
	(0.12)	(0.05)	(0.79)	(0.75)	(0.34)	(0.35)	(0.83)	(0.87)
Constant	-3.035	-3.297	-2.542	-2.71	1.033	1.057	1.418	1.487
	(4.35)***	(4.61)***	(3.82)***	(4.20)***	(1.55)	(1.54)	(2.54)**	(2.56)**
R^2 (overall)	0.63	0.63	0.68	0.68	0.69	0.69	0.71	0.71
DM	1.49	0.35	2.07	2.62	0.07	0.36	1.44	1.15
Hausman	0.22	0.21	7.48	18.63**	1.26	1.54	0.19	2.18
AR(1)	None	None	None	None	None	None	None	None
Turning point								
Observations	438	438	413	413	427	427	407	407

Robust z-statistics in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level, respectively. Turning point is in RMB at 1990 price.

Table 10: Linear and Quadratic Log Estimation Results with Random-effects for Industrial Soot and Dust

Variables		**Soot**				**Dust**		
	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*	*Column 8*
Y	0.0718 (0.48)	-0.279 (0.89)	0.393 (3.20)***	0.193 (0.54)	0.0106 (0.04)	-0.443 (0.85)	0.156 (0.58)	-0.300 (0.57)
Y^2		0.0845 (1.28)		0.0452 (0.60)		0.110 (0.86)		0.108 (0.86)
GIP/GDP	0.699 (5.28)***	0.696 (5.17)***			0.695 (3.59)***	0.687 (3.46)***		
GIPd/GDP			0.427 (3.87)***	0.439 (3.91)***			0.890 (4.57)***	0.904 (4.59)***
GIPh/GDP			0.0427 (1.24)	0.0435 (1.26)			0.0582 (1.26)	0.0590 (1.28)
GIPf/GDP			-0.00944 (0.30)	-0.00586 (0.18)			-0.0271 (0.68)	-0.0229 (0.57)
K/L	-0.0630 (0.67)	-0.0510 (0.53)	-0.130 (1.68)*	-0.123 (1.56)	-0.263 (2.16)**	-0.251 (2.15)**	-0.260 (2.34)**	-0.247 (2.32)**
Constant	0.877 (1.21)	1.184 (1.61)	1.553 (2.19)**	1.68 (2.25)**	1.674 (1.11)	2.095 (1.28)	0.819 (0.52)	1.150 (0.70)
R^2 (overall)	0.61	0.60	0.62	0.62	0.38	0.38	0.39	0.39
DM	1.21	0.27	9.30***	4.42**	0.01	0.42	1.88	0.49
Hausman	0.00	4.54	0.86	6.54	3.21	1.23	4.21	2.91
AR(1)	None	None	None	None	None	None	None	None
Turning point								
Observations	435	435	415	415	423	423	403	403

Robust z-statistics in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level, respectively. Turning point is in RMB at 1990 price.

6 Conclusions

In this paper we examine data for 112 Chinese cities over four years to identify the income-pollution relationship for several air and water pollutants. We also compare the environmental effects of output from domestic firms, Chinese-sourced affiliates from Hong Kong, Taiwan and Macao, and non-Chinese-sourced affiliates from other foreign economies. Our pollution indicators include four industrial water pollution emissions, wastewater, chemical oxygen dioxide, hexavalent chromium compounds, and petroleum-like matter; and four industrial air pollution emissions, waste gas, sulphur dioxide, soot, and dust.

Although an inverted U-shaped relationship is found to exist between income and per capita emissions of two pollutants, the evidence for most pollutants confirms that at current income levels in China, economic development will result in more industrial emissions. We also find that total industrial output has a strong positive effect on industrial emissions with this effect differing by country of ownership. Domestic firms have the strongest detrimental effect on industrial emissions; Chinese-sourced affiliates from Hong Kong, Taiwan and Macao have a moderate detrimental effect on three of the four water pollution emissions but have an insignificant impact on air pollution; and foreign owned firms have a significant and beneficial effect on CrVI but a detrimental influence on emissions of petroleum-like matter, with an insignificant effect in all other cases. These effects are likely to largely reflect the pollution intensity of the sectors that foreign, HTM and domestic investors concentrate in.

The broadly positive relationship between income and emissions provides little scope for optimism and suggests that the increased stringency and enforcement of environmental regulations is crucial to alleviate pressure on the natural environment in China. The Chinese government does increasingly appear to accept the need for such regulations. In October 2007 attempts to protect the environment were boosted by the implementation of the Law of Property Rights. Similarly, in 2004 the Chinese premier, Wen Jiabao, announced that a measure of 'green GDP', which deducts the depreciation costs of environmental damage and resource depletion from gross GDP, would begin to replace gross GDP as a measure of true economic growth. A recent report indicates that growth of ‘green GDP’ was virtually zero in some provinces in the first half of 2007, suggesting that ‘true’ economic growth in China may be significantly lower than it appears once the depreciation of natural capital is taken into account.[9] Only time will tell whether recent policies such as these will begin to lessen the environmental impact of China’s burgeoning economy.

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[9] Shanghai Securities News, 03 August 2007, in Chinese, http://paper.cnstock.com/paper_new/html/2007-08/03/content_58400546.htm

References

Antweiler, W., Copeland, B. R. and M. S. Taylor, 2001, 'Is Free Trade Good for the Environment?', *American Economic Review*, Vol. 91, 4, pp. 877-908.

Cole, M. A. and R. J. R. Elliott, 2003, 'Determining the Trade-Environment Composition Effect: The Role of Capital, Labour and Environmental Regulations', *Journal of Environmental Economics and Management*, Vol. 46, 3, pp. 363-83.

Cole, M. A. and R. J. R. Elliott, 2005, 'FDI and the Capital Intensity of 'Dirty' Sectors: A Missing Piece of the Pollution Haven Puzzle', *Review of Development Economics*, 9, 4, pp. 530-48.

Cole, M.A., Elliott, R. J. R and Shimamoto, K., 2005, 'Industrial Characteristics, Environmental Regulations and Air Pollution: An Analysis of the UK Manufacturing Sector', *Journal of Environmental Economics and Management,* 50, 1, pp.121-43

Cole, M.A., Elliott, R. J. R. and Strobl, E., 2008, 'The Environmental Performance of Firms: The Role of Foreign Ownership, Training and Experience', *Ecological Economics*, 68, pp.538-46.

Cole, M. A., A. J. Rayner, and J. M. Bates, 1997, 'The Environmental Kuznets Curve: An Empirical Analysis', *Environment and Development Economics*, Vol. 2, pp. 401-16.

Eskeland, G. S. and A. E. Harrison, 2003, 'Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis,' *Journal of Development Economics*, Vol. 70, pp. 1-23.

Grossman, G. M. and A. B. Krueger, 1995, 'Economic Growth and the Environment', *Quarterly Journal of Economics*, Vol. 110, 2, pp. 353-77.

Harbaugh, W. T., Levinson, A. and D. M. Wilson, 2002, 'Reexamining the Empirical Evidence for an Environmental Kuznets Curve', *Review of Economics and Statistics*, Vol. 84, 3, pp. 541-51.

He, J., 2006, 'Pollution Haven Hypothesis and Environmental Impacts of Foreign Direct Investment: The Case of Industrial Emission of Sulphur Dioxide (SO_2) in Chinese Provinces', *Ecological Economics*, Vol. 60, pp. 228-45.

Pargal, S. and D. Wheeler, 1996, 'Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia', *Journal of Political Economy*, Vol. 104, 6, pp. 1314-27.

Selden, T. M. and D. Song, 1994, 'Environmental Quality and Development: Is There A Kuznets Curve for Air Pollution?', *Journal of Environmental Economics and Management*, Vol.

27, 2, pp.147-62.

Shafik, N., 1994, 'Economic Development and Environmental Quality: An Econometric Analysis', *Oxford Economic Papers*, Vol. 46, Supplement, pp. 757-73.

Stern, D. I. and M. S. Common, 2001, 'Is There An Environmental Kuznets Curve for Sulphur?' *Journal of Environmental Economics and Management*, Vol. 41, 2, pp. 162-78.

The Economist, 2004, 'Special Report: A Great Wall of Waste – China's Environment', *The Economist,* Vol. 372, 8389, pp. 64.

UNCTAD, 2007, 'Rising FDI into China: The Facts Behind the Numbers', UNCTAD Investment Brief No.2.

Wang, A., 2007, Environmental Protection in China: The Role of Law, *China Dialogue*, February 5th.

World Bank, 2007, World Bank Development Indicators 2007, CD ROM.

Zeng, K. and J. Eastin, 2007, 'International Economic Integration and Environmental Protection: The Case of China', *International Studies Quarterly*, Vol.51, 4, pp. 971-95.

Appendices

Appendix A1 Variable Definitions and Data Sources

Variable	Definition/Source
Wastewater	Per capita emissions of industrial wastewater (tons per person). Source: China Environment Yearbook; industrial output and population data from China City Statistical Yearbook.
COD	Per capita emissions of industrial chemical oxygen demand (tons per 10 000 persons). Source: as above.
CrVI	Per capita emissions of industrial hexavalent chromium compounds (kg per 10 000 persons). Source: as above.
Petroleum	Per capita emissions of industrial petroleum-like matter (tons per 1 000 000 persons). Source: as above.
Waste Gas	Per capita emissions of industrial waste gas (10 000 m^3 per person). Source: as above.
SO_2	Per capita emissions of industrial sulphur dioxide (tons per 10 000 persons). Source: as above.
Soot	Per capita emissions of industrial soot (tons per 10 000 persons). Source: as above.
Dust	Per capita emissions of industrial dust (tons per 10 000 persons). Source: as above.
Y	Gross domestic product (GDP) per capita (1 000 yuan at 1990 price). Source: China City Statistical Yearbook.
GIP/ GDP	Gross industrial product (GIP) normalised by city GDP (100 yuan per yuan). Source: as above.
GIPd/GDP	GIP normalised by GDP for the domestic firms (100 yuan per yuan). Source: as above.
GIPh/GDP	GIP normalised by GDP for Hong Kong, Taiwan and Macao invested firms (100 yuan per yuan). Such firms refer to all industrial enterprises registered as the joint-venture, cooperative, sole investment industrial enterprises and limited liability corporations with funds from Hong Kong, Macao and Taiwan. Source: as above.
GIPf/GDP	GIP normalised by GDP for foreign countries invested firms (100 yuan per yuan). Such firms refer to all industrial enterprises registered as the joint-venture, cooperative, sole investment industrial enterprises and limited liability corporations with foreign funds. Source: as above.
K/L	Capital-labour ratio, i.e. the average balance of net fixed asset over industrial employment (10 000 yuan per worker at 1990 price). Source: as above.

Appendix A2. Information on Pollution Measures

Wastewater refers to the industrial wastewater discharged from factories, including wastewater from production processes, direct cooling water, mine groundwater that is in excess of the discharge standard, and the domestic sewage mixed within the industrial wastewater (indirect cooling water not included). .

The Chemical Oxygen Demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. It is a useful wastewater quality indicator. The COD test determines whether wastewater will have a significant adverse effect upon fish or aquatic plant life.

Hexavalent chromium compounds (CrVI) are toxic if ingested or inhaled. CrVI is an established human carcinogen. Chronic exposure to CrVI compounds may cause permanent eye injury and can increase risk of lung cancer. CrVI compounds are widely used in the smelting and pressing of non-ferrous metals, metal products, leather products, electronic equipment, smelting and pressing of ferrous metals and chemical products.

Petroleum-like matter refers to various kinds of hydrocarbon compounds. They float on the surface of the water and prevent gas exchange, thus lead to the deterioration of water quality. They can cause the death of fish and aquatic plants and hence affect the life of aquatic birds, and have negative effect on the aquatic products industry.

Industrial waste gas refers to the volume of total emitted gas comprising of pollutants caused through fuel combustion and industrial production processes such as smelting and processing of metals, chemical materials production, and paper production.

Sulphur dioxide (SO_2) is generated through fuel combustion, especially the burning of coal and oil; and production processes like smelting of non-ferrous ores. According to the annual reports of SEPA, in recent years 85% of SO_2 comes from fuel combustion, and 15% from industrial processes.

Industrial soot and dust are two kinds of suspended particulate matter. Soot refers to the weight of suspended particulates in the smoke caused from fuel combustion, especially the component of smoke caused by the imcomplete burning of carbon-rich organic fuels;

while dust are those from industrial production processes, for example, refractory dust from iron and steel firms, screen dust from coking firms, machine dust, lime kiln dust, and cement dust of constrution materials.[10] These two types of suspended particulates are considered as dangeous owing to both their particulate size and the chemical compounds present. They can stain clothing and can possibly cause illness if inhaled. They are hazardous to the lungs and general health when the particles are less than 5 micrometres in diameter, as such particles are no filtered out by the upper respiratory tract.

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[10] The particulates discharged from power stations are included in industrial soot.

Appendix A3. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Medium	Max
Wastewater (tons per person)	424	38.49	32.34	2.03	27.92	168.96
COD (tons per 10000 persons)	432	81.80	70.72	0.67	62.58	340.88
CrVI (kg per 10000 persons)	384	1.62	2.46	0.0021	0.50	13.83
Petroleum (tons per 1000000 persons)	424	46.33	51.17	0.026	25.46	236.16
Waste Gas (m^3 per person)	439	4.70	4.19	0.13	3.34	21.39
SO_2 (tons per 10000 persons)	428	325.39	252.65	4.38	260.84	1355.84
Soot (tons per 10000 persons)	436	138.54	103.47	0.74	107.83	693.93
Dust (tons per 10000 persons)	424	118.09	122.58	0.020	71.17	649.65
Y (1000 yuan)	428	8.55	6.37	1.94	6.56	48.04
GIP/ GDP (100 yuan per yuan)	427	96.44	42.10	11.89	87.73	277.76
GIPd/GDP (100 yuan per yuan)	424	75.94	32.14	9.82	72.87	179.99
GIPh/GDP (100 yuan per yuan)	422	9.00	16.14	0	3.86	119.13
GIPf/GDP (100 yuan per yuan)	422	11.60	16.86	0	4.80	120.61
K/L (10000 yuan per worker)	427	6.71	5.22	0.89	5.44	52.38

Note: extreme outliers have been removed for all dependent variables' statistics; the descriptive statistics of the independent variables are those in the sample for SO_2 without extreme outliers.

Appendix A4: Cities in the Sample (number of subgroups in brackets)

East (52)

- Municipalities (3)
  - *Beijing*
  - *Tianjin*
  - *Shanghai*
- Hebei (5)
  - *Shijiazhuang*
  - *Tangshan*
  - *Qinhuangdao*
  - *Handan*
  - *Baoding*
- Liaoning (6)
  - *Shenyang*
  - *Dalian*
  - *Anshan*
  - *Fushun*
  - *Benxi*
  - *Jinzhou*
- Jiangsu (8)
  - *Nanjing*
  - *Wuxi*
  - *Xuzhou*
  - *Changzhou*
  - *Suzhou*
  - *Nantong*
  - *Lianyungang*
  - *Yangzhou*
- Zhejiang (7)
  - *Hangzhou*
  - *Ningbo*
  - *Wenzhou*
  - *Jiaxing*
  - *Huzhou*
  - *Shaoxing*
  - *Taizhou*
- Fujian (3)
  - *Fuzhou*
  - *Xiamen*
  - *Quanzhou*
- Shandong (10)
  - *Jinan*
  - *Qingdao*
  - *Zibo*
  - *Zaozhuang*
  - *Yantai*
  - *Weifang*
  - *Jining*
  - *Taian*
  - *Weihai*
  - *Rizhao*
- Guangdong (8)
  - *Guangzhou*
  - *Shaoguan*
  - *Shenzhen*
  - *Zhuhai*
  - *Shantou*
  - *Foshan*
  - *Zhanjiang*
  - *Zhongshan*
- Hainan (2)
  - *Haikou*
  - *Sanya*

Central (31)

- Shanxi (5)
  - *Taiyuan*
  - *Datong*
  - *Yangquan*
  - *Changzhi*
  - *Linfen*
- Jilin (2)
  - *Changchun*
  - *Jilin*
- Heilongjiang (4)
  - *Harbin*
  - *Qiqiharr*
  - *Daqing*
  - *Mudanjiang*
- Anhui (3)
  - *Hefei*
  - *Wuhu*
  - *Maanshan*
- Jiangxi (2)
  - *Nanchang*
  - *Jiujiang*
- Henan (6)
  - *Zhengzhou*
  - *Kaifeng*
  - *Luoyang*
  - *Pingdingshan*
  - *Anyang*
  - *Jiaozuo*
- Hubei (3)
  - *Wuhan*
  - *Yichang*
  - *Jingzhou*
- Hunan (6)
  - *Changsha*
  - *Zhuzhou*
  - *Xiangtan*
  - *Yueyang*
  - *Changde*
  - *Zhangjiajie*

West (29)

- Municipality (1)
  - *Chongqing*
- Inner Mongolia AR (3)
  - *Huhhot*
  - *Baotou*
  - *Chifeng*
- Guangxi Zhuang AR (4)
  - *Nanning*
  - *Liuzhou*
  - *Guilin*
  - *Beihai*
- Sichuan (5)
  - *Chengdu*
  - *Panzhihua*
  - *Luzhou*
  - *Mianyang*
  - *Yibin*
- Guizhou (2)
  - *Guiyang*
  - *Zunyin*
- Yunan (2)
  - *Kunming*
  - *Qujing*
- Shaanxi (5)
  - *Xi'an*
  - *Tongchuan*
  - *Baoji*
  - *Xianyang*
  - *Yan'an*
- Gansu (2)
  - *Lanzhou*
  - *Jinchang*
- Qinghai (1)
  - *Xining*
- Ningxia Hui AR (2)
  - *Yinchuan*
  - *Shizuishan*
- Xinjiang Uyghur AR (2)
  - *Urumuchi*
  - *Karamay*