Does Foreign Direct Investment Harm the Host Country's Environment? Evidence from China

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Abstract

As more manufacturing is moved to the developing countries, policy makers become concerned with the environmental consequence. Relatively lenient environmental policies in the developing countries may give them a comparative advantage in pollution intensive goods, and openness to trade and foreign direct investment might harm the host country's environment. This study examines the relationship between the scale of foreign direct investment and local air pollution in China and suggests that the opposite might be true. Trade and foreign direct investment could have beneficial effect on a developing country's environment when the multinationals crowd out inefficient local firms, when they change the industry composition, and when they bring more efficient technology into the host country and improve productivity and energy efficiency. We examine the environmental consequence of foreign direct investment using city level data on air pollution, industry composition, foreign direct investment, and other social economic factors. We exploit China's half land-locked geographic feature and preferable trade policy granted to selected cities as exogenous variations in the cities' access to foreign investment. We find a negative correlation between foreign direct investment and air pollution, suggesting that the overall effect of foreign direct investment may be beneficial to the environment.

Key Words: Foreign Direct Investment, Environment, China

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1. Introduction

Are trade and growth good or bad for the environment? As competition becomes more global, people are concerned that relatively lenient environmental regulation and lax enforcement in developing countries give them a comparative advantage in pollution intensive goods. Lowering trade barrier may encourage a relocation of polluting industries from countries with strict environmental policy to those with lenient policy. These shifts may increase global pollution or lead to race-to-the-bottom environmental policy practices, as countries become reluctant to tighten environmental regulations due of their concerns over comparative advantage in international trade. On the other hand, some researchers argue that openness could improve developing countries' environment by increasing local income, introducing more energy efficient production technology, and increasing competition and driving out less efficient factories.

Grossman and Kruger initiated the research literature on trade, growth and pollution by proposing an environmental Kuznets curve (EKC) that hypothesizes an inverse-U-shaped relationship between a country's per capita income and its pollution level, i.e. increased incomes are associated with an increase in pollution in poor countries, but a decline in pollution in rich countries. Trade may alter environment outcomes through a variety of channels. One channel is scale effect considered harmful to the environment: when foreign investment set up production facilities in the host country or outsource to local factories, the total industrial output increases and leads to more pollution. Another channel is technique effect considered beneficial to the environment: domestic plants could learn from exporting or from foreign invested plants that are often use more advanced technology, or the domestic plants might be crowded out of the product market when the foreign plants expand and grab domestic market share and local labor supply. In such cases, openness to trade and foreign investment will improve the environment quality. A third channel is income effect: when foreign investment brings more jobs to the host country and increase the local income, local constituency might demand a higher environmental standard, more stringent regulation, and better enforcement by the government.

This paper investigates the effect of foreign direct investment on local air pollution in different municipal areas in China. In recent years, China has attracted a large amount of foreign direct investment and manufacturing outsourcing from the developed world. The environmental consequence of trade and foreign investment in China has caused great concerns as the pollution in the country increases with the expansion of the economy. Also, China is a country of vast geographic variety. The scattered locations of its major cities, together with different government policies they are subject to, to a large extent determine their access to foreign investment. We exploit these exogenous variations across cities to control for the endogenous choice of location of foreign investment. We use city-level social economic data in the late 1990s to examine the relationship between local pollution and the scale of foreign direct investment, industry composition, and income. Contrary to the concerns with the negative effect of trade and foreign investment on environment, our results show a negative correlation between foreign direct investment and local air pollution, suggesting that the aggregate effect of foreign direct investment might be beneficial to the host country's environment.

The rest of the paper is organized as follows. Section 2 reviews literature on the relationship between environment, trade, and growth, and develops hypotheses. Section 3 describes the environmental issues, and factors influencing the distribution of foreign investment, including regulation, trade policy, and the geographical features of China. Section 4 describes the data, measurement, and empirical strategy. Section 5 summarizes the results. Section 6 discusses the caveats and extension of the research.

2. Literature Review and Hypothesis – Trade, Growth, and Environment

The issue of trade, growth, and environment received increased attention in the past decade, as the negotiations for World Trade Organization and North American free Trade Agreement (NAFTA) went on and concerns over global warming and industrial pollution were rising.

The economic literature on these issues started in the 1970s with some normative research. The positive research to test hypothesis about trade policy and growth's impact on environmental outcomes started in the 1990s from the pioneering work by Grossman and Krueger (1993) on NAFTA[1]. In this paper they hypothesize an inverse U-shaped relationship between a country's

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[1] Copeland and Taylor (2004) provide a more complete summary of existing research on trade, growth, and environment.

per capita income and its level of environmental quality: increased incomes are associated with an increase in pollution in poor countries, but a decline in pollution in rich countries. They also break down the effects of growth on environment into three components: scale effect, composition effect, and technique effect[2]. Scale effect is the change in pollution with the change in the scale of the production, holding constant the mix of goods and production techniques. Composition effect is the change in the share of the dirty goods in national income and the increase in pollution as the economy devotes more of its resources to producing the dirty goods. Technique effect is the change in the pollution as cleaner technique is used for production. In a following paper, Grossman and Krueger (1995) use a cross-country data set covering 58 countries in the1980s and find support of an inverse U-shape relationship between income and pollution, i.e. pollution increases with income at low-levels of income and decreases at high-levels of income, with the turning point for most of the pollutants coming before a country reaches a per capita income of $8,000.

Grossman and Krueger's work led to a booming literature on the environmental Kuznets curve (EKC), i.e. the inversed U-shape relationship between growth and environmental quality. Although most existing researches support the EKC relationship, these researches often employ a reduced form that uses essentially only one explanatory variable, income per capita, and fail to break down the effects of growth into different channels, namely, scale, composition, and technique effect, as Grossman and Krueger (1993) did. Thus, the estimation in these works is sometimes sensitive to the functional form and the sample used.

Since China is a developing country with nominal per capita GDP of $911[3] in 2001, we expect to see pollution to increase with per capita GDP, but at a declining rate, i.e. China is on the left side of the hump on the inversed U-shape curve.

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[2] Although the notation of scale effect, composition effect, and technique effect predates Grossman and Krueger's paper – they cited a 1990 government report for the introduction of the three effect terminology, economists didn't pay much attention to this breakdown until Grossman and Krueger employed it.

[3] Source: World Development Report, World Bank. Although some researchers estimate China's per capita GDP as higher than $4000 in 2001 based on purchasing power parity, the number is still much lower than the threshold estimated by Grossman and Krueger when a country's increasing income leads to less pollution.

Hypothesis 1. Pollution level in China's cities increases with per capita GDP, but decreases with the square of per capita GDP.

Trade influences the relationship between growth and environment in many ways. Growth increases the country's endowments or improves the technology, while trade liberalization changes relative goods prices by opening up the economy to foreign competition. At the same time, trade liberalization could cause economic growth when the competition or technology transfers from foreign firms spur innovation or capital accumulation in domestic sectors, as supported by numerous empirical works on the relationship between trade and innovation and productivity improvement. Thus, trade can influence environmental outcome by increasing per capita income.

Trade also by itself impacts environment. Researchers have proposed two major hypotheses to explain the impact: the pollution haven hypothesis and the factor endowment hypothesis. Pollution haven hypothesis assumes that countries are identical except for exogenous differences in pollution policy, so it's cheaper to produce dirty goods in the country with weaker environmental policy, usually the poorer country. Trade induced by pollution policy differences creates a pollution haven in the poorer country.

Factor endowment hypothesis is the main alternative to the pollution haven hypothesis. It suggests the direction of trade is determined by the relative abundance of factor endowments (labor and capital in most models) in each country. Thus, if the dirty goods are more capital intensive, it should be produced in the North, instead of South. The problem with empirical tests of the two hypotheses is that few country governments are believed to make trade and environmental policy separately. There are many factors driving trade policy and environmental policies simultaneously. Rich countries are likely to be both capital abundant and have stricter pollution policy. Poor countries may be on the opposite. Unfortunately, many of the empirical works in this field use cross-sectional country level data and could hardly solve the problem.

Several recent works deal with the issue of endogenous trade policy and cast light on the relationship between trade, growth, and environment. Frankel and Romer (1999) use cross country data and geographic characteristics as instrument for trade flows and show trade has a positive effect on national income. Antweiler et al (2001) use a cross country panel data to show that freer trade has a beneficial effect on the environment, after breaking down the effects into the three components. Dean (2002) estimates the effect of trade liberalization on water pollution in China's provinces using a simultaneous equation system, and suggests that trade aggravates pollution via the improved terms of trade but mitigates it via income growth.

All these researches use export and import data to approximate for trade and openness, as most of the work in the field has done. Several papers address the question using foreign direct investment. Eskeland and Harrison (2003) use a panel data set on US outbound direct investment to four countries and find little support for the pollution haven hypothesis. Also, they find foreign plants are significantly more energy efficient and use cleaner types of energy than the domestic-owned plants. Wang and Jin (2002) find similar results in a study examining firm level pollution discharge in more than 1000 firms in China. They find foreign invested firms and community owned firms have better environmental performances than state-owned and privately owned firms. They suggest that foreign firms pollute less because they use superior technology in production and are more energy efficient, while community owned firms pollute less because they internalize the cost of pollution since the owner of the firm has to bear the consequence of local pollution.

Based on the previous researches, we hypothesize that the inflow of foreign direct investment into a developing country will reduce local pollution, for given levels of industrial output and composition.

Hypothesis 2. Everything else equal, pollution intensity in China's cities decreases with the scale of foreign direct investment.

3. Background: China's Environment and Foreign Investment

We chose China as the setting for this study because China's National Bureau of Statistics has compiled a detailed data set of pollution and economic activities in hundreds of the cities, also because the country has undergone rapid economic development and openness to trade and investment. China received the largest amount of foreign direct investment in 2003, and has been one of the largest destinations of manufacturing outsourcing. At the same time, the country's energy hunger and environmental problems have caused increased concerns. The environmental consequence of trade and growth in China has important policy implications.

3.1 Environmental Issues

China has experienced rapid industry growth during the period of economic reform. While this growth has increased incomes and reduced overall poverty levels, it has been accompanied by serious environmental damage. Chinese industry is a primary source of the pollution problems. China's State Environmental Protection Agency (SEPA) estimates that industrial pollution accounts for over 70 percent of the national total in 1996: 70 percent of wastewater, including organic water pollution (COD, or chemical oxygen demand); 72 percent of sulfur dioxide (SO2) emission; 75 percent of flue dust (a major component of suspended particulates); and 87 percent of solid wastes[4]. Many polluting industries are located in the densely populated metropolitan areas where emissions exposure causes serious damage to human health and economic activity.

Air and water pollutions are the most widely monitored and studied pollution types in China. This study will focus on air pollution, specifically Sulfur dioxide emission. Sulfur dioxide and soot (suspended particulate matter) caused by coal combustion are the two major air pollutants. Sulfur dioxide is emitted naturally by volcanoes, decaying organic matter, and sea spray. The major industrial sources are the burning of fuel containing sulfur (mainly coal and oil) and other industrial processes such as the smelting of nonferrous ores. Automobile exhaust and certain chemical manufacturers are also sources of SO2. Suspended particulates are generated from certain industrial processes and fuel combustion.

Sulfur dioxide emission is the focus of this study because this pollutant causes severe damage to human health and has resulted in acid rain falling on about 30% of China's total land area. The data on sulfur dioxide emission is recorded in detail by China's State Environmental Protection Agency. China's industrial sectors reported a total of 15.6 million tons of sulfur dioxide emission

[4] See Wheeler, Wang, and Dasgupta 2003.

in 2002, of which 85% is from fuel combustion, and 15% from industrial processes[5]. Industrial boilers and furnaces burning coal are the major sources of urban air pollution. As shown in Figure 3.1, of the total energy consumption in China in 2002, 63.9% was coal, 24.6% was oil, 3% natural gas, 8.5% electricity[6]. Figure 3.2 shows the industrial sector distribution of SO_2 emission in 2002: electricity generation, metal and nonmetal products, and chemical products account for the majority of emission.

The level of sulfur dioxide pollution in China is recorded in two ways: by ambient concentration (ug/m^3) and by mass emission (tons). Sulfur dioxide ambient concentration is widely used as an air quality indicator and is recorded by monitoring stations located within the cities. Although ambient concentration provides accurate ground-level air quality information, it combines all sources of sulfur dioxide emission, including industrial, residential, and natural sources, and can be influenced significantly by the climate factors such as wind direction. Thus it's hard to separate industrial pollution from other factors. Mass sulfur dioxide emission data are directly collect from factories and estimate by China's Environmental Protection Agency. The local bureaus calculate mass emissions from the factories by combining factory self-reported data on fuel consumption and industrial process and periodic boiler stack testing data. The approach to calculating mass emission, while recognized as not robust enough as ambient data, is more accurate than ambient data to estimate industrial pollution. While acknowledging the tradeoff, we will use mass industrial emission data for this study.

3.2 Foreign Direct Investment and Geography in China

China's wide variation in geography and the different trade policies imposed on the cities make the country an ideal context to test the environmental impact of foreign direct investment. As China opened up to trade and foreign investment, the central government imposed different trade policies across the cities. China established four special economic zones (SEZs)[7] in 1980 and

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[5] Source: China Environment Yearbook 2003, edited by Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory.

[6] Source: China Energy Databook V6.0 Figure 4.A.1 and Table 4.A.1.4. The data is compiled from the energy balance tables published by China's National Bureau of Statistics.

[7] The four special economic zones include Shenzhen, Zhuhai, and Shantou in Guangdong Province and Xiamen in Fujian Province. The province of Hainan was later designated as a special economic zone but the economic development and investment in Hainan has been less than satisfactory and atypical so it's not categorized as SEZ in this paper.

designated 14 coastal cities[8] open to overseas investment in 1984. Foreign firms investing in these places receive tax breaks and other regulatory privileges. The different policies received by the 18 cities and other cities influenced the inflow of foreign investment significantly.

China's geographic features is another source of variation across the cities' access to foreign investment. Since China is landlocked on the northwest side and surrounded by mountains, deserts, and foreign countries that barely participate in international trade[9], most of the trade activities and foreign investment come from the coastal side on the east and southeast. A city's distance to the coast significantly influences its access to foreign investment. Furthermore, a small number of seaports in China carry a large proportion of freight traffic and attract large number of investors. Thus, the distance from a city to these seaports can be used as a source of exogenous variation in the access to foreign direct investment. Wei (2001) uses this method to study the relationship between trade and income inequality in China. Similar technique is employed by Frankel and Romer (1999) and Frankel and Rose (2002) in cross-country studies on trade flows.

We use five sea ports as the major hubs of investment inflows. Hong Kong and Shanghai are by far the biggest ports for international trade in China, and the centers of foreign investment into China. Two other seaports in Northern China, Dalian and Qinhuangdao, are export hubs and attract large amount of investment from Japan and South Korea. Because investment and trade from Taiwan accounts for a significant proportion of trade and FDI in China, Taipei, the capital city of Taiwan, is also included as a trade hub.

4. Data and Empirical Strategy

Most data used in this paper is from the China Urban Statistical Yearbooks published by China's National Bureau of Statistics. The data covers more than 260 major cities, and economic, social, and demographic information of the cities from 1996 to 2003.

[8] The 14 coastal open cities include Dalian, Qinhuangdao, Tianjin, Yantai, Qingdao, Lianyungang, Nantong, Shanghai, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai.

[9] An incomplete list of these countries includes Afghanistan, Mongolia, Nepal, Pakistan, India, Cambodia, Vietnam, Burma, etc.

To study the relationship between pollution and foreign direct investment and income, I use a reduced form equation that relate sulfur dioxide emission in a city to a function of the scale of foreign direct investment, per capita income, industrial output and composition, and other covariates. All the variables are in log terms.

$$SO_2\ Emission_{it} = \beta_0 + \beta_1 * FDI_{i,t} + \beta_2 * per\ capita\ GDP_{it} + \beta_3 * per\ capita\ GDP\ square_{it} + \beta_4 * industrial\ output_{it} + \gamma * X_{it} + \alpha_i + \lambda_t + \varepsilon_{it}$$

The dependant variable is the volume of industrial sulfur dioxide emission, measured by total factory sulfur dioxide emission (tons).

The explanatory variables include the scale of foreign direct investment[10], measured by net assets or employment of foreign invested factories in each city, per capita GDP, per capita GDP square.

The control variables include year fixed effects, city and provincial fixed effects, and other city-year specific variables denoted X_{it}. These city-year specific variables include total industrial output value, land area, and capital intensity measured by capital labor ratio[11]. We also include predicated sulfur dioxide emission based on industry composition to control for the differences in industry mix across the cities. This variable is calculated by combining employment at the 4-digit SIC level from the National Bureau of Statistics industrial survey with pollution per worker per industry constructed as part of the World Bank Industrial Pollution Projection System[12] (IPPS).

10 Before 2003, a "foreign-owned firm" is defined as a firm with 25% or higher foreign ownership, in the form of cash, equipment, technology, and/or intellectual property rights. Starting from 2003, after China joined WTO, the definition of foreign-owned firm is expanded to those with lower than 25% foreign ownership. Source: Department of Commerce, China. As a special case in China, investment from Hong Kong and Taiwan are treated almost equivalent as foreign investment so are coded as "foreign" in this study.

11 In the following step, we will control export and import for each city.

12 See World Bank 2001,and Federman and Levine 2005. The IPPS data are based on industrial pollution in the US at 1987 levels – a decision based on the quality and quantity of data in the United States. The IPPS drew from the population of 200,000 US manufacturing firms spanning approximately 1,500 product categories, all operating technologies, and hundreds of pollutants.

A major empirical concern of this study is the unobserved variables influencing openness, income, and pollution levels at the same time. For example, a competent city government might be able to attract more investors, improve income faster, and enforce environment regulation better. But the capability of a city government is not observed in the data. Also, it could be the case that foreign investors are more attracted to the sites with a clean environment. Thus the causality goes in a reverse direction.

To deal with these issues, we use three instruments for foreign direct investment: geographic location, trade policy, and local population. All the three variables are predetermined and can be considered independent of pollution and income level of the city.

As stated in the previous section, China's geographic characteristics and trade policy can be considered predetermined and exogenous of pollution and income. Thus, a city's geographic location and the preferable trade policy it receives from the central government can be used as instruments for foreign direct investment to resolve the endogeneity of openness and access to foreign direct investment.

Specifically, we use the distance to major seaports as instruments for the inflow of foreign direct investment. The instrumental variable "distance" is the smallest distance from a city to one of the five major seaports or investment hubs. The distance is the greater circle distance between a pair of cities, computed with the "Oblique Spherical Triangle Method" using the latitudes and longitudes of the cities (Wei 2001)[13],[14].

[13] The Oblique Spherical Triangle Method to calculate greater circle distance: Arc Distance D = arcCos (Sin(latitude1)*Sin(latitude2) + Cos(latitude1)*Cos(latitude2)*Cos(longiude1-longitude2)). Sign convention: + (-) for north (south) latitude, and + (-) for west (east) longitude. Distance in Kilometers = 6378.7*D, where the latitudes and longitudes are in radians.
The empirical part used Arc distance, not the distance in kilometers. The information on the latitudes and longitudes of the Chinese cities is retrieved from the Defense Mapping Agency (1979), and supplemented with information from *The Encyclopedia of Chinese cities & counties* (*Zhongguo Shi Xian Da Ci Dian*), 1st edition, 1991.

[14] One may argue that geographic distance is a noisy measure of access to investment opportunities. For example, consider two cities of equal geographic distance to Shanghai but one is connected to Shanghai by highway and direct flight and the other is by mud road. Their access to the investors in Shanghai will be quite different. Due to data limit, we focus on distance in this study.

Trade policy is approximated with coastal dummies, coded as 1 if the city is one of the fourteen coastal open cities or four special economic zones, 0 otherwise. The preferable trade policy influences the foreign investors' choice of the site and scale of their investment, since coastal open cities and special economic zones offer incentives such as tax holidays and well developed infrastructure such as telecommunication, transportation, and financial services.

Because of China's residential registration system, the population of the urban area is relatively stable and not influenced by the economic condition except in several large metropolitan areas. A large local population is appealing to investors because of the large pool of cheap labor and skilled workers it offers. Thus, total local population is used as an instrument for foreign direct investment.

5. Results

The summary statistics are shown in Table 1. The estimation results with sulfur dioxide emission intensity as dependant variable are reported in Table 3. Model OLS1 and Model OLS2 are ordinary least square estimations using assets and employment to measure the scale of foreign investment respectively. Model IV1 and IV2 are instrumental variable models corresponding to OLS1 and OLS2, using distance to sea ports, trade policy, and population as instruments for foreign investment. Table 4 reports the results in fixed effect and instrumental variable fixed effect models.

The results in Table 3 support the hypothesis on environmental Kuznets Curve: the positive coefficient of per capita GDP and negative coefficient of per capita GDP square indicate that sulfur dioxide emission increases with per capita GDP, but at a decreasing speed. This result suggests that in most Chinese cities the increase of income is accompanied by an increase of pollution. The scale of income's effect on pollution is quite large. One percent increase in per capita GDP leads to 6 percent increase in sulfur dioxide emission intensity (Column 1&2 in Table 3). The sign of the coefficient is stable in all the four models. The coefficients of per capita GDP and per capita GDP square term indicate that the turning point of the inversed-U curve comes at a level of per capital GDP of about $1,200 in China[15] (Row 11 and 12 in Table 3). The income level of the turning point is much lower than that indicated by Grossman and Krueger (1995). In 2000, per capita GDP surpassed this level in 70 of the 230 cities, or about 30% of the sample. The proportion increases by about 4% each year. This might suggest that China's cities are increasingly move to the brighter side of the curve – higher income are associated with lower pollution in an increasing number of the cities[16].

Second, the coefficient of foreign direct investment is negative, significant in IV models but not significant in the OLS models. This suggests that local pollution decreases with the scale of foreign investment, but only when the selection of the location of FDI is taken into consideration. In the IV models, for one percent increase in foreign direct investment, sulfur dioxide emission intensity decreases by 0.6-0.7 percent (Column 4 and 5 in Table 3).

The coefficients on most other variables are of the predicted sign. Emission increases with total industrial output, predicted sulfur dioxide emission, the asset and employment of domestic factories, land area, and the employment in fossil-fuel power plants[17].

The results in the Fixed Effect models are insignificant and of the wrong sign (Table 4). This might due to the short period of our panel data set – the variation in pollution is more evident across cities than within cities and overtime.

6. Summary

The research literature on the impact of openness and growth on environment has causes great interests in recent years. While policy makers are concerned with the environmental consequence of free trade and off-shoring in the developing countries, evidence has not consolidated such concern. On the contrary, cross country studies suggest openness could be beneficial to the host

[15] This number is calculated by taking the average of the five models and then changing the amount from Chinese currency RMB into US$. The exchange rate in 2000 is 1US$=8.27 RMB Yuan.

[16] This overly optimistic interpretation, however, has to be taken with cautions. As in a national conference of EPA officials in China in April 2006, the officials predicted that the turning point is $3,000 for per capita GDP.

[17] The size of employment in the power plant has a significant effect on sulfur dioxide emission, since most power plants in China use coal as fuel.

country's environment. However, since national governments make both trade policies and environmental policies and could substitute one for another, cross country studies are hard to establish causality between openness and its environmental consequence.

This study asks whether a city receiving more foreign direct investment has higher air pollution, using a panel data covering more than 200 major cities in China, one the largest receiver of foreign direct investment and manufacturing outsourcing. We exploit the country's variety in geography and different trade policy imposed on cities as an exogenous source of variation in access to foreign direct investment. We found evidence that foreign investment has beneficial effect on local environment, controlling for industrial output and composition.

In the next phase, we will investigate the channels through which foreign investment impact local environment. Anecdotal evidence suggests that foreign owned factories in developing countries usually use superior technology and are more energy efficient in production. If this is the case and if the presence of foreign firms increases competition in host country market and crowds out domestic firms, then foreign direct investment could benefit host country environment via technology effect. On the other hand, foreign investment could flow into cleaner or more labor-intensive industries. If this is the case and if foreign firms crowd out domestic firms in labor supply market, then foreign direct investment benefit environment via composition effect. Another possible channel is foreign direct investment in electricity power plants using more efficient generating technology. China opened power plant industry to foreign investors in the early 1990s, in an effort to reduce the shortage of electricity supply. But due of regulatory burden, most of the foreign invested power plants are of small scale and could have only limited effect on the overall emission intensity of the industry.

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Tables and Graphs

Table 1. Summary Statistics of 231 China cities 1996-2003

Variable	Unit	Obs.	Mean	Std.Deviation	Min	Max
Volume of factory SO2 emission	Tons/Square Kilometer	1106	45.1128	71.5217	0.1	862
Intensity of factory SO2 emission	Tons/10,000 Yuan* output	680	.0339	.0534	0	.7126
Ambient SO2 level	ug/m3	502	61.0936	52.0935	2	418
Area reaching standard upon environmental noise	Square Kilometer	1098	36.9235	46.84579	0	538
Proportion of industrial waste water discharge qualifying standard	%	1111	62.7457	30.8207	0	100
Per capita GDP	Yuan*	1588	14,144.03	11733.84	990.2427	161,837.9
Total Population at year end	10,000 persons	1593	113.509	134.9712	12.91	1270.22
Land area	Square Kilometer	1593	1683.657	2255.76	50	20169
Foreign Direct Investment – Actually utilized foreign capital	10,000 US$	1533	15852.11	49191.93	0	751000
Gross industrial output value	10,000 Yuan*	919	2489028	5763638	29378	7.68E+07

*The exchange rate between Chinese Yuan and US$ is 1US$ = 8.27 Yuan in most of the years between 1996 and 2001

Table 2. Pair-wise Correlation

	logSO2 intensity	Log per capita GDP	Lagged Log FDI	Log industrial output	Log population density	Log capital over urban population	Distance to seaports
logSO2 intensity	1						
Log per capita GDP	-0.3910	1					
Lagged Log FDI	-0.4346	0.6269	1				
Log industrial output	-0.3007	0.7832	0.6839	1			
Log population density	-0.2503	0.2934	0.3887	0.3615	1		
Log capital intensity	-0.1637	0.6987	0.3853	0.6711	0.0648	1	
Distance to seaports	0.2830	-0.3068	-0.4659	-0.2654	-0.3913	-0.1545	1

Note: All the correlations are significant at 1% level.

Table 3. Estimation Results – OLS and Instrumental Variable Models
Total SO2 Emission (tons of SO2 emission)

Dependent Variable: log SO_2 (SO_2 emission in tons)

	OLS (1)	OLS (2)	OLS (3)	IV (1)	IV (2)
Log FDI asset	-.0314 (.0746)	--	--	-.6264 (.2893)*	--
Log Domestic asset	.3847 (.2292)†	--	--	-.0221 (.3587)	--
Log FDI employment	--	-.0901 (.0829)	--	--	-.7624 (.3691)*
Log domestic employment	--	.7734 (.2808)**	--	--	.5750 (.3227)†
Log expected SO2 Emission from FDI factories	--	--	-.1420 (.0539)**	--	--
Log expected SO2 Emission from domestic factories	--	--	.2571 (.1147)*	--	--
Log expected SO2 Emission	.1191 (.1469)	.0453 (.1463)	--	.2048 (.1504)	.0379 (.1489)
Log employment in fossil fueled power plants	.2150 (.0829)**	.1921 (.0782)*	.2530 (.0827)**	.3149 (.0892)**	.2404 (.0799)**
Log land area	.3901 (.1418)**	.3750 (.1380)**	.4290 (.1412)**	.3760 (.1537)*	.3638 (.1414)*
Log Industrial output	.2501 (.1795)	.0730 (.2165)	.4490 (.1411)**	1.0807 (.4694)*	.9802 (.5465)†
Log per capita GDP	6.0812 (2.2107)**	5.5370 (2.0393)**	6.0814 (2.3360)*	6.9149 (2.6531)*	5.3650 (2.0987)**
Log per capita GDP squared	-.3326 (.1148)**	-.2991 (.1055)**	-.3283 (.1225)**	-.3801 (.1399)**	-.2940 (.1100)**
Log Capital Intensity	-.2388 (.3160)	.1609 (.2527)	.0816 (.2509)	.2114 (.4305)	-.3427 (.3862)
Constant	-29.5920 (11.5528)**	-28.6770 (9.5020)**	-29.7058 (10.9511)**	-34.8852 (12.4684)**	-31.1879 (10.4358)**
Year Dummies	Yes	Yes	Yes	Yes	Yes
Provincial Dummies	Yes	Yes	Yes	Yes	Yes
No. of observations	733	733	732	721	721
R-square	.5245	.5335	.5273	.4269	.4565
First Stage F on instrument				57.46***	81.29***
First Stage adjusted R-Square				.7713	.8274

Notes: robust clustered standard errors in parentheses. The error terms are clustered at city level. The Instrumental variable models use coastal dummy, distance to sea ports, and log of population, together with all the other explanatory variables in the model as instruments for FDI asset and employment.
†, *, **, *** significant at 0.10, 0.05, 0.01, and 0.001 level.

Table 4. Estimation Results – Fixed Effects and Instrumental Variable Models Total SO2 Emission (tons of SO2 emission)

Dependent Variable: log SO_2 (SO_2 emission in tons)

	Fixed Effect (1)	Fixed Effect (2)	Fixed Effect & IV (1)	Fixed Effect & IV (2)
Log FDI asset	.0152 (.0493)	--	1.6044 (2.1375)	--
Log Domestic asset	.0367 (.1689)	--	.6912 (1.0045)	--
Log FDI employment	--	-.0271 (.0609)	--	.2003 (.6976)
Log domestic employment	--	.1801 (.4167)	--	.1152 (.3878)
Log expected SO2 Emission	.0546 (.1763)	.0258 (.1957)	-.5479 (.9202)	-.0189 (.3469)
Constant	-4.6236 (8.5837)	-5.2698 (9.0604)	-28.0001 (34.9222)	-11.5962 (17.7342)
Year Dummies	Yes	Yes	Yes	Yes
No. of observations	733	733	721	721
No. of groups	203	203	203	203
R-square (within)	.0390	.0395		
First Stage F on instrument			6.40***	3.36***

Notes: clustered standard errors in parentheses. The error terms are clustered at city level. The Instrumental variable models use coastal dummy interacting with time trend, distance to sea ports interacting with time trend, and log of population, together with all the other explanatory variables in the model as instruments for FDI asset and employment.
†, *, **, *** significant at 0.10, 0.05, 0.01, and 0.001 level.

Appendix I. Additional Tables and Graphs

Figure 3.1 Primary Energy Consumption, by fuel source
Source: China Energy Databook V6.0 Figure 4.A.1

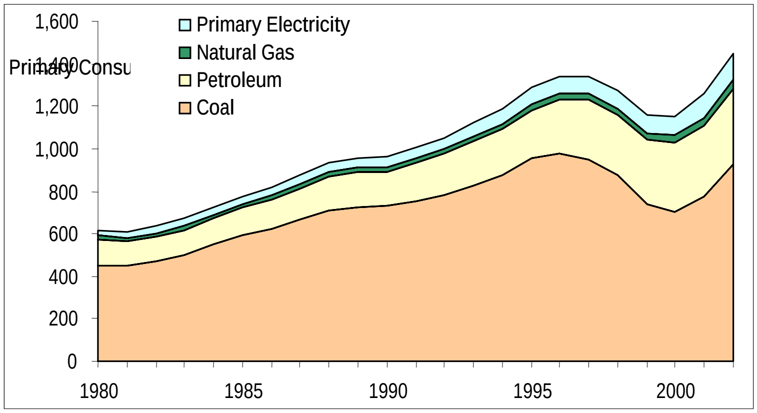
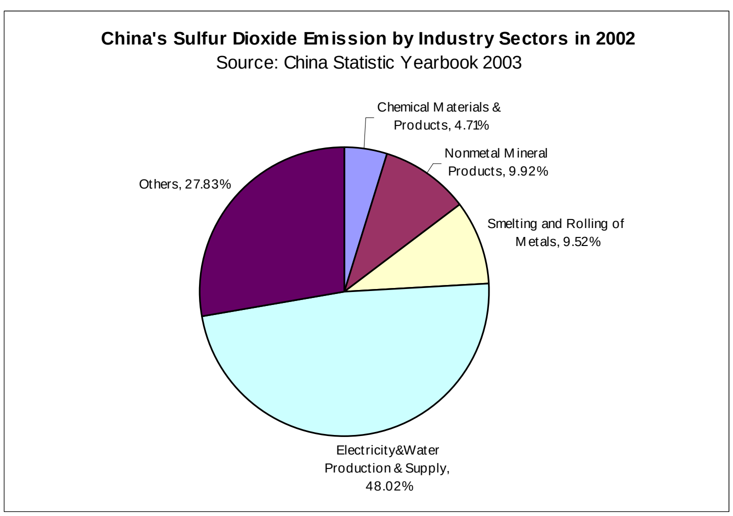
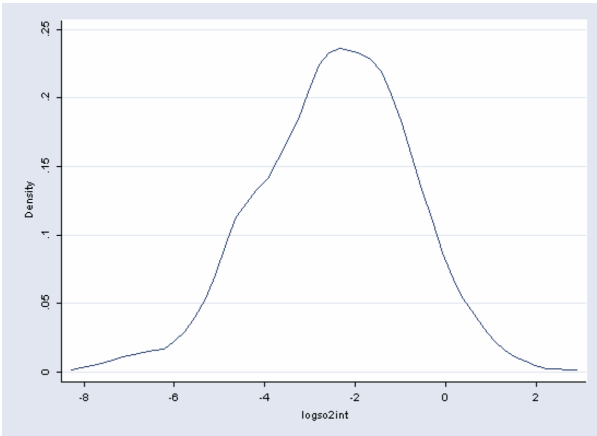


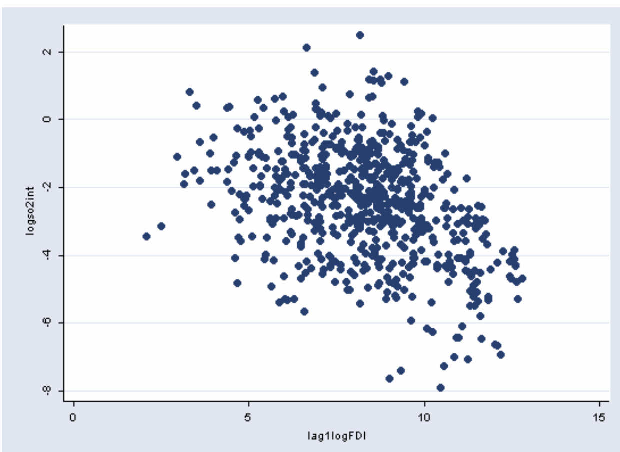
Figure 3.2 China's Sulfur Dioxide Emission by Industry Sectors in 2002
Source: China Statistic Yearbook 2003



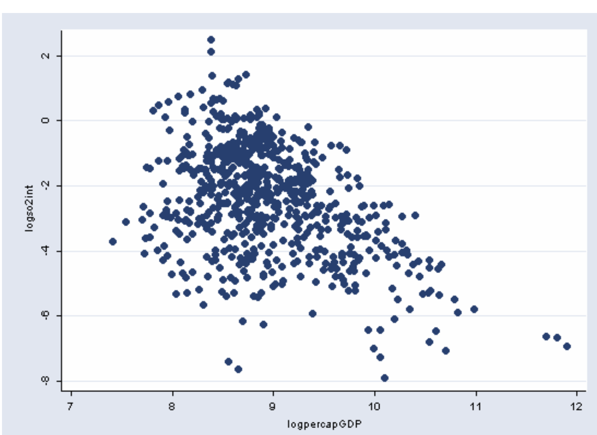
Graph 1. LogSO2 Intensity distribution



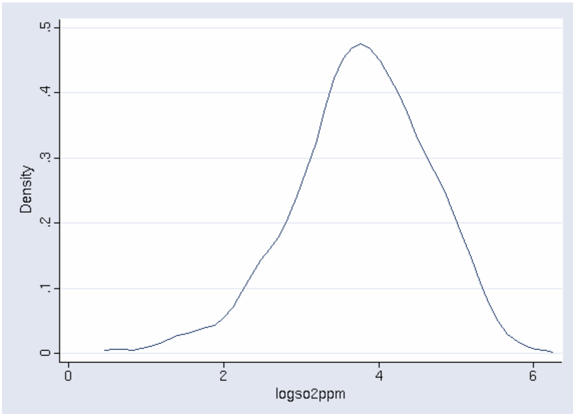
Graph 2. LogSO2 intensity and lagged log FDI



Graph 3. LogSO2 Intensity and log per capita GDP



Graph 4. Log Ambient SO_2 concentration level



Graph 5. SO_2 concentration in China Cities 1998-2000

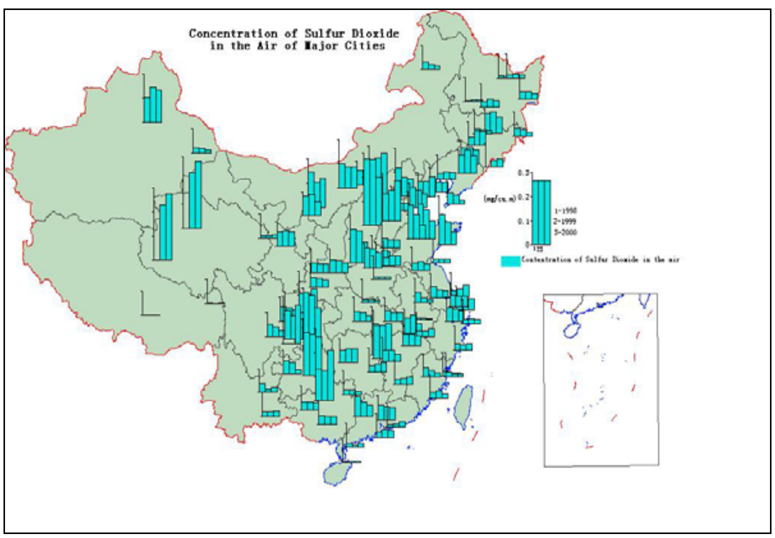


Table A1. Difference between foreign invested factories and domestics factories: Capital labor ratio and estimated SO2 emission per employee

	Foreign	Obs.	Domestic	Obs.	Difference
Capital[1] / Employment (1,000 Yuan/person)	154.258	1550	96.435	2124	57.822***
Estimated SO2 Emission Per Employee (kilograms)	0.498	1550	0.987	2124	-0.489***

†, *, **, *** 2-sample t-test significant at 0.10, 0.05, 0.01, and 0.001 level.
1. Capital is defined as the average balance of net fixed asset.

Table A2. Estimation Results – OLS and Instrumental Variable models on SO2 emission intensity (tons of SO2 emission per industrial output value)

Dependent Variable: log SO_2 intensity (log SO_2 in tons/10,000Yuan)

	OLS (1)	OLS (2)	IV (3)	IV (4)
Lagged Log FDI	-.1343 (.0295)**	-.1463 (.0478)**	-.4948 (.3611)	-.7836 (.4322)†
Log per capita GDP	2.8136 (1.7462)	3.7775 (1.8159)*	3.0170 (1.8444)	4.4726 (2.1319)*
Log per capita GDP squared	-.1586 (.0899)†	-.2183 (.0928)*	-.1611 (.0958)†	-.2403 (.1089)*
Log Population density	-.2549 (.1039)*	-.2583 (.1115)*	-.2367 (.1016)*	-.2032 (.1182)†
Log Capital Intensity	.4544 (.1645)**	.4521 (.1503)**	.4205 (.1713)**	.5683 (.1889)**
Log industrial output	-.6176 (.1382)***		-.5008 (.1786)**	
Log industrial output by domestic firms		-.3957 (.1342)**		-.5012 (.1545)**
Log industrial output by foreign firms		-.0813 (.0596)		.1514 (.1741)
Employment in Mining & quarrying	.2384 (.0885)**	.2188 (.0931)*	-.1530 (.1239)	.2222 (.1043)*
Employment in Manufacturing	.4668 (.1618)**	.3616 (.1773)*	.5701 (.2034)**	.5452 (.2386)*
Employment in Electricity generation, Gas and Water supply	1.5354 (.4344)***	1.7385 (.4423)***	2.0532 (.7075)**	2.3527 (.6750)**
Employment in Transportation, Storage, Post and Telecommunication	-.2305 (.1885)	-.2291 (.1878)	-.0498 (.2610)	.0883 (.2866)
Constant	-12.3035 (8.2384)	-18.0071 (8.5404)*	-13.6878 (8.9308)	-18.9571 (9.8393)†
Year Dummies	Yes	Yes	Yes	Yes
Provincial Dummies	Yes	Yes	Yes	Yes
No. of observations	636	613	636	613
R-square	.5272	.5264		
First Stage F on instrument			41.77***	44.97***
First Stage adjusted R-Square			.7341	.7597

Notes: robust clustered standard errors in parentheses. The error terms are clustered at city level. The Instrumental variable models use coastal dummy, distance to sea ports, and log of population, together with all the other explanatory variables in the model as instruments for FDI.
†, *, **, *** significant at 0.10, 0.05, 0.01, and 0.001 level.

Table A3. Estimation Results – OLS and Instrumental Variable models
SO2 emission per square kilometer

Dependent Variable: log SO_2 (log SO_2 in tons/sq.km)

	OLS (1)	OLS (2)	IV (3)	IV (4)
Lagged Log FDI	-.1500 (.0449)***	-.1535 (.0490)***	-1.4555 (.4138)***	-1.8486 (.4836)***
Log per capita GDP	5.1820 (1.8799)***	5.5092 (1.9629)***	5.8914 (2.2579)**	7.3287 (2.6716)**
Log per capita GDP squared	-.2458 (.0966)***	-.2674 (.1005)***	-.2536 (.1185)*	-.3248 (.1382)*
Log Population density	.8364 (.1052)***	.8359 (.1106)***	.9101 (.1101)***	.9904 (.1343)***
Log Capital Intensity	.6829 (.1707)***	.7638 (.1605)***	.5601 (.1927)**	1.0672 (.2347)***
Log industrial output	-.1501 (.1466)		.2814 (.2400)	
Log industrial output by domestic firms		-.1008 (.1321)		-.3662 (.2129)†
Log industrial output by foreign firms		-.0361 (.0610))		.5808 (.1912)**
Employment in Mining & quarrying	.2341 (.0923)***	.2323 (.0995)***	-.0691 (.1525)	.2567 (.1448)†
Employment in Manufacturing	.4220 (.1668)***	.3852 (.1720)**	.8078 (.2597)**	.9011 (.3012)**
Employment in Electricity generation, Gas and Water supply	.8761 (.4366)**	1.0512 (.4427)***	2.6136 (.7752)**	2.4816 (.7767)**
Employment in Transportation, Storage, Post and Telecommunication	-.4741 (.1865)***	-.4479 (.1878)**	.2072 (.3355)	.4334 (.3911)
Constant	-34.5471 (8.8852)***	-36.8103 (9.2959)***	-34.3732 (10.8449)**	-49.5709 (13.1970)***
Year Dummies	Yes	Yes	Yes	Yes
Provincial Dummies	Yes	Yes	Yes	Yes
No. of observations	638	615	638	615
R-square	.6444	.6479		
First Stage F on instrument			41.81	44.98
First Stage adjusted R-Square			.7337	.7591

Notes: robust clustered standard errors in parentheses. The error terms are clustered at city level. The Instrumental variable models use coastal dummy, distance to sea ports, and log of population, together with all the other explanatory variables in the model as instruments for FDI.
†, *, **, *** significant at 0.10, 0.05, 0.01, and 0.001 level.

Table A4. Estimation Results – Fixed Effect and Random Effect models
SO2 emission intensity (tons of SO2 emission per industrial output value)

Dependent Variable: log SO_2 intensity (log SO_2 in tons/10,000Yuan industrial output)

	Fixed Effect		Random Effect	
	(1)	(2)	(3)	(4)
Lagged Log FDI	.0198	-.0028	-.0675	-.0664
	(.0362)	(.0361)	(.0295)*	(.0316)*
Log per capita GDP	1.8008	2.8087	3.9706	4.8464
	(3.1001)	(3.2355)	(1.6956)*	(1.7605)**
Log per capita GDP squared	-.0979	-.1574	-.2254	-.2847
	(.1654)	(.1711)	(.0899)*	(.0927)**
Log Population density	-.2929	-.2816	-.2242	-.2292
	(.1426)*	(.1426)*	(.0702)***	(.0736)**
Log Capital Intensity	-.0071	-.0262	.1101	.1105
	(.0912)	(.0950)	(.0812)	(.0856)
Log industrial output	-.4951		-.4734	
	(.1768)**		(.1059)***	
Log industrial output by domestic firms		-.2207		-.1248
		(.1977)		(.1048)
Log industrial output by foreign firms		.2735		-.0727
		(.0723)***		(.0428)†
Employment in Mining & quarrying	.1239	.2275	.3174	.2745
	(.2897)	(.2909)	(.0924)***	(.0998)**
Employment in Manufacturing	.4632	.3954	.4421	.2416
	(.2005)*	(.2011)†	(.1340)***	(.1394)†
Employment in Electricity generation, Gas and Water supply	-.0565	.2877	1.2403	1.2321
	(.7470)	(.8211)	(.3356)***	(.3508)***
Employment in Transportation, Storage, Post and Telecommunication	-.3761	-.2236	-.3396	-.2875
	(.2637)	(.2607)	(.1591)*	(.1617)†
Constant	-4.3109	-15.4357	-15.2176	-21.8230
	(15.0846)	(15.9517)	(8.1132)†	(8.3787)**
Year Dummies	Yes	Yes	Yes	Yes
No. of observations	636	613	636	613
No. of groups	225	216	225	216
Overall R-square	.1630	.0073	.3545	.3565
F-statistics	2.75**	3.26***		
Wald chi-square			162.40***	140.92***
Hausman test			34.85***	55.02***

Notes: robust clustered standard errors in parentheses. The error terms are clustered at city level.
†, *, **, *** significant at 0.10, 0.05, 0.01, and 0.001 level.