Is China Still A Pollution Haven? Evidence from City-Level Analysis

Jiaxi Tang

14th February 2022

This dissertation is submitted in part requirement for the MSc Spatial Data Science and Visualization in the Centre for Advanced Spatial Analysis, Bartlett Faculty of the Build Environment, UCL.

**Submission Date:** 14th February 2022

**Module:** CASA0012 MSc Dissertation

**Supervisor:** David Concannon

**Git repository URL:** https://github.com/Keroroscar/Dissertation.git

**Word Count:** 10,365

**Abstract**

The pollution haven hypothesis (PHH) assumes that pollution-intensive industries will transfer from developed countries to developing countries through investment. This study uses city-level data during 2008-2015 of China and investigates how investments from different sources affect the emission of sulfur dioxide. This study uses the system Generalized Method of Moment (GMM) to solve the potential endogeneity of variables to examine the effect of domestic and foreign investments on the emission of sulfur dioxide. I find that investment in suburban areas positively and significantly impacts air pollution measured by sulfur dioxide. In contrast, investment in city centres does not have such a pollution effect. In addition, more stringent environmental regulations are found to effectively reduce the pollution level due to investments, particularly from foreign countries and Hong Kong, Macao and Taiwan. These findings support the pollution haven hypothesis for suburban areas, but not city centres, probably because environmental regulations are more effectively enforced in city centres than in suburban areas.

**Declaration of Authorship**

I, Jiaxi Tang, hereby declare that this dissertation is all my own original work and that all sources have been acknowledged. This dissertation is 11,984 words in length.

Signed: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date: 14 February 2022

Table of Content

[Table of Content v](#_Toc95666578)

[I. Introduction 1](#_Toc95666579)

[II. Literature Review 4](#_Toc95666580)

[III. Empirical Methodologies 7](#_Toc95666581)

[3.1 Theoretical framework 7](#_Toc95666582)

[3.2 Estimation Method 7](#_Toc95666583)

[3.3 Model Specification 8](#_Toc95666584)

[IV. Data 11](#_Toc95666585)

[4.1 Data Source 11](#_Toc95666586)

[4.2 Overview of FDI inflows to China 11](#_Toc95666587)

[4.3 China high resolution emission database (CHRED) 15](#_Toc95666588)

[4.4 Variable Construction 17](#_Toc95666589)

[4.4.1 Dependent Variable 17](#_Toc95666590)

[4.4.2 Key Independent Variables 17](#_Toc95666591)

[4.4.3 Control Variables 19](#_Toc95666592)

[V. Results 22](#_Toc95666593)

[5.1 Empirical results 22](#_Toc95666594)

[5.2 Results from data for suburban areas 26](#_Toc95666595)

[5.3 Robustness Analysis 27](#_Toc95666596)

[5.4 CHRED 29](#_Toc95666597)

[5.5 Further Discussion 30](#_Toc95666598)

[VI. Conclusions 32](#_Toc95666599)

[References 33](#_Toc95666600)

[Appendix 36](#_Toc95666601)

[**Table 5 Regression result of City Center (System GMM)** 36](#_Toc95666602)

[**Table 6 Regression results of City Suburban Area (System GMM)** 36](#_Toc95666603)

[**Table 7 Regression Results of City Center (POLS Model)** 38](#_Toc95666604)

[**Table 8 Regression Results of City Suburban areas (OLS Model)** 38](#_Toc95666605)

[**Table 9 Regression Results of City Center (Fixed Effect Model)** 39](#_Toc95666606)

[**Table 10 Regression Results of City Suburban areas (Fixed Effect Model)** 40](#_Toc95666607)

[**Table 11 Regression Results of City Center (Difference GMM Model)** 41](#_Toc95666608)

[**Table 10 Regression Results of City Suburban areas (Difference GMM Model)** 42](#_Toc95666609)

[**Data for key variables** 43](#_Toc95666610)

# I. Introduction

The environmental consequences of foreign direct investment (FDI) have become one of the most controversial issues on the procedure of globalization (Erdogan 2014). Specifically, one of the prominent environmental consequences is the pollution level within a country. On the one hand, the critics of FDI argue that the pollution-intensive firms will relocate their production to the developing countries and transfer the pollution volume to those countries due to the pollution haven effect. On the other hand, supporters of FDI argue that FDI ought to contribute to a positive impact on the environment in terms of the environmental-friendly technology provided by foreign enterprises, which is later called the pollution halo effect.

The pollution haven hypothesis was first put forward by Walter and Ugelow (1979) and improved theoretically by Baumol and Oates (1988). The pollution haven hypothesis assumes that a healthier environment is a normal good. Since the demand for a normal good will be higher, the countries with higher GDP per capita will prefer to protect the environment compared to those countries with lower GDP per capita Copeland and Taylor (2001). At the preliminary stage of development, the developing countries focus on rapid economic development and maintain a relatively high economic growth rate Borensztein, De Gregorio, and Lee (1998). Therefore, these countries are motivated to welcome all forms of investments and postpone the discussion of environmental protection. Furthermore, empirical studies have been done in searching for evidence for the pollution haven effect. Mani and Wheerler (1999) find that the outputs produced by pollution-intensive enterprises are decreasing continuously in OECD countries from 1960 to 1995, while the import volume increases rapidly. Their findings are consistent with Lucas and Hettige (1992) and Low, and Yeats (1992), which show Southeast Asian countries and Korea are the pollutions havens for OECD countries because of the weak environmental regulations. Some scholars even argue that the pollution haven hypothesis only exists in the industry transfer from OECD to Southeast Asian countries. (Merican Y, 2007; Waldkirch & Gopinath, 2008)

China is also being regarded as a pollution haven for a long time. Some surveys by the Institute of Publics and Environmental Affairs also pointed out that foreign firms are more likely to invest in the chemical and industrial industry. These industries are associated with using heavy energy and toxic chemicals, which produce large-yield of energy and chemical pollutants as byproducts. Moreover, the foreign firms investing in China are more likely to employ less-sophisticated equipment in China than in their home countries because of the technology lag. As a result, the pollution level would not decrease as suggested by the pollution halo hypothesis. Instead, the pollution progressively worsens because of older equipment in these firms. However, the pollution production is not limited to only foreign firms since China has its domestic firms that contribute to the pollution. Dean, Lovely, and Wang (2009) examine the pollution haven hypothesis from a different starting point. Their results show that pollution industries from Hong Kong, Macao, and Taiwan increase pollution in China. Yang and Wang (2016), using data from 1997 to 2013, shows that investment from Hong Kong, Macao, and Taiwan are positively related to pollution emission while the FDI is negatively related to pollution emission. Based on this evidence, the Chinese government needs to calculate and cut back the number of emissions generated by its domestic firms instead of narrowly focusing on limiting the pollution produced by foreign firms. In the year 2008, the average pollution level of city-suburban areas is 20 times more than city-centres.

In addition, the investment in China shows two city-level patterns. First, it follows regional distribution which most of the investments flow into coastal cities rather than inner regions. (Cheng & Masser, 2003) The cities located in the most inner regions, such as Urumqi and Xining, cannot attract much investment regardless of where the investments are. Second, pollution-intensive firms are shifting the location from more developed cities to less-developed ones. Developed cities like Beijing show a decreasing trend of sulfur dioxide emission from 57783 tons in 2008 to 22070 tons in 2015. For developing cities, such as Taiyuan, the emission level increased from 100089 tons in 2008 to tons 117397 in 2015. In other words, the emission volumes of pollutants from megacities are decreasing every year while the amounts for less developed cities are increasing year by year. So simply applying the provincial-level data cannot get a consistent result. Using city-level data might provide the paper with a more accurate result.

Ever since the pollution haven hypothesis development, a large set of literature has been written to determine the consistency of results around different parts of the world. Many different empirical studies examine the flow of FDI and the pollution as a consequence of investments from abroad. However, Pingfang, Zhengyu, and Guolin (2011) propose a different hypothesis from the rest of the literature on China. Their paper showed that FDI is positively significantly related to increasing pollution levels. Still, they also propose that the pollution has a high probability of transferring from more-developed to less-developed areas in China.

Since then, Chinese scholars have found inconsistent results using provincial-level data in China. This has led to a fierce debate on whether there is a positive or negative impact on the environment of less-developed areas of china compared to more-developed areas because of FDI. On the one hand, they argue that FDI negatively affects the environment of less-developed areas because of lax-environmental regulations in these parts of the country. On the other hand, the opponents argue that FDI facilitated the transfer and use of green or environmental-friendly technologies, reducing the level of pollution in these areas. However, consistent results cannot be reached as the provincial-level data diluted the pollution measurements, resulting in inconsistent observations in these studies. With the census yet to be reached, this paper investigates the proposition of Pingfang et al. (2011) using city-level data in order to settle the debate on the FDI and geographic pollution transfer within China.

This paper mainly applies the empirical analysis method to examine the effect of investments on the environment. According to how China stipulates the city, 223 medium and large size cities were chosen from 2008 to 2015 because these cities are attractive to foreign investment. All the data applied in the model, such as investments and emissions of sulfur dioxide, are collected from the Chinese City Statistical Yearbook from 2009 to 2016. This is an official publication that can provide trustable data. Moreover, this paper firstly applies descriptive statistics to summarize and discuss the data. Then, the data will be analysed using Python and embedded STATA software through the system GMM method. The system GMM method is applied due to the feature of collected data which is "small-time period and relatively large groups".

This paper contributes to the literature by building on previous knowledge of the pollution haven hypothesis. First, this paper examines the types of foreign or domestic investments that influence the level of air pollutant emission as a limited number of studies have been done on this subject. Second, the study splits the pollution measurements into two parts, the emissions of pollutants in the city-centres and the city-suburban areas. The purpose is to investigate the difference in the air pollution level between city-centres investments and city-suburban areas' investments which no studies have undertaken yet. Finally, this paper adds to the studies by using city-level data since the FDI inflow pattern of China is diversified based on city. City-level data might provide us with a more accurate result than provincial data does.

This study is organized into the following sections. Section II is a literature review that provides the theoretical knowledge of the relationship between FDI and pollution. Section III focuses on the model construction, and then other necessary tests and modifications will be used to adjust the models. Section IV presents the results of the study and discuss the findings of these results. Section V concludes the study with the implications for future policy.

# II. Literature Review

Walter and Ugelow (1979) first identified the association between FDI and environmental pollution. They proposed the idea of Pollution Haven which the firms maximize their profit by reducing the cost of waste management. That is, the firms will relocate their productions to the area where the costs of waste management are lowest. Later, Baumol and Oates (1988) extend this idea which completes the 'Pollution Haven' hypothesis. They argue that severe environmental regulations cost firms more and require more budgets to deal with pollution. Hence, the pollution-intensive firms are more willing to relocate to developed countries where the environmental regulations are not strictly enforced. Copeland and Taylor (2004) further extend the idea by pointing out that managing pollution is cheaper in developing countries. With the pollution haven hypothesis, Chinese scholars empirically test the hypothesis. They found results consistent with the hypothesis that China is a perfect choice for relocation as the lack of waste management requirements and the enforcement of regulations reduce waste costs for the pollution-intensive firms.

In contrast to the pollution haven hypothesis, other researchers find no evidence that FDI is responsible for pollution. On the contrary, FDI provides benefits to the local environment. In particular, Eskeland and Feyzioğlu (1997) find the Pollution Halo effect in which FDI from the developed countries transfer environmentally-friendly technologies to the developing countries. These technologies can benefit the local environment by using cleaner energy and generating fewer pollutants. Eskeland and Harrison (2003) point out that the foreign firms specialized in the pollution-intensive industries employed production and abatement technologies which are more environment-friendly than domestic firms of the host developing countries. Letchumanan and Kodama (2000) find the evidence for the horizontal spillovers of environmental-friendly technologies and conclude that transnational firms transfer these technologies to domestic firms in developing countries. Later, Liang (2008) shows the spillovers of FDI can improve the efficiency of production, energy-saving and save the investments on the local environment management.

Scholars also discuss the accurate definition of pollution. Grossman and Krueger (1995) firstly introduced three determinants of emission indicators. Environment regulation stringency is assumed as technique effect. The second indicator is an industrial composition known as the composition effect, and the last one represents economic growth as the scale effect. FDI entry and results of pollution also have a mutual relationship. The discussion between Pollution Haven Hypothesis and Pollution Halo Hypothesis has continued for nearly 20 years. No agreement has been made. But Chinese scholars suggest that China's relatively lax environmental regulations attract the FDI inflows with pollution-intensive companies in industrial composition. Also, China's rich endowment in the cheap labour force and less polluting but labour-intensive industries will also boom with increasing FDI inflow. Letchumannan and Kodama (2000) and He (2006) suggest that the relationship between FDI and environment cannot be simply analyzed by single question measurement simultaneously. Mechanisms should apply. He uses panel data from 29 provinces of China to test the relationship between FDI and sulfur emission. He finds that 1% increase in FDI, the sulfur dioxide will increase by 0.098%. Jorgensen (2007) uses panel data from 39 developing countries to test how the FDI affects the local environment. The result from his paper suggests that FDI to developing is positively related to the emission of air pollution.

Plot 1 Carbon footprint hotspots of global and regional consumptions in mainland China in 2012Map

Description automatically generated

**Subplot a**: domestic carbon footprint hotspots of foreign final consumption.

**Subplot** **b:** carbon footprint hotspots of the consumption of United States

**Subplot c:** carbon footprint hotspots of the consumption of Hong Kong

**Subplot d**: carbon footprint hotspots of the consumption of Japan

Among all foreign regions, United States, Hong Kong, and Japan have the largest carbon footprints in China, contributing approximately 23.0%, 10.8%, and 9.0%, respectively, to the total foreign carbon footprint in China in 2012.

# III. Empirical Methodologies

## 3.1 Theoretical framework

This paper investigates the relationship between FDI and the environment based on the pollution haven hypothesis. The theory dictates that the firms from developed countries will relocate their pollution-intensive production to city suburban areas in China to reduce the penalty of pollution. It is noted that governments of city-suburban areas focusing on economic development do not enforce their environmental regulations in regulating pollution production to attract foreign investments regardless of the cost to the environment. Furthermore, the hypothesis is supported by the profit-maximization assumption. In other words, firms relocate to an area where they can generate the highest profit. As the pollution-intensive firms are cost-sensitive since they need space to locate heavy equipment, they are more likely to transfer their production factories to developing areas. As a result, the pollution is also transferred along with the production.

Taking the above ideas and China's reality into consideration, this paper would like to establish the following hypothesis:

1) Investments from foreign firms will result in a negative association with pollution. In contrast, investments from domestic will lead to a positive association with pollution.

2) The investments, regardless of the firms' origins, are associated with lower pollution levels in the city centre, whereas the investments in the city-suburban area produce a higher level of pollution.

## 3.2 Estimation Method

In order to estimate the model, two potential problems have to be overcome in this case. The first problem is the presence of endogeneity in the explanatory variables. Usually, economic factors are considered related to each other in one model. So, the endogeneity problem is a critical concern in economic models. The second problem is the presence of lagged dependent variables and city-specific effects. Cities are unique; the city-specific effect is not easy to measure. Thus, both problems make it impossible to use the fixed and random effects. The coefficients will be biased if I directly estimate the panel data using OLS. Therefore, a better model is needed to overcome this problem. Arellano and Bond (1991) came up with the Generalized Method of Moment (GMM). Our model manages the city-specific effects by taking the first difference of regression functions. Then, I use a forward orthogonal deviation transformation according to Arellano and Bover (1995) to adjust the city-specific effects. However, a correlation problem arises between the lagged dependent variable and the error terms, generating new bias. Thus, Arellano and Bond (1991) and Arellano and Bover (1995) provided an improved method which is the lagged level can be used as instruments for the differenced lagged dependent variables. This method also can be applied to other endogenous variables. The method can be regarded as a one-step or two-step difference GMM method.

Alonso-Borrego and Arellano (1999) and Blundell and Bond (1998) show that the lagged dependent variables and independent variables possessing a random walk or stability over time are poor instruments for the differenced-equation. The systematic inaccuracies caused by differenced estimators can be reduced by estimating the differenced-equation and the level-equation together as a system. In this way, system GMM, proposed by Arellano and Bover (1995), reduces the biases. In the system estimation, the instruments for the regression in levels are the lagged first-differenced variables.

This paper adopts the two-step system GMM since Windmeijer (2005) suggests that two-step GMM is more efficient than the one-step GMM in estimating the coefficients because of the smaller bias and the standard errors. Also, the unbiased and consistent of the GMM estimator is estimated on the three specification tests, namely the Sargan test for over-identifying restrictions, the serial correlation test for disturbances, and the difference in Hansen test for extra moment’s conditions (Arellano & Bond, 1991; Arellano & Bover, 1995; and Blundell &Bond, 1998). The Sargan test is a test of the instruments' validity. The failure to reject the null hypothesis of the Hansen or Sargan test would indicate that the instruments chosen are valid and the system GMM estimation has been well specified and defined. Furthermore, the serial correlation test is essential as well. The test differentiates the types of serial correlation. The null hypothesis indicates the presence of first-order serial correlation, AR (1), and the alternative hypothesis indicates the second-order serial correlation, AR (2). The failure to reject the null hypothesis would indicate the presence of AR (1) in the error terms. The failure to reject the null hypotheses of difference in the Hansen test would support the validity. These three specification tests here are major concerns in this paper.

## 3.3 Model Specification

This model estimates the impact of investment, government scale and environmental regulation on sulfur dioxide at the city level.

The model is shown as follows:



1) ln(SO2) is the emission volume measured by sulfur dioxide. The original data is measured as a whole. Here I split the total sulfur dioxide into the city centre and city-suburban areas using the ratio of city centre's size to total city's size and the ratio of city suburban's size to total city's size. [[1]](#footnote-1)

2) Investments are divided into three parts due to where the investments come from: the domestic investments (Investment\_Domestic), investments from Hong Kong, Macao, and Taiwan (Investment\_HMT), and the investments from the foreign direct investment (FDI).

3) The Penalty represents the environmental regulation stringency. It consists of the ratio of firms that the department of environment fines and the total penalty required by the provision. The city-specific effect is represented by , is estimated by the GMM estimator,  and is estimated by other control variables related to the emission of sulfur dioxide level. This is the error term here. The lagged variable needs to be taken into consideration on past emission level, which presents a persistent trend.

To forecast the sign for these variables, the different economic levels of centre and suburban cities should be considered.

Table 1 Forecast of the dependent variable

|  |  |  |
| --- | --- | --- |
|  | City center | City Suburban areas |
| **Independent Variable** | ln(SO2) ln(SO2) | |
| Investment |  |  |
| Investment from domestic enterprises (Investment\_domestic) | **-** | **+** |
| Investment from Hong Kong, Macao, Taiwan's enterprises(Investment\_HMT) | **-** | **+** |
| Foreign Direct Investment (FDI) | **-** | **+** |
| Penalty | **-** | **+** |

The forecast is made due to the following reasons:

The coefficient of investment in the centre of the city should be negative since costs in the centre city are much higher than in suburban areas, and firms would like to invest in advanced technology that can generate more profit. Meanwhile, the sign for the coefficient of investment in the suburban city should be positively related to pollution since the pollution-intensive enterprises would like to locate their enterprises in the city-suburban areas. Then, the sign for the coefficient of penalty in the centre city should be negatively related to the pollution level since they already reached a relatively higher economic level than suburban areas. The government in the city's centre would like to focus on the better welfare of citizens' daily lives. So, governments would be more severe to enterprises in the city centre than enterprises in suburban areas. They may even provide heavy industrial enterprises with more conveniences. According to the idea above, the forecast is made in Table 1.

Comparison with existing relevant works were conducted by replicating the visualization results using same datasets. This part of replication analysis consolidates the statistical results generated by the model mentioned in above. It is also considered as an alternative way of robustness check for the system GMM model.

# IV. Data

## 4.1 Data Source

This model uses panel data from 226 cities from 2008 to 2015. These 226 cities are chosen for the following reasons: First, the Chinese top administrative unit is province according to the administrative level. Every province governs cities separated into two categories: the Prefecture-level city and the County-Level city. Cities belonging to the 'Prefecture-level city' and above have larger populations, better-educated workforce, and access to more convenient transportation. With these infrastructures, these cities attract investments. Second, the Chinese Department of Statistics collected these data, which can be regarded as reliable data. Thus, using these data to estimate the results may be less sensitive to censorship. Third, most existing papers focus on the provincial level or country-level data. Therefore, using city-level data that compared the city-centre and suburban may provide a new perspective to the pollution haven hypothesis.

Furthermore, the data being used is from 2008 to 2015. 2008 is selected as the start point of the dataset because it is the year of the subprime mortgage financial crisis. This is of great importance as the financial crisis is linked to reducing foreign direct investments. In other words, the selection of starting point before 2008 may underestimate the true effects of the PHH because of the financial crisis in 2008. Considering this fact, 2008 is a better starting point than any other year. Finally, the city level may provide a more accurate picture of PHH. That is, the provincial-level data diluted the effect of pollution by FDI or other investments due to the fact that there are significant variations in the economic performances of different cities even within a province. And that the utilization of provincial-level data will ignore these facts, which “dilute” the results lead to a less clear picture of PHH.

## 4.2 Overview of FDI inflows to China

As mentioned in the introduction part, the investment inflows to China have some patterns. One is the 'city pattern' which the investors prefer megacities in China. The other regional pattern is that investments are gathering around China's south areas rather than west areas. However, the two cities will show a different feature due to how the investment flows in.

To begin with, I made a comparison between the cities belonging to 'SEASIDE' and 'SUB-PROVINCIAL' in Figure 1 and Figure 2. Once a city is located along the seaside, the convenience of sea transportation may attract more foreign investment since sea transportation has a comparative price advantage. Those cities are Tianjin, Shanghai, Dalian, Qinhuangdao, Yantai, Qingdao, Lianyungang, Nantong, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai.

'SUB-PROVINCIAL' indicates whether a city belongs to the sub-provincial level or not. The sub-provincial cities are mega cities in China, also defined as the most developed cities in China. Cities that belong to the sub-provincial level also usually have a more regulatory government scale and efficiency. Those cities are Shenyang, Dalian, Changchun, Harbin, Nanjing, Hangzhou, Ningbo, Xiamen, Jinan, Qingdao, Wuhan, Guangzhou, Shenzhen, Chengdu, and Xian.

Figure 1 Comparison of the investment inflows to China (SEASIDE)

Source: China City Statistical Yearbook

"SEASIDE" shows the average natural logarithm of investments that belong to the cities located at the coastal economic zone. Also, "SUB PROVINCIAL*"* means the average natural logarithm of investments when a city is classified as a sub-provincial level city.

Figure 2 Comparison of the investment inflows to China (SUB-PROVINCIAL)

Source: China City Statistical Yearbook

“Seaside” cities which belong to the coastal economic zone have major advantages such as better transportation, a good industrial foundation, more educated workforce. Moreover, these cities are open and well-prepared for potential foreign investments. In other words, they are the relatively developed areas of China. These developed areas absorb capital, technologies, and knowledge from foreign countries by opening up to investments from abroad

The sub-provincial level is a term used in Chinese governance. Cities belonging to the vice-provincial level have a higher self economic management, and those cities are sensitive to react to the policy requirements. Whenever the central government makes the new proposal, the central government will watch how those cities reach the goal. From 2008, the growth rate of sulfur dioxide emission is planned to be less than 5.25% every year. Thus, to maintain the high economic growth level while having a relatively fewer pollution emissions. The sub-provincial cities will show more willingness to attract high technology level investment than others.

From figure 1, I can tell that FDI to seaside cities has an opposite trend versus the vice-provincial level cities. FDI from foreign and non- HMT countries prefers to invest in the city-centre of seaside cities while FDI from HMT would like to invest more in the suburban of vice-provincial level. All kinds of investments in seaside cities show that they invest more in the city centre than suburban areas. However, only domestic investments in the city centre are more significant than that of the city-suburban areas. Both investments from Hong Kong, Macao and Taiwan and investments from foreigners are more significant in suburban areas than city centre level. Considering the variations of these two groups, it can be inferred that the sub-provincial level cities have more stringent environmental regulations. In other words, these cities welcome FDI with environmental-friendly technologies to the centre-city while transferring the pollution-intensive investments to the suburban of these cities. The seaside cities attract investments with advanced and non-pollution intensive technologies as the environmental regulations and better infrastructure are major points for these investments. Therefore, it can be inferred that the FDI follows its expectation of HPP.

Figure 3 Regional comparing the investment inflows to China (SOUTH AREA)

Source: China City Statistical Yearbook

Figure 4 Regional comparing the investment inflows to China (NORTHWEST AREA)

Source: China City Statistical Yearbook

Figures 3 and 4 select two special districts to be used as a comparison, the south and the northwest. The south is considered the most developed area of China, while the northwest is considered the least developed area of China. As there are variations in development both in infrastructure and workforce at these two locations, investments prefer the city-centre and the suburban in the South. In contrast, only the city centre is famous for investment in Northwest. From the figure above, I can see that both domestic investments and investments from HMT to the city centre are relatively higher than that of the suburban. FDI prefers the suburban in South which the FDI to the city-centre shows an increasing trend. FDI is potentially linked to the investments in the city-centre, which the firms are less pollution-intensive. Furthermore, the domestic investments are much higher than any other investments in Northwest, while the FDI is comparatively low.

## 4.3 China high resolution emission database (CHRED)

As robustness check aside of system GMM model analysis, visualization of CHRED carbon footprint in China provides good understanding of carbon emission characters among Chinese main cities. By industries, Plot 2 is a visualized overview of Carbon Dioxide emissions in China in 2012 – in the middle of the observation window (2008-2015). Each economic center in China Mainland has shown a different structure of their pollution sources. In the North and East, the top hotspots: Beijing, and Shanghai areas had more pollution generated from both agriculture and transportation. Whereas Guangzhou and Hong Kong in the south, were most polluted by only transportation, but not agriculture.

In the following part of this paper, there will be an investigation into the redirection of pollution from foreign countries and most developed parts in China (Yangtze River Delta, Pearl River Delta, and North China Plain) to less developed part in China, through investments.

For reference, central city of manufacturing hubs (darkest red cluster groups) in Plot 1 (f):

East - Yangtze River Delta: Shanghai

South - Pearl River Delta: Guangzhou, Shenzhen

North - North China Plain: Beijing

Plot 2 Spatially explicit Overview of CO2 emissions in China 2012 (unit: tonne) - By Industry Types

Map

Description automatically generated

where (a) Agriculture; (b) Industry (including CO2 emissions from energy combustion and industrial processes); (c) Services; (d) Urban and rural households; (e) Transportation; (f) Total.

## 4.4 Variable Construction

### 4.4.1 Dependent Variable

Using the emission level of sulfur dioxide generated by firms as the independent variable follows the idea from He (2006). The variable is chosen here for the reasons below: Firstly, the emission of sulfur dioxide is the core concern and the critical indicator of the environment quality and condition. It is also a better measure method than carbon dioxide since, theoretically, the sulfur dioxide from carbon dioxide is the main cause of acid rain. Besides, the sulfur element itself is also closely related to the industrial product. From decades ago, most countries, including China, start to record and report this data, which provides us with a mature and consistent data source. Secondly, the pollution problem raised by sulfur emission, such as acid rain, is related to the local living condition. It may prevent and influence the investment decision of investors. Thirdly, this variable has a theoretical foundation mentioned in chapter 2, and the data show patterns that differ around the city.

According to the hypothesis, sulfur dioxide is chosen as an endogenous variable because of the fact that the more notoriously China's air, the more executives from foreign firms resign from their positions in China. And losing the talents from foreign firms may be closely linked to the loss of advanced technologies, which further accelerate the level of dirty investments being invested in China. The advantages mentioned above support that sulfur dioxide generated by industrial enterprises is suitable and applicable.

### 4.4.2 Key Independent Variables

Output value generated by foreign direct investment (FDI) will be applied to this paper for the following reason: First, the output values of the factories are closely related to the sulfur dioxide emission, and it is an endogenous variable. Foreign firms are not merely investing in factories. Some will also invest in the environmental infrastructure, research, and development to cultivate new talents and public facilities. But investments in these factors are not related to our model. So, I will select the output values generated by foreign direct investment as the dependent variable. Second, the data gives details about the number of investments with information on the origin of the firms. Specifically, investment data from the domestic level (Investment\_Domestic) and investment from Hong Kong, Macao, and Taiwan (Investment\_HMT) can be used in this paper as a comparison because domestic firms and firms from Hong Kong, Macao, and Taiwan have a different level of technologies.

Existing literature used foreign investment as the main variable of interest to examine whether the foreign firms are transferring pollution-intensive factories to China or not. However, I cannot ignore the possibility of domestic and foreign firms investing in the same developing region. Moreover, there is also a possibility that domestic firms are generating pollution instead. A comparison between these three regions will offer a better explanation.

Then the penalty charged by the government is regarded as environmental regulation. Erodogan (2014) published a survey paper arguing that environmental regulation is related to investment and is usually measured by environmental cost. This paper applies the penalty of firms charged by the government as the indicator representing environmental regulations. On the one hand, the government only fine the most pollution-intensive industrial enterprises if the enterprises generate more polluted air than the average level. This is closely related to the independent variable. On the other hand, Local governments can decide to charge the firms or just warn the firms, which means that the penalty represents the willingness of governments. Following the PHH hypothesis, governments may charge heavily in the developed areas but less stringent in developing areas.

The government scale, in this paper, is defined as the number of officials a city has. Fisman and Gatti (2002) indicate that they are negatively correlated in developed countries to relate the government scale and the corruption level. The conclusion from Fishman's paper projects the idea that government scale may be positively related to the pollution level. Three mechanisms of the government scale influence the emission of sulfur dioxide. First, the competitions will trigger the "race to the bottom" between cities. The “race to the bottom” was proposed to represent the competition among American states to attract the firms by loosening the local financial regulations. Applying this theory to Chinese political and economic realities, the race to the bottom is triggered for the environmental regulation of the developing cities. The political reality is such that China's target growth rate is determined by the central government. Then, the local governments reach the determined target rate through their methods. However, the economic reality is such that the local governments from the developing cities cannot achieve the target realistically because of the lack of infrastructure and workforce advantages. In order to circumcise these shortcomings, they deregulate the environmental regulations to increase their attractiveness to the domestic and foreign firms knowing that their production and investments are pollution-intensive. In this way, the government scale may show a tendency that is positively related to the pollution level in suburban areas. Second, the government scale is also an important indicator of government efficiency, as Goel and Nelson (1998) noted. They pointed out that a large government is more likely to be corrupt. The corruption itself represents low efficiency in China. A larger government scale lowers the government's efficiency at dealing with problems, particularly pollution, which translates into longer-term problems. From the evidence above, this paper applies these variables as independent variables. Fisman and Gatti (2002) indicate that the relationship between corruption and government scale is negative in developed countries. The conclusion from Fishman's paper projects the idea that government scale may be positively related to the pollution level. This paper applies these variables as key independent variables from the evidence above.

### 4.4.3 Control Variables

In order to reduce the bias of this model, this paper applies control variables (X) in this model. Table 1 defines each control variable, and these variables are defined as in the following:

*ln(Population)* is the population indicator meaning how many populations a city has. A large amount population in the city-suburban area can provide the enterprises with more labour force. A cheap labour force will attract the industrial enterprises to locate in that area to reduce the production cost. On the contrary, a large population in the city centre means the number of talents will also be more prominent, which is attractive to advanced enterprises. Thus, the population need to be taken into consideration.

The ratio of labour in the industry to the total labour force (*ln(Labor in industrial enterprises)*): Generally speaking, the larger the ratio, the more pollution-intensive firms a city has. Moreover, it also indicates the level of technologies possessed by the firms. Also, it indicates the technology level of enterprises. For instance, the ratio of Beijing is decreasing from more than 50% to less than 25% from 2008 to 2015. However, remote inner cities such as Urumqi remain at the same level, more than 70% from 2008 to 2015.

City size (*ln(Land)*): In China, the most developed cities such as Beijing and Shanghai are relatively small in terms of city size. Also, their suburban areas are almost zero. The suburban area is seven times larger for less developed cities such as Chengdu from Sichuan province than the city centre. In this way, foreign enterprises have much larger space to establish their factories in suburban areas.

The ratio of gross regional product from industry to total city gross regional product (*ln (Industrial GRP ratio)*): Compared to the ratio of labour in the second industry, this ratio indicates how large the industry scale is in a certain area.

Wage noted as *ln(Wage)* is usually considered the average technology level of one city. According to city-level data, the average wage level has a huge gap in China. Developed cities have an average wage above 4000RMB while developing cities, predominantly suburban areas, is about 1000RMB. Braconier Norbäck and Urban (2005) argue that relatively low wage in developing countries attracts FDI mainly. Thus in my model, the FDI invested in developing cities in China may have a large possibility to relate with emission of sulfur dioxide, so it should be considered as a control variable

The variable *ln(Freight Delivery)* follows the speech of Prime minister Li[[2]](#footnote-2) who indicate that the real GDP can be represented by freight delivery. Compared to railway delivery, which mostly connects relatively large cities, freight delivery exists everywhere, especially for short-distance industrial product delivery. This model applies this variable to control for the city level validity of enterprises.

Table 2 Model variable description

|  |  |  |
| --- | --- | --- |
| **Variable name** | **Definition** |  |
| ln(SO2) | Natural logarithm of emission of sulfur dioxide |  |
| ln(Investment\_Domestic) | Natural logarithm of output value generated by domestic investment |  |
| ln(Investment\_HMT) | Natural logarithm of output value generated by Hong Kong, Macao, and Taiwan's investment |  |
| ln(FDI) | Natural logarithm of output value generated by FDI |  |
| ln(Gov scale) | Natural logarithm of the number of public officials | |
| Table 2 (Cont.) |  | |
| **Variable name** | **Definition** | |
| ln(Penalty) | Natural logarithm of total penalties from local government to local industrial enterprises which violate the environmental regulations | |
| ln(Labour in industrial enterprises) | Natural logarithm of total labour work in industrial enterprises | |
| ln(Population) | Natural logarithm of the total population | |
| ln(Industrial GRP ratio) | Natural logarithm of Industrial Gross Region Product |  |
| ln(Wage) | Natural logarithm of the average wage | |
| ln(Freight Delivery) | Natural logarithm of highway freight volume |  |
| ln(Land) | Natural logarithm of the city area | |

Table 2 defines how the variables are named in the model. Then, Table 3 and Table 4 give a descriptive statistic of the value due to 'city centre' and 'City suburban areas'.

Table 3 Descriptive Statistic of City Center

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dependent Variable** | | |  | | **Mean** | | **Min** | | **Median** | | **Max** | |
|  | | ln(SO2) |  | | 8.518811 | | 4.190072 | | 8.559633 | | 12.1819 | |
| **Independent Variable** | | |  | |  | |  | |  | |  | |
|  | | ln(Investment\_Domestic) |  | | 15.57074 | | 11.57028 | | 15.59408 | | 18.81236 | |
|  | | ln(Investment\_HMT) | | | 12.41725 | | 6.684612 | | 12.42206 | | 17.7899 | |
|  | | ln(FDI) |  | | 13.01704 | | 7.437795 | | 13.01174 | | 18.83321 | |
|  | | ln(Penalty) |  | | 1.049681 | | 0.223144 | | 0.916291 | | 7.579679 | |
|  | | ln(Gov scale) |  | | 5.062849 | | 1.891911 | | 4.990897 | | 7.949394 | |
| **Control Variable** | | |  | |  | |  | |  | |  | |
|  | | ln(Labor in industrial enterprises) | | | 3.853344 | | 2.422144 | | 3.913422 | | 4.434975 | |
|  | | ln(Population) |  | | 4.682329 | | 2.99072 | | 4.581902 | | 7.341983 | |
|  | | ln(Industrial GRP ratio) |  | | 3.919589 | | 2.373975 | | 3.94874 | | 4.435567 | |
|  | | ln(wage) |  | | 10.5284 | | 9.404403 | | 10.56082 | | 11.55664 | |
|  | ln(Highway Freight) | | |  | | 7.804263 | | 4.814068 | | 7.817771 | | 10.78389 |
|  | ln(Land) | | |  | | 7.169026 | | 4.574711 | | 7.272398 | | 10.76439 |

Table 4 Descriptive Statistic of City Suburban Areas

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Dependent Variable** | |  | **Mean** | **Min** | **Median** | **Max** |
|  | ln(SO2) |  | 10.4974 | 6.04494 | 10.62482 | 12.88075 |
| **Independent Variable** | |  |  |  |  |  |
|  | ln(Investment\_Domestic) |  | 15.8271 | 8.694838 | 15.88847 | 18.32917 |
|  | ln(Investment\_HMT) | | 12.29925 | 0.693147 | 12.3838 | 17.11724 |
|  | ln(FDI) |  | 12.51492 | 0.693147 | 12.62962 | 18.2244 |
|  | ln(Penalty) |  | 5.062849 | 1.891911 | 4.990897 | 7.949394 |
|  | ln(Gov scale) |  | 1.225126 | 0.24846 | 1.214913 | 9.007244 |
| **Control Variable** | |  |  |  |  |  |
|  | ln(Labor in industrial enterprises) | | 3.783092 | 2.26761 | 3.836172 | 4.504258 |
|  | ln(Population) |  | 5.599443 | 2.112634 | 5.648234 | 7.474023 |
|  | ln(Industrial GRP ratio) |  | 0.02235 | 0.003546 | 0.020092 | 0.130134 |
|  | ln(Wage) |  | 10.41058 | 9.216873 | 10.43603 | 11.3453 |
|  | ln(Highway Freight) |  | 8.293504 | 0 | 8.394618 | 10.52701 |
|  | ln(Land) |  | 9.148079 | 4.682131 | 9.220093 | 12.83329 |

One fact from these data is that minimum data in the city-suburban areas are significantly smaller since some of the numbers are approaching 0.5 while the maximum level of investments is nearly the same as that in the city centre. This is a signal that cities vary significantly according to their capability to attract investment, especially FDI. Then, the penalty is much larger in city suburban areas than in the city centre. This provides us with the idea that whether the enterprises in city suburban areas are more pollution-intensive makes the government fines more frequently and punish them severely.

From the descriptive statistic, it can be told that data in the city centre and city-suburban areas do have some different patterns. Thus, regressions of the model need to be classified as city centre group and city-suburban areas group.

# V. Results

## 5.1 Empirical results

In this section, firstly, the regression results are shown below. Then, an analysis is offered to discuss the results from regression models. Later, other methods conducting the same regression model are applied to test the robustness of the main method.

Table 5 offers the estimation results of our model using the system GMM method from the city centre group. The first regression (1) shows all investments' impact on sulfur dioxide. Then, regression (2), (3) and (4) detect the individual effect of investment from domestic, investment from Hong Kong Macao, Taiwan and investment from foreign companies on emission level.

Table 5 Regression result of City Center (System GMM)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **City Center** | | | | | | |
|  | | (1) | | (2) | | (3) | | (4) |
|  | | Total Investment | | Domestic | | HMT | | FDI |
|  | | ln(SO2) | | ln(SO2) | | ln(SO2) | | ln(SO2) |
| Lagged ln(SO2) | | -0.223\*\*\* | | -0.167\*\*\* | | -0.234\*\*\* | | -0.213\*\*\* |
|  | | (0.037) | | (0.043) | | (0.056) | | (0.045) |
| ln(Investment\_Domestic) | | 0.150 | | 0.212 | |  | |  |
|  | | (0.160) | | (0.155) | |  | |  |
| ln(Investment\_HMT) | | 0.008 | |  | | 0.079 | |  |
|  | | (0.062) | |  | | (0.066) | |  |
| ln(FDI) | | -0.051 | |  | |  | | -0.017 |
|  | | (0.054) | |  | |  | | (0.059) |
| ln(Penalty) | | -0.257\*\*\* | | -0.187 | | -0.375\*\*\* | | -0.113 |
|  | | (0.098) | | (0.114) | | (0.115) | | (0.098) |
| ln(Gov scale) | | 1.286\*\* | | 0.887 | | 1.755\*\*\* | | 1.433\*\* |
|  | | (0.518) | | (0.639) | | (0.579) | | (0.655) |
| Control | | YES | | YES | | YES | | YES |
| Dummy | | YES | | YES | | YES | | YES |
| Constant | | -0.019 | | -7.706 | | 4.735\*\* | | -1.047 |
|  | | (3.069) | | (4.889) | | (2.226) | | (3.705) |
| artests | | 2 | | 2 | | 2 | | 2 |
| sargan | | 61.02 | | 57.04 | | 48.85 | | 56.79 |
| N | 780 | | 780 | | 780 | | 780 | |
| N\_g | 223 | | 223 | | 223 | | 223 | |
| Standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | | | | | | | |

In terms of the instrument the model selected, the Sargan test and autocorrelation test results show the model generally have a validity instrument. Sargan test and its results prove that the instruments chosen are suitable and appropriate. The other concern in our model is the auto regression test. Compared to the unit root test, the auto regression test to this paper is more important because this paper only applies a ten year period which implies that the most vital concern in this model is not from a time period. As part of the prerequisite of estimating the GMM model, an autocorrelation between variables is required. The autocorrelation test is performed on dependent and independent variables to check the autocorrelation. That is, autocorrelation tests are applied both to the variable group of the city centre and the variable group of city-suburban areas using the method provided by Drukker (2003). The null hypothesis is no first-order autocorrelation. Results are F(1,239)=32.106 and F(1,237)=0.000 respectively. Both results indicate that I can reject the null hypothesis and the first-order autocorrelation. In regression analysis, I need to test the heteroskedasticity of a model since heteroscedasticity may make the expectations of the second moment of the error misspecified. Since the paper assumes that modelling errors are uncorrelated and not uniform, the existence of heteroscedasticity may also violate the basic assumption of models. This paper applies the method provided by Poi and Wiggins (2001), who argued that iterated GLS with heteroskedastic panels would produce MLE. An LR test can be used. The chi value of 238 degrees of freedom shows results of -66.94, which offer a 100% probability to accept the null hypothesis, which is homoskedasticity. Also, the lagged instrument is restricted to 3 time periods to control for the most appropriate instrument number.

From the city centre group results, our concern mainly focuses on the different impacts of investment from different areas on environmental quality. According to the regression (1), I can find the following results: Firstly, the lagged dependent variable, the emission of sulfur dioxide, shows a downward tendency compared to the one year before. It is significant at the 1% level. Also, with a 1% increase in the last year emission of sulfur dioxide, the current year emission level will decrease 0.223%. This is a good sign indicating that the cities are following the central government's requirement to clean up the environment.

Secondly, all of the investment variables to the city centre do not show significance related to sulfur emission. It is consistent with our expectation that the investment in the city centre will be clean. Besides, investment in the city centre improves the environmental condition to some extent. It may be possible that investment to the city centre will use better product technology and pollution control method. Besides, the government will manage the investment in the city centre to be clean. From these results, the pollution haven effect does not exist.

Thirdly, environmental regulation reveals the fact that stringent regulation can positively affect the pollution level by reducing the emission of sulfur dioxide. Every year, the Minister of Environment will fine the firms that perform poorly in pollution control. The amount charged by the government is enormous, and the enterprise will be listed on the website. In 2016, the Beijing Minister of Environment charged an average amount of 100000 RMB per enterprise while Chengdu, an inner-city, charged only about 40000 RMB per enterprise. Generally speaking, it is huge damage to an enterprise's reputation when their names are listed. Then, their supplier or custom will be less willing to maintain a long term relationship with those enterprises. Besides, the amount is also costly, which can reduce the profit of the enterprises. Then the enterprises will have less funding to sustain future research and development. According to the reason above, the regulation effectively reduces emissions.

Fourthly, the government scale positively relates to the emission level, especially enterprises from HMT and FDI. With a 1% increase in the government scale, the emission level increases by 1.755% and 1.433%, respectively. The reasoning behind the government scale and its relationship to the emission level can be explained in two ways. First, the Chinese government scale has a pattern that denotes a trend of "increasing- decreasing-increasing" of the number of officials in the government. The six large reductions are in 1982, 1988, 1998, 2003, and 2008. From 2008 to 2015, the government scale is in the "increasing" period. However, in the period of “increasing” government scale, problems such as corruption and low efficiency usually accompany the growth. The results from this model indicate that the government's scales are positively related to the low efficiency of controlling the emission level. In addition, a large government scale represents the separation of power and wealth (Pingfang et al., 2011). This provides the idea that the less connection between wealth and power of a government, the government has to rely more on the local economic growth rate, which gives the local government an incentive to relax the control of enterprises.

In order to compare the effect of investment from different areas on emission, regression (2) to (4) are applied.

Based on the results from regression (2) to (4), none of the investment variables is significant at any level. They are all consistent with the hypothesis. From the results, I can tell no matter where the investments come from, the investments to the city centre cannot show the significance of the emission of sulfur dioxide. However, environmental regulations only reveal significance from regression (3), which indicates that the restrictions can mostly affect investment from Hong Kong, Macao, and Taiwan. This is mainly because many enterprises invested by Hong Kong, Macao and Taiwan are relatively more minor enterprises than those invested by domestic investors and foreign investors. Wayne et al. (2002) found that small enterprises are more sensitive to environmental regulations in America. It is with the high possibility that small enterprises in China are also sensitive to environmental regulations. Also, according to the survey conducted by an NGO, foreign-invested firms are more willing to follow the environmental regulations, which indicates that foreign firms are following the local rules, so the government will not charge them for their performance in pollution control.

## 5.2 Results from data for suburban areas

After conducting a regression on the city centre group, this paper applies the group of city-suburban areas below as a comparison. According to the hypothesis, the investment in the city centre is not necessarily related to pollution. However, the investment to city suburban areas should relate to the emission according to the pollution haven hypothesis.

From the results of the city-suburban areas, the investment from FDI is no longer pollution-free anymore. Firstly, according to regression, the pollution shows an opposite trend compared to the city centre's emission trend (5). With a 1% increase in FDI, the emission of sulfur dioxide is increasing by 0.114%. This is consistent with our hypothesis that the pollution-intensive enterprises invest heavy industry in the city-suburban areas rather than the city centre. Moreover, results show that. Moreover, the results show that pollution-intensive enterprises will transfer from developed to developing areas.

Table 6 Regression results of City Suburban Area (System GMM)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **City Suburban Areas** | | | |
|  | (5) | (6) | (7) | (8) |
|  | Total Investment | Domestic | Hong Kong, Macao, and Taiwan | FDI |
|  | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
| Lagged ln(SO2) | 0.280\*\*\* | 0.356\* | 0.266\*\*\* | 0.327\*\*\* |
|  | (-0.066) | (-0.059) | (-0.028) | (-0.025) |
| In(Investment\_Domestic) | 0.196 | 0.410\*\*\* |  |  |
|  | (-0.142) | (-0.111) |  |  |
| In(Investment\_HMT) | -0.019 |  | 0.058\*\* |  |
|  | (-0.036) |  | (-0.024) |  |
| ln(FDI) | 0.114\*\*\* |  |  | 0.237\*\*\* |
|  | (-0.0327) |  |  | (-0.028) |
| ln(Penalty) | 0.011 | -0.078 | 0.012 | -0.034 |
|  | (-0.054) | (-0.052) | (-0.044) | (-0.043) |
| Ln(Gov scale) | 0.544\*\* | 0.880\*\*\* | 0.740\*\*\* | -0.05 |
|  | (-0.248) | (-0.271) | (-0.266) | (-0.281) |
| Control | YES | YES | YES | YES |
| Dummy | YES | YES | YES | YES |
| Constant | 10.48\*\*\* | 5.265\* | 12.101\*\*\* | 7.339\*\*\* |
|  | (-2.134) | (-3.186) | (-2.397) | (-2.269) |
| artests | 2 | 2 | 2 | 2 |
| sargan | 74.17 | 53.88 | 63.25 | 57.57 |
| N | 780 | 780 | 780 | 780 |
| N\_g | 223 | 223 | 223 | 223 |
| Standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | | | |

Then, the results show that the pollution-intensive enterprises will transfer from the developed area to the developing area. Secondly, compared to the previous results individually, it can be found that all the investments shown from regression (6) to (8) have the same result. The investments in city suburban areas are significantly related to the emission of sulfur dioxide. Thirdly, environmental regulation is less stringent to enterprises than the city centre. Results from variables representing penalty do not show significance here. If I think that the significance of the investment variable reveals the attitude of investors, then the regulation results show the attitude of local government. And the attitude of local government in city suburban areas is not to pay much attention to pollution heavy industry. Then, it can be concluded that the regulations of the city-suburban areas are less effective than the regulations of that in the city centre. This may be the willingness of firms to follow the rule is weaker, and the government shows a vague attitude to manage the enterprise as well. The local government has already lost their potential economic growth from the second industry from the city centre. They may largely need the growth from suburban areas, which shows the same conclusion from Ferrara, Missios and Yildiz (2015).

## 5.3 Robustness Analysis

After a series of regressions is applied using the system GMM method, this paper will also apply another method to conduct the regression. This paper selects the fixed-effect model and difference GMM model, and the results are shown in Table 7 to Table 12. OLS method should decide the maximum coefficient value, while the fixed-effect method should decide the minimum coefficient value. In addition, a fixed-effect model is applied according to the Hausman test, which helps decide whether I should use a fixed effect or random-effect model. The results from the Hausman test suggests that the fixed effect is more suitable. Next, the difference GMM method is applied because, in economic activities, the variables are correlated with each other. So far, there are two solutions to the endogenous problem in the dynamic panel model—the difference between GMM and the system of GMM. In this study, using a system GMM model has been explained before since this analysis has an endogenous relationship. Table 9 and Table 10 provide the results from the different GMM methods. Compared with the system-GMM method, both the difference and level equations are estimated. However, the lagged terms of the different variables are used in the level equation as instruments in the system GMM model, making the system-GMM method use more instrument variables than the difference GMM model. System GMM method is considered to enhance the accuracy of the estimation.

Table 7 and Table 8 are the first robustness checks for the city centre and suburban areas. In this set, pooled ordinary least squares (POLS) method is applied to test the same model function. The dependent variable is ln(SO2), another proxy for firm performance. The Lagged ln(SO2) coefficient should be relatively larger than that in system GMM and FE methods. Results indicate that investment in the city centre is not related to pollution no matter where do the investments come from. Penalty works effectively. Then, the results from Table 8 offer a similar conclusion compared to the benchmark model. But this model indicates that FDI is not significantly related to pollution. The penalty is positively related to pollution. Taking the upward bias of the POLS method into consideration, the conclusion from the OLS model is considered to be consistent with the benchmark model.

In Table 9 and Table 10, two more robustness checks are applied using the FE effect method. Compared to the POLS method, which has an upward measurement-error bias, the FE effect method usually provides the minimum level of coefficients because the method has a downward measurement-error bias.

The results of the city centre give the conclusion that investment is not related to the pollution and penalty are effective to all kinds of enterprises while the investment in the suburban areas is more related to the emission of sulfur dioxide. The main difference between these models and the benchmark model is that the government's effect in the city centre is not significant. Still, the effect of government scale on pollution is negatively related. Thus, the robustness check of the FE model is considered to get the same conclusion as the benchmark model.

Table 11 and Table 12 provides the robustness check conducted by the different GMM method. This method may provide bias when the lagged independent variable has a large coefficient caused by weak instruments (Arellano & Bover, 1995).

The lagged level in this model is restricted with no more than three time periods. These regressions show very similar results to the benchmark model. Considering the number of groups, the coefficients from system GMM method are considered to be more accurate than the difference GMM method.

From Tables 7, 9 and 11, different methods are used to test variables of the city centre groups. Coefficients of core independent variables present the same conclusion: the investment in the city centre is uncorrelated to the pollution level. In addition, the coefficient of penalty in the city centre is significantly negatively related to the pollution level, indicating that environmental regulations are very effective in the city centre. Thus, considering the endogenous problem, the results of the benchmark model are credible.

## 5.4 CHRED

Consolidation check of visualizing CHRED carbon footprint in China in 2012 confirms the idea of heavy export-driven pollution were redirected to less developed part in China. The three main blue grid clustering areas in Plot 3 are Beijing, Shanghai, and Guangzhou, respectively. These three cities and their surrounding economic areas are the three most developed and well-known workhorse of Chinese economy.

Plot 3 Emission differences between original CHRED emission map and the export-driven carbon footprint map.

Map

Description automatically generated

Blue grids mean that the original CHRED emissions in these grids are less than the export-driven carbon footprint, while red grids imply the opposite.

## 

## 5.5 Further Discussion

Table 5 and Table 6 indicate that investments in city centres pollute less than those in suburban areas. The results here are consistent with the finding from Jones and Kammen (2014). They argue that the suburban area in New York is much more polluted than New York City, which indicates the industrial transfer from city developed area to city suburban area not only exists in developing countries.

Following reasons may cause the results:

(1) Pollution intensive enterprises would proactively select city suburban areas for the following reasons: Firstly, the regulation indicator is more severe in the city centre than that of city-suburban areas. Governments reflect this charge the firms and enterprises much more frequently than suburban areas. In 2016, Chengdu charged 74 pollution intensive enterprises, and 61 of them were located in the city centre. In addition, some of the pollution-intensive enterprises such as power plants, refineries and cement plants located in the suburban area are exempted from the charge by the government's policy. Secondly, the cost and ownership of land would lead the pollution-intensive enterprises to locate in suburban areas. Pollution intensive enterprises usually occupy a relatively large space since they need the space to put machines and equipment. Since all the land in China is governed and managed by the government. How much government sells the right to use the land indicates the government's willingness. The transaction frequencies in developed cities are much less than those in developing cities. In 2017 March, the transaction area of the industrial estate of Chongqing was 11.6 million square meters with 329 RMB per square meter compared to 2.1 million square that in Shenzhen with a price of 6005 RMB per square meter. Governments in less developed cities continue to rapidly approve more industrial estates that attract more pollution intensive enterprises simultaneously.

(2) With the increasing intensity of environmental regulation, pollution-intensive enterprises would passively increase their technology in the city centre. In the early stages of environmental regulation improvements, enterprises will be affected by the emission charges (Lin Q 2017). Pollution control and technology improvement are costly. It will cause an increase in production costs. Enterprises that can relocate will transfer to suburban areas. However, enterprises that cannot relocate have to suffer a “squeeze effect”. The squeeze effect is that some enterprises will be eliminated from the competition with more severe environmental regulation. To survive, enterprises have to from a passive reaction to response. Improving the production technology or improving pollution management will increase their ability.

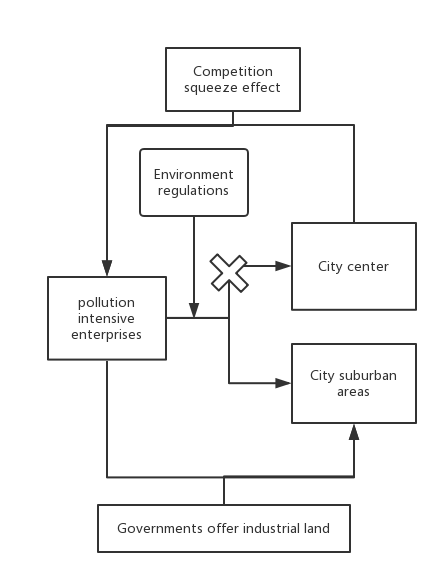
Both reasons above provide some facts to discuss why the investments behave differently in the city centre and city-suburban areas. The main idea is shown below.

Figure 5 The formation of difference between the city centre and city-suburban areas

# VI. Conclusions

Using the system GMM method to control the endogeneity problem, this paper finds that the FDI to the city centre is not related to pollution. However, results indicate that the pollution haven hypothesis still exists in China regarding the pollution transfer from the city centre (developed areas) to city suburban areas (developing areas). In addition, not only foreign enterprises, domestic enterprises also show a willingness to transfer the pollution-intensive enterprises to suburban areas. Compared to FDI and investments from domestic enterprises, investments from Hong Kong, Macao and Taiwan in suburban areas are relatively more minor, contributing to the emission of sulfur dioxide in city suburban areas. Meanwhile, the results from the penalty variable show that environmental regulations are more effective in the city centre than in city suburban areas. This shows that governments are trying to weaken their environmental control to transfer pollution from the city centre to suburban areas.

This paper has limitations that only consider that one city's action is separated from other cities, but in reality, cities within the same provinces are linked closely. Investment in one city will be influenced by the amount invested in the other cities. Understanding the network and space connections impacts on cities could be an interesting point in the future.

# References

Alonso-Borrego, C., & Arellano, M. (1999). Symmetrically normalized instrumental-variable estimation using panel data. *Journal of Business & Economic Statistics*, *17*(1), 36-49.

Antweiler, W., Copeland, B. R., & Taylor, S. M. (2001). Agyeman, Julian, Environmental Justice and Sustainability, in Atkinson/Dietz/Neumayer (eds), Handbook of Sustainable Development, Cheltenham, UK/Northampton, MA, USA: Edward Elgar 2007, reprinted 2008,

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies*, *58*(2), 277-297.

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of econometrics*, *68*(1), 29-51.

Baumol, W. J., & Oates, W. E. (1988). *The theory of environmental policy*. Cambridge university press.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics*, *87*(1), 115-143.

Borensztein, E., De Gregorio, J., & Lee, J. W. (1998). How does foreign direct investment affect economic growth?. *Journal of international Economics*, *45*(1), 115-135.

Braconier, H., Norbäck, P. J., & Urban, D. (2005). Multinational enterprises and wage costs: Vertical FDI revisited. *Journal of International Economics*, *67*(2), 446-470.

Copeland, B. R., & Taylor, M. S. (2001). *International trade and the environment: a framework for analysis* (No. w8540). National bureau of economic research.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic literature*, *42*(1), 7-71.

Cheng, J., & Masser, I. (2003). Urban growth pattern modeling: a case study of Wuhan city, PR China. *Landscape and urban planning*, *62*(4), 199-217.

Dean, J. M., Lovely, M. E., & Wang, H. (2009). Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of development economics*, *90*(1), 1-13.

Drukker D M. Testing for serial correlation in linear panel-data models[J]. Stata Journal, 2003, 3(2): 168-177.

Erdogan, A. M. (2014). Foreign direct investment and environmental regulations: a survey. *Journal of Economic Surveys*, *28*(5), 943-955.

Eskeland, G. S., & Feyzioğlu, T. N. (1997). Is demand for polluting goods manageable? An econometric study of car ownership and use in Mexico. *Journal of Development Economics*, *53*(2), 423-445.

Eskeland, G. S., & Harrison, A. E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of development economics*, *70*(1), 1-23.

Ferrara, I., Missios, P., & Yildiz, H. M. (2015). Pollution havens, endogenous environmental policy, and foreign direct investment. *Southern Economic Journal*, *82*(1), 257-284.

Fisman, R., & Gatti, R. (2002). Decentralization and corruption: evidence across countries. *Journal of Public Economics*, *83*(3), 325-345.

Goel, R. K., & Nelson, M. A. (1998). Corruption and government size: A disaggregated analysis. *Public Choice*, *97*(1-2), 107-120.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The quarterly journal of economics*, *110*(2), 353-377.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: the case of industrial emission of sulfur dioxide (SO 2) in Chinese provinces. Ecological economics, 60(1), 228-245.

Hettige, H., Lucas, R. E., & Wheeler, D. (1992). The toxic intensity of industrial production: global patterns, trends, and trade policy. *The American Economic Review*, 478-481.

Letchumanan, R., & Kodama, F. (2000). Reconciling the conflict between thepollution-haven'hypothesis and an emerging trajectory of international technology transfer. *Research policy*, *29*(1), 59-79.

Liang, F. H. (2008). Does foreign direct investment harm the host country’s environment? Evidence from China..

Lin, Q. (2017). China’s Pollution-Intensive Industry Transfer Path and Driving Factors—An Empirical Study Based on Spatial Panel Model. *iBusiness*, *9*(01), 13.

Low, P., & Yeats, A. (1992). Do" dirty" industries migrate?. *World Bank Discussion Papers[WORLD BANK DISCUSSION PAPER.]. 1992.*

Jones, C., & Kammen, D. M. (2014). Spatial distribution of US household carbon footprints reveals suburbanization undermines greenhouse gas benefits of urban population density. *Environmental science & technology*, *48*(2), 895-902.

Jorgenson, A. K. (2007). Does foreign investment harm the air we breathe and the water we drink? A cross-national study of carbon dioxide emissions and organic water pollution in less-developed countries, 1975 to 2000. *Organization & Environment*, *20*(2), 137-156.

Mani, M., & Wheeler, D. (1998). In search of pollution havens? Dirty industry in the world economy, 1960 to 1995. *The Journal of Environment & Development*, *7*(3), 215-247.

Merican, Y. (2007). Foreign direct investment and pollution in five Asean nations. *International Journal of Economics & Management*, *1*(2), 245-261.

Pingfang, Z., Zhengyu, Z., & Guolin, J. (2011). Empirical Study of the Relationship between FDI and Environmental Regulation: An Intergovernmental Competition Perspective [J]. *Economic Research Journal*, *6*, 133-145.

Poi, B., & Wiggins, V. (2001). Testing for panel-level Heteroskedasticity and Autocorrelation. *StataCorp LP*.

Walter, I., & Ugelow, J. L. (1979). Environmental policies in developing countries. *Ambio*, 102-109.

Waldkirch, A., & Gopinath, M. (2008). Pollution control and foreign direct investment in Mexico: an industry-level analysis. *Environmental and Resource Economics*, *41*(3), 289-313.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of econometrics*, *126*(1), 25-51.

Yang, J., & Wang, Y. (2016). FDI and environmental pollution nexus in China.

# Appendix

**Table 5 Regression result of City Center (System GMM)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City center** | | | | |
|  | (1) | (2) | (3) | (4) |
|  | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
| Lagged ln(SO2) | -0.223\*\*\* | -0.167\*\*\* | -0.234\*\*\* | -0.213\*\*\* |
|  | (0.037) | (0.043) | (0.056) | (0.045) |
| ln(Investment\_Domestic) | 0.150 | 0.212 |  |  |
|  | (0.160) | (0.155) |  |  |
| ln(Investment\_HMT) | 0.008 |  | 0.079 |  |
|  | (0.062) |  | (0.066) |  |
| ln(FDI) | -0.051 |  |  | -0.017 |
|  | (0.054) |  |  | (0.059) |
| ln(Penalty) | -0.257\*\*\* | -0.187 | -0.375\*\*\* | -0.113 |
|  | (0.098) | (0.114) | (0.115) | (0.098) |
| ln(Gov scale) | 1.286\*\* | 0.887 | 1.755\*\*\* | 1.433\*\* |
|  | (0.518) | (0.639) | (0.579) | (0.655) |
| ln(Population) | -0.450\* | -0.197 | -0.191 | -0.045 |
|  | (0.246) | (0.337) | (0.349) | (0.330) |
| ln(Land) | 0.740\*\*\* | 0.728\*\*\* | 0.731\*\*\* | 0.763\*\*\* |
|  | (0.076) | (0.070) | (0.078) | (0.059) |
| ln(Labor in industrial enterprises) | 0.508\*\*\* | 0.615\*\*\* | 0.563\*\* | 0.571\*\* |
|  | (0.196) | (0.185) | (0.270) | (0.223) |
| ln(Industrial GRP ratio) | 0.122 | 0.111 | -0.054 | 0.104 |
|  | (0.134) | (0.145) | (0.143) | (0.141) |
| ln(Freight Delivery) | 0.042\*\* | 0.039\* | 0.055\*\*\* | 0.042\*\* |
|  | (0.018) | (0.021) | (0.021) | (0.020) |
| ln(Wage) | 0.265 | -0.066 | -0.148 | 0.253 |
|  | (0.265) | (0.301) | (0.246) | (0.282) |
| seaside | 1.903\*\*\* | 3.624\*\*\* | 2.100\*\* | 2.415\*\*\* |
|  | (0.458) | (0.999) | (0.870) | (0.732) |
| Sub-Provincial | -2.173\*\*\* | -1.717 | -4.099\*\*\* | -3.296\*\*\* |
|  | (0.768) | (1.076) | (0.995) | (1.205) |
| Constant | -0.019 | -7.706 | 4.735\*\* | -1.047 |
|  | (3.069) | (4.889) | (2.226) | (3.705) |
| Number of id | 223 | 223 | 223 | 223 |
| arm1 | -2.807 | -2.608 | -2.654 | -2.421 |
| artests | 2 | 2 | 2 | 2 |
| sargan | 61.02 | 57.04 | 48.85 | 56.79 |
| N | 780 | 780 | 780 | 780 |

**Table 6 Regression results of City Suburban Area (System GMM)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City Suburban Area** | | | | |
|  | (5) | (6) | (7) | (8) |
|  | Total Investment | Domestic | HMT | FDI |
|  | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
| Lagged ln(SO2) | 0.280\*\*\* | 0.356\* | 0.266\*\*\* | 0.327\*\*\* |
|  | (0.066) | (0.059) | (0.028) | (0.025) |
| ln(Investment\_Domestic) | 0.196 | 0.410\*\*\* |  |  |
|  | (0.142) | (0.111) |  |  |
| ln(Investment\_HMT) | -0.019 |  | 0.058\*\* |  |
|  | (0.036) |  | (0.024) |  |
| ln(FDI) | 0.114\*\*\* |  |  | 0.237\*\*\* |
|  | (0.0327) |  |  | (0.028) |
| ln(Penalty) | 0.011 | -0.078 | 0.012 | -0.034 |
|  | (0.054) | (0.052) | (0.044) | (0.043) |
| ln(Gov scale) | 0.544\*\* | 0.880\*\*\* | 0.740\*\*\* | -0.050 |
|  | (0.248) | (0.271) | (0.266) | (0.281) |
| ln(Population) | -0.489\*\* | -1.014\*\*\* | -0.682\*\*\* | -0.125 |
|  | (0.195) | (0.188) | (0.166) | (0.195) |
| ln(Land) | 0.234\*\*\* | 0.243\*\*\* | 0.190\*\*\* | 0.260\*\*\* |
|  | (0.034) | (0.044) | (0.052) | (0.057) |
| ln(Labor in industrial enterprises) | 0.0451 | -0.091 | 0.074 | 0.070 |
|  | (0.123) | (0.094) | (0.118) | (0.107) |
| ln(Industrial GRP ratio) | -15.40\*\*\* | -17.145\*\*\* | -19.489\*\*\* | -14.239\*\*\* |
|  | (2.668) | (3.325) | (2.822) | (3.071) |
| ln(Freight Delivery) | -0.002 | 0.007 | 0.021\* | 0.013 |
|  | (0.010) | (0.010) | (0.011) | (0.012) |
| ln(Wage) | -0.478\*\*\* | -0.733\*\*\* | -0.319\* | -0.469\*\*\* |
|  | (0.161) | (0.190) | (0.173) | (0.178) |
| seaside | 1.909\*\*\* | 1.596\*\*\* | 0.582\*\*\* | 0.764\*\*\* |
|  | (0.411) | (0.412) | (0.120) | (0.145) |
| SubProvincial | -1.590\*\* | -0.603 | -0.621 | -0.521 |
|  | (0.788) | (0.372) | (0.431) | (0.526) |
| Constant | 10.48\*\*\* | 5.265\* | 12.101\*\*\* | 7.339\*\*\* |
|  | (2.134) | (3.186) | (2.397) | (2.269) |
| Number of id | 223 | 223 | 223 | 223 |
| arm1 | -1.835 | -1.791 | -2.600 | -2.497 |
| arm2 | -1.191 | -1.250 | -1.473 | -0.919 |
| artests | 2 | 2 | 2 | 2 |
| sargan | 74.17 | 53.88 | 63.25 | 57.57 |

Table 6 (Cont.)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **City center** | | | | | | |
|  | | (5) | (6) | | (7) | (8) |
|  | | ln(SO2) | ln(SO2) | | ln(SO2) | ln(SO2) |
|  | |  |  | |  |  |
| N\_g | | 223 | 223 | | 223 | 223 |
| Standard errors in parentheses | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Table 7 Regression Results of City Center (POLS Model)**

| **City center** | | | | |
| --- | --- | --- | --- | --- |
|  | (9) | (10) | (11) | (12) |
| VARIABLES | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | -0.107\*\*\* | -0.106\*\*\* | -0.108\*\*\* | -0.108\*\*\* |
|  | (0.0340) | (0.0377) | (0.0384) | (0.0385) |
| ln(Investment\_Domestic) | 0.0276 | 0.00262 |  |  |
|  | -0.0438 | -0.0416 |  |  |
| ln(Investment\_HMT) | -0.0124 |  | -0.0199 |  |
|  | -0.016 |  | -0.0139 |  |
| ln(FDI) | -0.0196 |  |  | -0.023 |
|  | -0.017 |  |  | -0.0143 |
| ln(Gov scale) | 0.115 | 0.114 | 0.121 | 0.118 |
|  | -0.09 | -0.09 | -0.0895 | -0.0893 |
| ln(Penalty) | -0.0952\*\* | -0.0712 | -0.0950\*\* | -0.126\*\*\* |
|  | (0.0461) | (0.0447) | (0.0405) | (0.0428) |
| ln(population) | -0.163\* | -0.146 | -0.135 | -0.0946 |
|  | (0.0959) | (0.0958) | (0.0941) | (0.0938) |
| ln(Industrial GRP ratio) | 0.207 | 0.182 | 0.278\*\* | 0.290\*\* |
|  | (0.147) | (0.148) | (0.138) | (0.138) |
| ln(Land) | 0.564\*\*\* | 0.548\*\*\* | 0.557\*\*\* | 0.555\*\*\* |
|  | (0.0391) | (0.0390) | (0.0391) | (0.0391) |
| ln(Labor in industrial enterprises) | 0.443\*\*\* | 0.483\*\*\* | 0.488\*\*\* | 0.608\*\*\* |
|  | (0.130) | (0.125) | (0.122) | (0.119) |
| ln(Freight Delivery) | 0.128\*\*\* | 0.124\*\*\* | 0.137\*\*\* | 0.138\*\*\* |
|  | (0.0423) | (0.0426) | (0.0420) | (0.0421) |
| ln(Wage) | 0.000415 | 0.0224 | 0.0307 | 0.140 |
|  | (0.187) | (0.185) | (0.183) | (0.183) |
| Constant | -6.311\*\*\* | -6.179\*\*\* | -5.982\*\*\* | -7.565\*\*\* |
|  | (2.068) | (2.014) | (2.022) | (2.044) |
| Observations | 780 | 780 | 780 | 780 |
| R-squared | 0.619 | 0.614 | 0.615 | 0.613 |
| N | 780 | 780 | 780 | 780 |
| Standard errors in parentheses | | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Table 8 Regression Results of City Suburban areas (OLS Model)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City suburban areas** | | | | |
|  | (13) | (14) | (15) | (16) |
| VARIABLES | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | 0.646\*\*\* | 0.652\*\*\* | 0.648\*\*\* | 0.649\*\*\* |
|  | (0.0266) | (0.0264) | (0.0265) | (0.0264) |
| ln(Investment\_Domestic) | 0.124\* | 0.117\* |  |  |
|  | (0.0666) | (0.0664) |  |  |
| ln(Investment\_HMT) | 0.0626\*\*\* |  | 0.0414\*\* |  |
|  | (0.0223) |  | (0.0204) |  |
| ln(FDI) | -0.0630\*\*\* |  |  | -0.0308 |
|  | (0.0238) |  |  | (0.0218) |
| ln(Gov scale) | 0.144 | 0.138 | 0.167 | 0.225 |
|  | (0.143) | (0.142) | (0.139) | (0.140) |
| ln(Penalty) | 0.0704\*\* | 0.0580\* | 0.0696\*\* | 0.0790\*\*\* |
|  | (0.0327) | (0.0319) | (0.0271) | (0.0288) |
| ln(population) | -0.0888 | -0.0998\* | -0.0825 | -0.0821 |
|  | (0.0597) | (0.0594) | (0.0564) | (0.0562) |
| ln(Industrial GRP ratio) | -10.85\*\*\* | -10.62\*\*\* | -11.25\*\*\* | -11.45\*\*\* |
|  | (3.370) | (3.370) | (3.149) | (3.159) |
| ln(Land) | 0.165\*\*\* | 0.167\*\*\* | 0.166\*\*\* | 0.166\*\*\* |
|  | (0.0269) | (0.0269) | (0.0268) | (0.0268) |
| ln(Labor in industrial enterprises) | 0.276\*\*\* | 0.271\*\*\* | 0.295\*\*\* | 0.281\*\*\* |
|  | (0.0843) | (0.0832) | (0.0803) | (0.0789) |
| ln(Freight Delivery) | 0.0282 | 0.0341 | 0.0324 | 0.0310 |
|  | (0.0214) | (0.0211) | (0.0209) | (0.0210) |
| ln(Wage) | -0.0463 | -0.0852 | -0.0752 | -0.0570 |
|  | (0.117) | (0.115) | (0.115) | (0.116) |
| Constant | -1.881 | -1.415 | -1.471 | -1.596 |
|  | (1.506) | (1.484) | (1.429) | (1.433) |
| Observations | 780 | 780 | 780 | 780 |
| R-squared | 0.657 | 0.656 | 0.657 | 0.657 |
| N | 780 | 780 | 780 | 780 |
| Standard errors in parentheses | | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Table 9 Regression Results of City Center (Fixed Effect Model)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City center** | | | | |
|  | (17) | (18) | (19) | (20) |
| VARIABLES | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | -0.400\*\*\* | -0.409\*\*\* | -0.414\*\*\* | -0.412\*\*\* |
|  | (-0.0283) | (-0.0283) | (-0.0281) | (-0.0282) |
| ln(Investment\_Domestic) | 0.112 | 0.115 |  |  |
|  | (0.148) | (0.207) |  |  |
| ln(Investment\_HMT) | 0.0257 |  | 0.0296 |  |
|  | (0.0449) |  | (0.0445) |  |
| ln(FDI) | -0.0275 |  |  | -0.0142 |
|  | (0.0597) |  |  | (0.0622) |
| ln(Gov scale) | -0.555 | -0.559 | -0.545 | -0.534 |
|  | (0.406) | (0.419) | (0.425) | (0.421) |
| ln(Penalty) | -0.297\*\*\* | -0.295\*\* | -0.270\*\* | -0.259\*\* |
|  | (0.102) | (0.118) | (0.116) | (0.114) |
| ln(population) | -0.0742 | -0.0801 | -0.0202 | -0.0126 |
|  | (0.283) | (0.328) | (0.317) | (0.318) |
| ln(Industrial GRP ratio) | 0.898\*\*\* | 0.900\*\*\* | 0.898\*\*\* | 0.900\*\*\* |
|  | (0.0520) | (0.0849) | (0.0850) | (0.0851) |
| ln(Land) | -0.0227 | -0.0188 | 0.000401 | 0.0134 |
|  | (0.167) | (0.159) | (0.169) | (0.171) |
| ln(Labor in industrial enterprises) | -0.102 | -0.0993 | -0.0864 | -0.0614 |
|  | (0.198) | (0.227) | (0.219) | (0.213) |
| ln(Freight Delivery) | -0.0276 | -0.0293 | -0.0240 | -0.0235 |
|  | (0.0506) | (0.0440) | (0.0433) | (0.0433) |
| ln(Wage) | 0.446 | 0.463 | 0.486 | 0.513 |
|  | (0.350) | (0.396) | (0.371) | (0.368) |
| Constant | 1.812 | 1.650 | 2.175 | 2.138 |
|  | (4.739) | (4.782) | (4.754) | (4.711) |
| Hausman | FE | FE | FE | FE |
| Observations | 780 | 780 | 780 | 780 |
| R-squared | 0.432 | 0.431 | 0.431 | 0.431 |
| Number of id | 223 | 223 | 223 | 223 |
| N | 780 | 780 | 780 | 780 |
| Standard errors in parentheses | | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Table 10 Regression Results of City Suburban areas (Fixed Effect Model)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City suburban areas** | | | | |
|  | (21) | (22) | (23) | (24) |
| VARIABLES | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | 0.134\*\*\* | 0.158\*\*\* | 0.140\*\*\* | 0.174\*\*\* |
|  | (0.0319) | (0.0306) | (0.0289) | (0.0292) |
| ln(Investment\_Domestic) | 0.169 | 0.193 |  |  |
|  | (0.129) | (0.145) |  |  |
| ln(Investment\_HMT) | 0.0170 |  | 0.0617\*\*\* |  |
|  | (0.0314) |  | (0.0223) |  |
| ln(FDI) | 0.171\*\*\* |  |  | 0.247\*\*\* |
|  | (0.0506) |  |  | (0.0429) |
| ln(Gov scale) | 0.266\*\*\* | 0.273\*\*\* | 0.218\*\*\* | 0.253\*\*\* |
|  | (0.0426) | (0.0481) | (0.0486) | (0.0445) |
| ln(Penalty) | 0.931\*\*\* | 0.790\*\*\* | 1.115\*\*\* | 0.227 |
|  | (0.320) | (0.232) | (0.384) | (0.297) |
| ln(population) | -0.0433 | 0.186\*\*\* | 0.242\*\*\* | 0.112\* |
|  | (0.0621) | (0.0638) | (0.0504) | (0.0605) |
| ln(Industrial GRP ratio) | -0.0458 | -0.0122 | 0.131 | 0.0739 |
|  | (0.136) | (0.0995) | (0.135) | (0.119) |
| ln(Land) | -0.882\*\*\* | -0.782\*\*\* | -0.771\*\*\* | -0.336\*\* |
|  | (0.212) | (0.186) | (0.219) | (0.157) |
| ln(Labor in industrial enterprises) | -12.17\*\*\* | -16.34\*\*\* | -20.05\*\*\* | -17.48\*\*\* |
|  | (3.306) | (3.744) | (3.533) | (3.396) |
| ln(Freight Delivery) | -0.000930 | 0.00434 | 0.00919 | -0.000159 |
|  | (0.0101) | (0.0106) | (0.0133) | (0.0112) |
| ln(Wage) | -0.538\*\* | -0.547\*\* | -0.138 | -0.157 |
|  | (0.225) | (0.245) | (0.245) | (0.204) |
| Constant | -1.881\*\* | -1.415 | -1.471\* | -1.596\* |
|  | (0.894) | (0.910) | (0.857) | (0.868) |
| Hausman | FE | FE | FE | FE |
| Observations | 780 | 780 | 780 | 780 |
| R-squared | 0.4717 | 0.4624 | 0.4699 | 0.473 |
| Number of id | 223 | 223 | 223 | 223 |
| N | 780 | 780 | 780 | 780 |
| Standard errors in parentheses  \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | | | |

**Table 11 Regression Results of City Center (Difference GMM Model)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | (25) | (26) | (27) | (28) |
|  | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | -0.343\*\*\* | -0.466\*\*\* | -0.333\*\*\* | -0.489\*\*\* |
|  | (0.059) | (0.063) | (0.128) | (0.090) |
| ln(Investment\_Domestic) | -0.043 | 0.293 |  |  |
|  | (0.245) | (0.188) |  |  |
| ln(Investment\_HMT) | -0.045 |  | 0.209 |  |
|  | (0.085) |  | (0.166) |  |
| ln(FDI) | -0.050 |  |  | 0.052 |
|  | (0.084) |  |  | (0.036) |
| ln(Gov scale) | -0.077 | -0.462\*\*\* | -0.060 | -0.629\*\*\* |
|  | (0.205) | (0.154) | (0.262) | (0.148) |
| ln(Penalty) | -0.301\*\*\* | -0.360\*\*\* | -0.327\*\* | -0.221\*\*\* |
|  | (0.065) | (0.079) | (0.149) | (0.082) |
| ln(population) | 0.303 | 1.475\*\*\* | 0.459 | 1.506\* |
|  | (0.672) | (0.553) | (1.240) | (0.773) |
| ln(Industrial GRP ratio) | 0.262 | -0.062 | 0.113 | -0.423 |
|  | (0.277) | (0.241) | (0.476) | (0.326) |
| ln(Land) | 0.909\*\*\* | 0.901\*\*\* | 1.097\*\*\* | 0.850\*\*\* |
|  | (0.084) | (0.081) | (0.121) | (0.117) |
| ln(Labor in industrial enterprises) | 0.926\*\*\* | 0.825\*\*\* | 1.479\*\*\* | 0.598 |
|  | (0.315) | (0.283) | (0.559) | (0.462) |
| ln(Freight Delivery) | -0.106 | 0.095\*\* | 0.022 | -0.034 |
|  | (0.076) | (0.043) | (0.134) | (0.048) |
| ln(Wage) | 0.370 | 1.156\*\*\* | -0.618 | -0.323 |
|  | (0.439) | (0.430) | (1.119) | (0.519) |
| Constant | -1.512 | -18.377\*\*\* | -0.480 | 1.929 |
|  | (5.337) | (6.737) | (11.058) | (7.146) |
| Number of id | 223 | 223 | 223 | 223 |
| arm1 | -2.738 | -2.192 | -2.175 | -2.005 |
| arm2 | -0.901 | -2.146 | 0.0201 | -1.084 |
| artests | 2 | 2 | 2 | 2 |
| sargan | 42.38 | 33.56 | 17.58 | 26.36 |
| N | 780 | 780 | 780 | 780 |
| N\_g | 223 | 223 | 223 | 223 |
| Standard errors in parentheses | | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Table 10 Regression Results of City Suburban areas (Difference GMM Model)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City Suburban Areas** | | | | |
|  | (29) | (30) | (31) | (32) |
|  | ln(SO2) | ln(SO2) | ln(SO2) | ln(SO2) |
|  |  |  |  |  |
| Lagged ln(SO2) | 0.281\*\*\* | 0.353\* | 0.274\*\*\* | 0.328\*\*\* |
|  | (0.066) | (0.129) | (0.084) | (0.095) |
| ln(Investment\_Domestic) | 0.361\*\*\* | 0.022 |  |  |
|  | (0.140) | (0.143) |  |  |
| ln(Investment\_HMT) | -0.107\*\*\* |  | 0.041\*\*\* |  |
|  | (0.023) |  | (0.008) |  |
| ln(FDI) | -0.053 |  |  | 0.315\*\*\* |
|  | (0.035) |  |  | (0.085) |
| ln(Gov scale) | -0.030 | 0.072\* | 0.064 | -0.055 |
|  | (0.040) | (0.042) | (0.044) | (0.045) |
| ln(Penalty) | 0.280\*\*\* | 0.158\*\*\* | 0.247\*\*\* | 0.235\*\*\* |
|  | (0.011) | (0.032) | (0.024) | (0.016) |
| ln(population) | 1.091\*\*\* | 0.379 | 1.367\* | -0.130 |
|  | (0.345) | (0.578) | (0.804) | (0.924) |
| ln(Industrial GRP ratio) | -1.110 | 1.606 | -8.598\*\* | 8.478\*\* |
|  | (2.509) | (3.533) | (3.766) | (4.265) |
| ln(Land) | 0.022 | 0.020 | -0.017 | 0.082\*\*\* |
|  | (0.022) | (0.030) | (0.035) | (0.027) |
| ln(Labor in industrial enterprises) | -0.009 | -0.574\*\*\* | -0.171 | 0.027 |
|  | (0.161) | (0.076) | (0.159) | (0.170) |
| ln(Freight Delivery) | -0.025\* | 0.047\*\*\* | -0.043\*\*\* | -0.026 |
|  | (0.013) | (0.007) | (0.007) | (0.017) |
| ln(Wage) | -0.420\*\* | -0.882\*\*\* | -0.586\* | -0.639\*\*\* |
|  | (0.197) | (0.195) | (0.341) | (0.245) |
| Constant | 15.378\*\*\* | 29.638\*\*\* | 20.319\*\*\* | 26.907\*\*\* |
|  | (2.957) | (4.332) | (4.149) | (6.334) |
| Number of id | 223 | 223 | 223 | 223 |
| arm1 | 1.590 | 2.211 | 1.131 | 2.046 |
| arm2 | -1.430 | -1.388 | -0.896 | -1.262 |
| artests | 2 | 2 | 2 | 2 |
| sargan | 49.79 | 35.27 | 26.62 | 48.01 |
| N | 780 | 780 | 780 | 780 |
| N\_g | 223 | 223 | 223 | 223 |
| Standard errors in parentheses | | \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | |

**Data for key variables**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Pollution** | | **Domestic Investment** | | **Investment from Hong Kong, Macao, Taiwan** | | **FDI** | |
|  | **(million ton)** | | **(10,000 RMB)** | | **(10,000 RMB)** | | **(10,000 RMB)** | |
| City | so\_a | so\_b | domestic\_a | domestic\_b | HMT\_a | HMT\_b | fdi\_a | fdi\_b |
| Beijing | 22070 | NA | 103904167 | NA | 18669714 | NA | 51922388 | NA |
| Tianjin | 154605 | NA | 179518583 | NA | 31393841 | NA | 71508881 | NA |
| Shijiazhuang | 28393.0233 | 85258.9767 | 37177485 | 51277676 | 2183046 | 1118995 | 1614316 | 733227 |
| Tangshan | 58017.9759 | 156705.024 | 49233071 | 33420370 | 709763 | 1395938 | 1900165 | 6603846 |
| Qinhuangdao | 4732.85999 | 41956.14 | 5232716 | 3245587 | 2263188 | 2695 | 3264891 | 82561 |
| Handan | 31126.185 | 79066.815 | 11860354 | 31591311 | 193511 | 2243486 | 1300854 | 462011 |
| Xingtai | 14657.8496 | 61377.1504 | 3965117 | 20516170 | 555378 | 1089730 | 78361 | 824584 |
| Baoding | 4400.09526 | 45449.9047 | 19150179 | 19355450 | 185704 | 475083 | 1051691 | 984272 |
| Zhangjiakou | 8020.84083 | 53837.1592 | 6392124 | 5710194 | 3993 | 184457 | 269044 | 903510 |
| Chengde | 4088.01522 | 51304.9848 | 4586736 | 12188162 | 0 | 117463 | 21182 | 44467 |
| Cangzhou | 6491.87652 | 26220.1235 | 10362841 | 42031269 | 620271 | 1157102 | 2766622 | 953722 |
| Langfang | 5050.09643 | 33339.9036 | 3055311 | 28391171 | 878127 | 326896 | 2918609 | 1362889 |
| Hengshui | 3836.62281 | 26082.3772 | 4972068 | 11818535 | 304666 | 105642 | 104774 | 569857 |
| Taiyuan | 11871.8268 | 52784.1732 | 13490357 | 2180707 | 4197850 | 0 | 1576638 | 147150 |
| Datong | 13611.2054 | 82361.7946 | 9522524 | 781876 | 0 | 50084 | 180769 | 7004 |
| Yangquan | 11460.2609 | 66667.7391 | 2844806 | 2403871 | 39560 | 0 | 77930 | 23787 |
| Changzhi | 11597.6567 | 74897.3433 | 3682575 | 9939053 | 33567 | 33102 | 17504 | 576084 |
| Jincheng | 10766.3811 | 63610.6189 | 2322941 | 4382224 | 995561 | 264840 | 101679 | 662837 |
| Shuozhou | 5157.39349 | 59218.6065 | 3360314 | 4010768 | 80548 | 0 | 145013 | 27286 |
| Jinzhong | 15116.8583 | 76102.1417 | 1874422 | 8215601 | 125063 | 302208 | 144449 | 230388 |
| Yuncheng | 12765.0339 | 106761.966 | 1771503 | 11156459 | 0 | 120020 | 27784 | 161760 |
| Xinzhou | 9866.64067 | 69100.3593 | 905589 | 6067747 | 0 | 0 | 0 | 12666 |
| Linfen | 9590.56143 | 58833.4386 | 912331 | 11650123 | 19478 | 270154 | 30427 | 14217 |
| Lvliang | 8744.03558 | 89116.9644 | 411354 | 11569776 | 0 | 1063806 | 0 | 240283 |
| Hohhot | 17978.5607 | 49300.4393 | 5431125 | 7621899 | 332214 | 912263 | 67790 | 2310502 |
| Baotou | 77292.7874 | 98837.2126 | 23608566 | 7110311 | 331223 | 40905 | 697316 | 23757 |
| Wuhai | 80594 | NA | 9170707 | NA | 51145 | NA | 52062 | NA |
| Chifeng | 19052.7365 | 86256.2635 | 7579355 | 12640266 | 92808 | 70760 | 360175 | 13032 |
| Tongliao | 18327.0832 | 73438.9168 | 7556759 | 13996826 | 175146 | 151282 | 676126 | 177778 |
| Erdos | 57069.9918 | 142288.008 | 4966413 | 35660570 | 4104 | 371054 | 507440 | 1873452 |
| Hulunbuir | 15887.422 | 65516.578 | 2107058 | 10462388 | 3083 | 222482 | 62403 | 202533 |
| Bayannur | 13859.2979 | 46716.7021 | 2523738 | 5105957 | 364742 | 255308 | 105341 | 379158 |
| Ulanqab | 5716.77386 | 49841.2261 | 1177911 | 8651190 | 9626 | 21021 | 0 | 103319 |
| Shenyang | 18350.527 | 79488.473 | 37914708 | 27621231 | 3190362 | 23065957 | 0 | 23545492 |
| Dalian | 28029.1921 | 67766.8079 | 21129585 | 22868946 | 3517114 | 18412362 | 0 | 21582482 |
| Anshan | 34691.2611 | 79537.7389 | 9023385 | 13551195 | 138518 | 255601 | 0 | 893439 |
| Fushun | 11644.021 | 35039.979 | 7692253 | 449420 | 215963 | 231583 | 0 | 234591 |
| Benxi | 13145.8581 | 39408.1419 | 11344653 | 4288618 | 1975753 | 11334 | 0 | 272262 |
| Dandong | 7279.27512 | 25441.7249 | 775552 | 2892406 | 52855 | 122740 | 0 | 551704 |
| Jinzhou | 12965.893 | 29472.107 | 6513670 | 14162313 | 1088169 | 1007624 | 0 | 1519912 |
| Yingkou | 13411.4309 | 32640.5691 | 10979563 | 6967478 | 799830 | 274763 | 2090527 | 1119305 |
| Fuxin | 14487.5344 | 78854.4656 | 2938891 | 1512836 | 94187 | 86193 | 267932 | 36788 |
| Liaoyang | 15230.5808 | 28375.4192 | 4578689 | 6801360 | 1691678 | 273231 | 614740 | 33998 |
| Panjin | 14781.1271 | 35341.8729 | 12314270 | 11912002 | 166133 | 387942 | 533345 | 709200 |
| Tieling | 7046.75021 | 29692.2498 | 691381 | 3268667 | 268316 | 36239 | 54805 | 216423 |
| Chaoyang | 6327.05208 | 57123.9479 | 1762835 | 3801499 | 23701 | 101875 | 2060 | 61165 |
| Huludao | 17273.5056 | 36478.4944 | 4852610 | 2820751 | 10975 | 3738 | 68649 | 165274 |
| Changchun | 6038.56324 | 46330.4368 | 63758874 | 8994185 | 3529033 | 40690 | 9142266 | 498859 |
| Jilin | 5742.91865 | 57448.0813 | 17647548 | 11307783 | 793805 | 194737 | 460460 | 605590 |
| Siping | 7570.43494 | 26485.5651 | 7553626 | 13273035 | 236128 | 595404 | 30159 | 366236 |
| Liaoyuan | 2051.72076 | 17386.2792 | 8700310 | 5322728 | 271738 | 17887 | 213670 | 0 |
| Tonghua | 2523.38436 | 37677.6156 | 9791579 | 10440193 | 108731 | 254473 | 33595 | 822288 |
| Baishan | 424.717066 | 13698.2829 | 5918778 | 7239290 | 97053 | 322762 | 94950 | 400813 |
| Songyuan | 4543.04945 | 25571.9505 | 5825892 | 14658451 | 3267 | 48481 | 256726 | 30562 |
| Baicheng | 524.157729 | 15029.8423 | 1223329 | 4449671 | 25690 | 26715 | 686038 | 185075 |
| Harbin | 2793.8107 | 46552.1893 | 21531412 | 11812353 | 642252 | 69591 | 3650940 | 553534 |
| Qiqihar | 6609.81425 | 26251.1858 | 4800372 | 4099810 | 81011 | 243953 | 223674 | 945208 |
| Jixi | 2181.3189 | 15483.6811 | 1133343 | 1056066 | 67581 | 76813 | 0 | 39367 |
| Hegang | 1300.47324 | 12439.5268 | 1215993 | 601147 | 0 | 0 | 0 | 8272 |
| Shuangyashan | 789.214538 | 17296.7855 | 1411187 | 1009177 | 29333 | 65345 | 0 | 0 |
| Daqing | 3288.61191 | 30881.3881 | 22779631 | 4974334 | 67025 | 1122845 | 1303723 | 269913 |
| Yichun | 978.64688 | 16799.3531 | 632398 | 278864 | 0 | 0 | 43862 | 3270 |
| Jiamusi | 1304.1686 | 8703.8314 | 1853659 | 3635728 | 17624 | 0 | 363212 | 27419 |
| Qitaihe | 1276.22123 | 13003.7788 | 1304381 | 241714 | 0 | 0 | 2933 | 0 |
| Mudanjiang | 1816.3683 | 19729.6317 | 1125744 | 8172793 | 70630 | 62703 | 273355 | 209070 |
| Heihe | 648.990174 | 16839.0098 | 354259 | 902906 | 0 | 17508 | 4741 | 37168 |
| Suihua | 684.662186 | 8076.33781 | 598152 | 8584926 | 12754 | 68270 | 351109 | 0 |
| Shanghai | 12088.1109 | 92811.8891 | 119910038 | 3049166 | 45334787 | 276719 | 144565672 | 89858 |
| Nanjing | 101021 | NA | 74750100 | NA | 9707100 | NA | 44594100 | NA |
| Wuxi | 14584.3765 | 61507.6235 | 27334632 | 67544168 | 7498714 | 10832086 | 25423884 | 6865216 |
| Xuzhou | 18704.5342 | 83457.4658 | 46304688 | 64478012 | 4299218 | 2548482 | 2703755 | 1824945 |
| Changzhou | 7241.88545 | 27178.1145 | 65558309 | 8433291 | 12671669 | 5135731 | 20659049 | -1441649 |
| Suzhou | 16272.6167 | 133737.383 | 32665205 | 75602695 | 23037739 | 26750561 | 63166187 | 81270113 |
| Nantong | 9170.38535 | 45891.6146 | 24240999 | 66991401 | 4391752 | 11857748 | 15375441 | 12295959 |
| Lianyungang | 6629.62395 | 34949.3761 | 21882053 | 20526847 | 1408018 | 723282 | 9182819 | 608381 |
| Huai'an | 8151.86918 | 60388.1308 | 25837514 | 25109886 | 9564362 | 1831538 | 2549025 | 712675 |
| Yancheng | 3239.6817 | 38098.3183 | 22284986 | 40923914 | 1042170 | 2467430 | 12763157 | 3054543 |
| Yangzhou | 5456.25934 | 36958.7407 | 40078304 | 26184896 | 7355119 | 3553581 | 8748375 | 6021625 |
| Zhenjiang | 7642.62527 | 38686.3747 | 17546455 | 38300645 | 4330688 | 8316712 | 10867741 | 4675959 |
| Taizhou | 1889.43768 | 32280.5623 | 38485567 | 48544133 | 2780128 | 4098472 | 7855482 | 8867618 |
| Suqian | 2147.81032 | 19153.1897 | 10310389 | 24863811 | 1431668 | 810832 | 650524 | 565976 |
| Hangzhou | 9375.66408 | 54438.3359 | 73406639 | 16563955 | 14540526 | 1064253 | 17694554 | 886875 |
| Ningbo | 19708.2005 | 82271.7995 | 52343934 | 38885219 | 22824532 | 6254010 | 12701623 | 5685260 |
| Wenzhou | 2861.49351 | 34454.5065 | 16374140 | 29285411 | 414713 | 893833 | 907134 | 1567068 |
| Jiaxing | 12468.1517 | 55455.8483 | 11288111 | 40929684 | 1666060 | 7010120 | 4336740 | 10462370 |
| Huzhou | 7727.93843 | 32498.0616 | 13072341 | 20825826 | 1380473 | 4028602 | 1687084 | 3136682 |
| Shaoxing | 11837.8139 | 48142.1861 | 49557827 | 28227778 | 9242233 | 2746885 | 5339855 | 2349268 |
| Jinhua | 4171.7299 | 35370.2701 | 5738704 | 37753218 | 1045541 | 1316400 | 366532 | 988032 |
| Quzhou | 9493.75183 | 37298.2482 | 6447146 | 7917071 | 34996 | 132441 | 740984 | 356353 |
| Zhoushan | 2512.49108 | 9866.50892 | 12310443 | 2663923 | 112876 | 7550 | 348872 | 890012 |
| Taizhou | 4136.17409 | 27731.8259 | 12429854 | 22000034 | 465438 | 933769 | 908191 | 1785150 |
| Lishui | 2642.20598 | 21585.794 | 3659841 | 12855859 | 14732 | 367370 | 20624 | 125189 |
| Hefei | 11242.6204 | 29586.3796 | 44493428 | 27101937 | 5200454 | 5376500 | 10260938 | 1022688 |
| Wuhu | 6469.26869 | 31594.7313 | 24927808 | 23112853 | 2274160 | 334982 | 7072775 | 567495 |
| Bengbu | 7368.53138 | 8557.46862 | 12387967 | 11502041 | 1370374 | 363246 | 209964 | 134567 |
| Huainan | 20345.4536 | 40588.5464 | 6704563 | 2311578 | 613653 | 4599 | 64367 | 15111 |
| Maanshan | 12946.1382 | 35766.8618 | 11524243 | 11489131 | 435032 | 109617 | 887317 | 962164 |
| Huaibei | 21037.6938 | 24282.3062 | 12293321 | 5166259 | 90142 | 1761 | 249059 | 58153 |
| Tongling | 5261.91892 | 22551.0811 | 14313540 | 3532606 | 4338863 | 17065 | 487993 | 0 |
| Anqing | 3229.5463 | 11508.4537 | 6852970 | 19066564 | 66376 | 735098 | 362271 | 148371 |
| Huangshan | 505.101492 | 2465.89851 | 2284268 | 3287062 | 57772 | 15648 | 30379 | 4400 |
| Chuzhou | 8549.60595 | 9966.39405 | 6029528 | 16295530 | 1336791 | 186499 | 1029524 | 409667 |
| Fuyang | 9010.02634 | 7816.97366 | 5544285 | 13674017 | 246021 | 208664 | 39842 | 184094 |
| Suzhou | 9826.87899 | 16070.121 | 5657467 | 9803410 | 512108 | 93138 | 27288 | 139094 |
| Lu'an | 4033.74958 | 10256.2504 | 5584162 | 8394570 | 112837 | 57809 | 125683 | 1145924 |
| Bozhou | 6213.80322 | 6446.19678 | 4309422 | 5219180 | 4500 | 0 | 53198 | 7564 |
| Chizhou | 3716.90456 | 13628.0954 | 3689995 | 3392546 | 79274 | 23651 | 80777 | 138011 |
| Xuancheng | 5612.1471 | 13582.8529 | 2454699 | 14600184 | 3097 | 112979 | 30035 | 762798 |
| Fuzhou | 8614.23908 | 46755.7609 | 16530631 | 33265833 | 4605766 | 12131792 | 3839709 | 8076314 |
| Xiamen | 5990.37722 | 11037.6228 | 15698806 | 0 | 15130855 | 0 | 19457127 | 0 |
| Putian | 1844.92379 | 9237.07621 | 14880322 | 4242493 | 3905018 | 216665 | 2801315 | 88365 |
| Sanming | 6665.40231 | 30901.5977 | 6356867 | 24712589 | 172565 | 1008510 | 15403 | 474868 |
| Quanzhou | 18460.1421 | 76238.8579 | 9056026 | 52677329 | 8799277 | 26897956 | 7728586 | 8822059 |
| Zhangzhou | 6988.29582 | 28549.7042 | 4385744 | 24055264 | 4227382 | 8674680 | 609062 | 3417254 |
| Nanping | 1727.71798 | 18301.282 | 4999339 | 10654778 | 70112 | 450198 | 436653 | 611329 |
| Longyan | 6331.14839 | 21644.8516 | 7919878 | 8196958 | 477980 | 847686 | 671950 | 454637 |
| Ningde | 1497.85661 | 16180.1434 | 2838940 | 25636250 | 671199 | 214243 | 162740 | 237616 |
| Nanchang | 4950.72237 | 25448.2776 | 31195593 | 13175619 | 3277441 | 1104675 | 5441426 | 657249 |
| Jingdezhen | 2425.54947 | 27089.4505 | 4892521 | 5560457 | 30623 | 195415 | 129918 | 167232 |
| Pingxiang | 8138.27441 | 74978.7256 | 9941724 | 6002734 | 427914 | 55558 | 230364 | 115514 |
| Jiujiang | 14076.1416 | 65918.8584 | 10141166 | 32020515 | 1507044 | 834095 | 1958077 | 0 |
| Xinyu | 28607.7063 | 25419.2937 | 9716046 | 2097754 | 693754 | 2198200 | 2198200 | 0 |
| Yingtan | 3969.61995 | 17594.38 | 4967032 | 15648444 | 18451 | 31370 | 42527 | 209719 |
| Ganzhou | 10363.0893 | 47067.9107 | 8832822 | 15820112 | 1310419 | 1737651 | 2982247 | 0 |
| Ji’an | 6420.70011 | 31901.2999 | 3833170 | 21179430 | 91770 | 612540 | 2349400 | 0 |
| Yichun | 16019.6155 | 50573.3845 | 3122602 | 28932592 | 119077 | 2573537 | 62003 | 1539157 |
| Fuzhou | 5042.20889 | 14633.7911 | 5486700 | 9312022 | 221628 | 481671 | 76698 | 126966 |
| Shangrao | 7868.35003 | 27152.65 | 6042706 | 18113117 | 709639 | 3489603 | 49396 | 150517 |
| Shandong | 12232.0589 | 58094.9411 | 26597963 | 22091101 | 562443 | 669036 | 1521752 | 1965237 |
| Jinan | 10302.2892 | 53726.7108 | 61873676 | 62391228 | 4457463 | 4639808 | 17513365 | 17242759 |
| Qingdao | 39446.9217 | 118902.078 | 79298585 | 20115158 | 1896377 | 1010557 | 4052296 | 4982856 |
| Zibo | 4628.07712 | 54931.9229 | 19477387 | 12632414 | 770615 | 203517 | 842697 | 383972 |
| Zaozhuang | 6271.53716 | 41588.4628 | 41674285 | 81227290 | 3719951 | 83089 | 4270956 | 914943 |
| Dongying | 12525.7867 | 55005.2133 | 19125215 | 78597133 | 4259971 | 4509933 | 37950265 | 8533050 |
| Yantai | 21954.1366 | 84644.8634 | 22667878 | 94086662 | 701454 | 3875577 | 2032561 | 4211808 |
| Weifang | 17196.3811 | 65997.6189 | 27065203 | 25043272 | 480810 | 513694 | 999224 | 618447 |
| Jining | 4643.1964 | 38773.8036 | 10050874 | 49222509 | 62778 | 637644 | 877099 | 1148249 |
| Tai'an | 4268.32397 | 20394.676 | 24254683 | 25710766 | 820488 | 605871 | 7323315 | 10610494 |
| Weihai | 8910.80366 | 33217.1963 | 10060083 | 9715932 | 141203 | 83025 | 5025493 | 373064 |
| Rizhao | 64055 | NA | 16758912 | NA | 103415 | NA | 226143 | NA |
| Laiwu | 19880.9893 | 69095.0107 | 38309076 | 52132668 | 2019557 | 1595487 | 5788108 | 1549433 |
| Linyi | 8767.91991 | 61156.0801 | 21843134 | 71169646 | 406299 | 322766 | 1589936 | 2564152 |
| Dezhou | 13172.1334 | 57690.8666 | 9403602 | 78256076 | 64838 | 413908 | 631223 | 527411 |
| Liaocheng | 18025.7734 | 75883.2266 | 11819323 | 57919737 | 255799 | 477621 | 635841 | 777306 |
| Binzhou | 7163.30081 | 57417.6992 | 13154549 | 54487872 | 1741811 | 868424 | 820869 | 817675 |
| Zhengzhou | 15016.6187 | 91481.3813 | 24515775 | 77830996 | 28126224 | 364286 | 2490958 | 3205032 |
| Kaifeng | 1982.45062 | 39169.5494 | 7422231 | 18895077 | 182666 | 146976 | 442446 | 143688 |
| Luoyang | 20099.7481 | 98973.2519 | 21869391 | 43479697 | 249144 | 822526 | 647223 | 432321 |
| Pingdingshan | 15672.7345 | 97421.2655 | 7271923 | 16880134 | 391028 | 215211 | 243942 | 271059 |
| Anyang | 18182.0362 | 76112.9638 | 8234730 | 27186431 | 188610 | 246046 | 104310 | 106587 |
| Hebi | 8236.16758 | 29188.8324 | 7472593 | 11187052 | 174226 | 138227 | 175694 | 0 |
| Xinxiang | 9942.367 | 39077.633 | 10139813 | 27607286 | 579721 | 178245 | 1544678 | 845296 |
| Jiaozuo | 8918.28605 | 29962.714 | 8871142 | 41735919 | 217149 | 1432906 | 108796 | 442460 |
| Puyang | 1505.42059 | 19943.5794 | 6495362 | 26434684 | 6541 | 920527 | 64841 | 366400 |
| Xuchang | 4377.12379 | 30091.8762 | 6988391 | 46827218 | 54052 | 223883 | 290629 | 1374317 |
| Luohe | 1793.50101 | 9771.49899 | 12026835 | 11740369 | 2082940 | 189153 | 1623883 | 142069 |
| Sanmenxia | 8813.23019 | 61445.7698 | 4866086 | 26714176 | 106382 | 937747 | 1237401 | 0 |
| Nanyang | 7384.9462 | 39443.0538 | 7368179 | 35466094 | 348142 | 0 | 522476 | 0 |
| Shangqiu | 5495.14342 | 27706.8566 | 6453136 | 23343526 | 55651 | 0 | 144708 | 0 |
| Xinyang | 2093.60795 | 21864.3921 | 7800048 | 16882192 | 464136 | 145485 | 165991 | 36012 |
| Zhoukou | 2752.20074 | 16117.7993 | 2772832 | 36671273 | 59659 | 0 | 745991 | 0 |
| Zhumadian | 2892.17117 | 21892.8288 | 4846817 | 22309929 | 140991 | 0 | 769192 | 0 |
| Wuhan | 16894.1987 | 58140.8013 | 65361900 | 23001100 | 5482400 | 0 | 26041200 | 0 |
| Huangshi | 10676.6387 | 52371.3613 | 6310500 | 9816600 | 1710800 | 0 | 1775500 | 0 |
| Shiyan | 1740.18217 | 14245.8178 | 9626455 | 4628066 | 36372 | 0 | 3902604 | 0 |
| Yichang | 12106.3673 | 60664.6327 | 17828370 | 33346328 | 1063691 | 0 | 715861 | 0 |
| Xiangyang | 9091.65763 | 24525.3424 | 22214511 | 30668651 | 695968 | 0 | 3872521 | 0 |
| Ezhou | 38776 | NA | 12520959 | NA | 660618 | NA | 516511 | NA |
| Jingmen | 6500.28922 | 28101.7108 | 8239105 | 20960255 | 455332 | 225300 | 258225 | 757753 |
| Xiaogan | 1962.35629 | 32118.6437 | 2182705 | 22453568 | 83235 | 917338 | 647347 | 429807 |
| Jingzhou | 4254.6732 | 35489.3268 | 7247881 | 14937182 | 596156 | 124372 | 643803 | 80030 |
| Huanggang | 1786.63925 | 14959.3608 | 1125900 | 16223100 | 257700 | 464100 | 41900 | 416500 |
| Xianning | 4045.97381 | 18354.0262 | 4402600 | 11512100 | 234500 | 612400 | 499500 | 87500 |
| Suizhou | 762.347468 | 2014.65253 | 4663589 | 7924420 | 320613 | 334638 | 170634 | 21150 |
| Changsha | 3914.12431 | 12037.8757 | 42263857 | 49330205 | 2069159 | 6643290 | 1049354 | 4103358 |
| Zhuzhou | 7898.48081 | 28565.5192 | 14993941 | 16421500 | 229600 | 473700 | 553400 | 385400 |
| Xiangtan | 5597.32358 | 32440.6764 | 14903613 | 12931065 | 663308 | 140288 | 1820673 | 77547 |
| Hengyang | 13328.0142 | 59903.9858 | 6210004 | 12352631 | 305676 | 421401 | 1168290 | 51744 |
| Shaoyang | 4110.2633 | 11501.7367 | 4310400 | 14429100 | 241900 | 129300 | 151700 | 129200 |
| Yueyang | 8176.34649 | 34907.6535 | 16557798 | 30624414 | 378062 | 385570 | 741970 | 533578 |
| Changde | 5047.9802 | 28285.0198 | 11034201 | 12439523 | 676115 | 795193 | 285700 | 100843 |
| Zhangjiajie | 2049.4583 | 23602.5417 | 481892 | 738780 | 0 | 0 | 121 | 58096 |
| Yiyang | 7863.78436 | 36272.2156 | 9983289 | 9215816 | 624376 | 229080 | 206164 | 90767 |
| Chenzhou | 9246.3207 | 27090.6793 | 7593363 | 22306166 | 889182 | 1371448 | 79888 | 111892 |
| Yongzhou | 1804.90118 | 20498.0988 | 3409559 | 7057676 | 124877 | 514232 | 113362 | 74189 |
| Huaihua | 3118.38591 | 36442.6141 | 863300 | 7765420 | 0 | 49180 | 63800 | 326800 |
| Loudi | 16293.5621 | 71483.4379 | 5686535 | 10010741 | 428640 | 313092 | 192597 | 4794 |
| Guangzhou | 47846 | NA | 75370333 | NA | 30931622 | NA | 80540207 | NA |
| Shaoguan | 8732.8024 | 24366.1976 | 5207847 | 5219922 | 640746 | 607496 | 117611 | 424139 |
| Shenzhen | 4132 | NA | 141240674 | NA | 72528066 | NA | 41655704 | NA |
| Zhuhai | 21946 | NA | 20193180 | NA | 7349803 | NA | 12117250 | NA |
| Shantou | 2587.12469 | 19835.8753 | 24552536 | 6720 | 2505126 | 8457 | 2603661 | 11510 |
| Foshan | 67108 | NA | 134010120 | NA | 34322385 | NA | 27116980 | NA |
| Jiangmen | 7658.1691 | 37931.8309 | 11756356 | 8038869 | 9137848 | 5844876 | 2748976 | 2460661 |
| Zhanjiang | 6279.14826 | 23319.8517 | 6793213 | 9927914 | 4315973 | 866074 | 593281 | 227503 |
| Maoming | 5690.01012 | 26102.9899 | 15651325 | 6629684 | 63011 | 695994 | 257878 | 22615 |
| Zhaoqing | 3604.93663 | 27339.0634 | 14948074 | 10897926 | 6090753 | 2649659 | 4714844 | 1042438 |
| Huizhou | 4514.85215 | 24168.1478 | 15650958 | 11524434 | 13338395 | 7349930 | 21011857 | 1571718 |
| Meizhou | 3869.47143 | 23343.5286 | 2731214 | 2960950 | 395579 | 490140 | 379852 | 89884 |
| Shanwei | 1089.11318 | 11717.8868 | 2399636 | 4965969 | 1511660 | 1685146 | 115780 | 982635 |
| Heyuan | 1818.68676 | 9920.31324 | 4161056 | 5357694 | 1735306 | 1310471 | 1673522 | 192154 |
| Yangjiang | 5133.0714 | 18932.9286 | 10352226 | 4769388 | 1469240 | 963446 | 1790162 | 555980 |
| Qingyuan | 4971.47016 | 16353.5298 | 9056606 | 2074237 | 1586425 | 2837906 | 914352 | 331725 |
| Dongguan | 84940 | NA | 56332151 | NA | 41863635 | NA | 29248393 | NA |
| Zhongshan | 24430 | NA | 29253700 | NA | 13544146 | NA | 20654931 | NA |
| Chaozhou | 2592.44488 | 10275.5551 | 8474387 | 2117763 | 1576499 | 160236 | 500794 | 428333 |
| Jieyang | 2323.8058 | 20582.1942 | 20045117 | 20292261 | 1776189 | 3822336 | 864359 | 1230911 |
| Yunfti | 2670.5346 | 17946.4654 | 2056745 | 6263385 | 371116 | 1898079 | 65796 | 339764 |
| Nanning | 7924.17373 | 22753.8263 | 21588565 | 4492397 | 4476020 | 155026 | 1387673 | 270925 |
| Liuzhou | 10664.0629 | 31200.9371 | 27111481 | 6102485 | 668783 | 0 | 10635655 | 34102 |
| Guilin | 4271.78445 | 27932.2155 | 5012985 | 16849842 | 189973 | 134599 | 268041 | 1291669 |
| Wuzhou | 1822.58468 | 8994.41532 | 11276680 | 7943768 | 778290 | 555309 | 556755 | 187913 |
| Beihai | 3245.469 | 8938.531 | 12764573 | 1066286 | 3892326 | 137832 | 428882 | 158795 |
| Fangchenggang | 4910.39586 | 22944.6041 | 6653810 | 2024009 | 183781 | 269188 | 3848982 | 29228 |
| Qinzhou | 4642.6359 | 11324.3641 | 7565874 | 4412273 | 207820 | 167930 | 1195838 | 34939 |
| Guigang | 4968.27823 | 19038.7218 | 2672549 | 4538734 | 697627 | 202043 | 34762 | 413071 |
| Yulin | 3457.45287 | 6486.54713 | 1846363 | 10851877 | 78071 | 1061711 | 1636272 | 403537 |
| Baise | 7968.59026 | 48390.4097 | 2143241 | 10077237 | 154520 | 495714 | 2456 | 0 |
| Hezhou | 1224.05831 | 7968.94169 | 2631262 | 1091034 | 42486 | 413250 | 27035 | 38520 |
| Hechi | 6129.56696 | 40694.433 | 877004 | 2783638 | 0 | 51435 | 23709 | 64583 |
| Laibin | 5193.60065 | 54951.3993 | 2021439 | 2474748 | 12566 | 292423 | 250998 | 56505 |
| Chongzuo | 936.371651 | 6529.62835 | 894467 | 4103855 | 157192 | 8034 | 593512 | 790698 |
| Chongqing | 399855.056 | 26944.9439 | 149231660 | 13959712 | 17752834 | 193251 | 32588941 | 273721 |
| Chengdu | 4617.48333 | 32606.5167 | 44821488 | 25466631 | 17105548 | 742183 | 22516284 | 1707175 |
| Zigong | 3273.08542 | 14458.9146 | 11991549 | 4551868 | 0 | 16705 | 467720 | 7550 |
| Panzhihua | 27227.1319 | 54999.8681 | 12134143 | 3206135 | 7724 | 4389 | 106767 | 0 |
| Luzhou | 4624.39656 | 25451.6034 | 11532712 | 6178942 | 84407 | 50657 | 139382 | 50322 |
| Deyang | 3995.95357 | 14574.0464 | 8060686 | 20901898 | 81714 | 1613856 | 152227 | 802971 |
| Mianyang | 3006.17355 | 29019.8265 | 13912308 | 8837849 | 982263 | 79846 | 524493 | 58097 |
| Guangyuan | 2054.58 | 16752.42 | 3959286 | 3031929 | 0 | 27254 | 396792 | 16911 |
| Suining | 920.321829 | 5737.67817 | 4739629 | 6375770 | 247352 | 4738 | 263514 | 153449 |
| Neijiang | 5255.64033 | 65260.3597 | 4798200 | 11137800 | 132500 | 33700 | 198900 | 183800 |
| Leshan | 9887.79992 | 35514.2001 | 7344527 | 7857874 | 9976 | 261563 | 78873 | 106941 |
| Nanchong | 619.816172 | 6471.18383 | 9282116 | 11994171 | 144221 | 88726 | 150166 | 139808 |
| Meishan | 3772.72439 | 16386.2756 | 4265038 | 8689000 | 72248 | 4209 | 347490 | 337448 |
| Yibin | 7832.02061 | 76245.9794 | 8746599 | 10294440 | 162521 | 249843 | 0 | 106466 |
| Guang'an | 37164.6525 | 4201.34751 | 3749242 | 10377812 | 151208 | 84981 | 28506 | 25482 |
| Dazhou | 8422.20914 | 37344.7909 | 2974354 | 6757441 | 16512 | 132785 | 0 | 0 |
| Ya’an | 866.041366 | 4410.95863 | 1479500 | 3317200 | 63700 | 0 | 0 | 0 |
| Bazhong | 123.856379 | 1913.14362 | 1806891 | 3625812 | 15783 | 5504 | 11711 | 0 |
| Ziyang | 1038.56698 | 5551.43302 | 6086564 | 12259520 | 24032 | 0 | 289932 | 0 |
| Guiyang | 15740.427 | 41451.573 | 16515481 | 6729681 | 340931 | 0 | 685220 | 0 |
| Liupanshui | 0 | 136992 | 4227400 | 9839172 | 0 | 0 | 25500 | 61037 |
| Zunyi | 24546.2879 | 50374.7121 | 4363485 | 15813184 | 9050 | 0 | 30886 | 0 |
| Anshun | 4773.72899 | 28447.271 | 4018021 | 1211576 | 233397 | 0 | 3093 | 0 |
| Bijie | 0 | 123308 | 1594071 | 6444392 | 0 | 0 | 0 | 0 |
| Tongren | 1306.81105 | 23481.1889 | 1098597 | 4847422 | 4039 | 63037 | 0 | 0 |
| Kunming | 16654.9865 | 57362.0135 | 18329763 | 8802748 | 778746 | 0 | 1056153 | 0 |
| Qujing | 5162.05315 | 166250.947 | 5324493 | 9492684 | 68833 | 0 | 56320 | 0 |
| Yuxi | 8641.59326 | 23743.4067 | 8406090 | 6834362 | 113850 | 51808 | 184809 | 54645 |
| Baoshan | 1839.92047 | 12291.0795 | 1229175 | 2306155 | 0 | 34735 | 32275 | 31488 |
| Zhaotong | 1806.17971 | 23466.8203 | 1045900 | 2643628 | 54829 | 21048 | 0 | 0 |
| Lijiang | 741.129248 | 6006.87075 | 202895 | 1060591 | 0 | 2414 | 0 | 28751 |
| Pu'er | 885.082343 | 6832.91766 | 254098 | 1792281 | 0 | 59854 | 94819 | 5234 |
| Lincang | 2786.77414 | 23956.2259 | 449388 | 2133415 | 0 | 0 | 22324 | 14177 |
| Lasa | 0 | 0 | 412266 | 509320 | 0 | 0 | 34424 | 15142 |
| Xi'an | 11116.3079 | 27574.6921 | 38665455 | 1596254 | 2731249 | 2544 | 6038517 | 211702 |
| Tongchuan | 3373.24329 | 13517.7567 | 5051715 | 385926 | 0 | 0 | 214704 | 0 |
| Baoji | 7144.70953 | 24561.2905 | 11975236 | 12002469 | 553 | 771999 | 1192748 | 51280 |
| Xianyang | 7768.48974 | 44965.5103 | 13405027 | 16461283 | 442947 | 263299 | 139199 | 1664932 |
| Weinan | 22088.3934 | 96756.6066 | 2631313 | 16734172 | 0 | 24624 | 62697 | 336558 |
| Yan'an | 1559.32455 | 17754.6755 | 11325186 | 2118176 | 4710 | 3763 | 0 | 7355 |
| Hanzhong | 0 | 0 | 1861862 | 8563949 | 2798 | 136177 | 2566 | 71235 |
| Yulin | 30048.4769 | 144491.523 | 4798500 | 19472400 | 30300 | 0 | 23800 | 157000 |
| Ankang | 1657.10833 | 9616.89167 | 1780031 | 7185519 | 2293 | 2525 | 0 | 106778 |
| Shangluo | 2208.5499 | 17609.4501 | 1443500 | 6358600 | 0 | 131600 | 0 | 0 |
| Lanzhou | 9027.6542 | 52212.3458 | 15397000 | 5574200 | 60600 | 179400 | 516600 | 119800 |
| Jiayuguan | 59247 | NA | 8390965 | NA | 0 | 0 | 0 | 0 |
| Jinchang | 21046.334 | 80928.666 | 6970551 | 909935 | 0 | 0 | 0 | 0 |
| Baiyin | 17932.9045 | 73208.0955 | 5412437 | 883509 | 22346 | 5303 | 148524 | 0 |
| Tianshui | 391.950821 | 6323.04918 | 2616260 | 617248 | 0 | 0 | 85888 | 0 |
| Wuwei | 3216.86815 | 14284.1318 | 2655222 | 1263935 | 4591 | 0 | 0 | 0 |
| Zhangye | 2786.04544 | 22510.9546 | 1005910 | 2212921 | 26533 | 65781 | 0 | 0 |
| Pingliang | 3876.30745 | 23925.6925 | 326941 | 1467668 | 0 | 0 | 0 | 0 |
| Jiuquan | 3491.76062 | 21092.2394 | 927533 | 3648263 | 3636 | 29765 | 2133 | 78413 |
| Qingyang | 495.083458 | 5737.91654 | 1624748 | 2593723 | 0 | 0 | 0 | 0 |
| Dingxi | 854.008996 | 8592.991 | 555011 | 961250 | 0 | 0 | 0 | 5418 |
| Longnan | 338.177509 | 6470.82249 | 102680 | 1525668 | 0 | 0 | 0 | 0 |
| Xining | 10592.1348 | 47103.8652 | 7295935 | 6019542 | 142485 | 10127 | 441641 | 9132 |
| Haidong | 1870.54172 | 11480.4583 | 1563654 | 1277046 | 0 | 393490 | 0 | 0 |
| Yinchuan | 12746.9257 | 52136.0743 | 4813273 | 11301916 | 109819 | 1817696 | 495380 | 85135 |
| Shizuishan | 21239.9733 | 63410.0267 | 4803886 | 3137083 | 23520 | 6543 | 62186 | 58647 |
| Wuzhong | 13458.7609 | 32481.2391 | 1920906 | 3721136 | 158956 | 0 | 0 | 0 |
| Guyuan | 2949.69739 | 7376.30261 | 244363 | 281543 | 0 | 0 | 0 | 0 |
| Zhongwei | 3947.10286 | 21565.8971 | 2008428 | 2694636 | 0 | 3210 | 0 | 9852 |
| Urumqi | 7279.06585 | 51698.9341 | 20078432 | 34490 | 157817 | 0 | 356776 | 0 |
| Karamay | 25270 | NA | 10606397 | NA | 3809 | NA | 9853 | NA |
| Source: China City Statisitical Yearbook | | | | | | | | |
| 1) NA means the city has no suburban area when cities are quite developed; | | | | |  |  |  |  |
| 2) 15 Sub-Provincial Cities: Shenyang, Dalian, Changchun, Harbin, Nanjing, Hangzhou, Ningbo, Xiamen, Jinan, Qingdao, Wuhan, Guangzhou, Shenzhen, Chengdu and Xian; | | | | | | | | |
|
| 3) 14 Coastal Open Cities: Tianjin, Shanghai, Dalian, Qinhuangdao, Yantai, Wingdao, Lianyungangm Nantong, Ningbo, Wenzhou, Fuzhou, Zhangjiang, and Beihai. | | | | | | | | |
|

1. The sulfur dioxide data is only the emission volume from industrial enterprise. But the enterprises are response for over 90% of total emission of sulfur dioxide. [↑](#footnote-ref-1)
2. Prime minister Li discussed on 2007 March 12th, the GDP growth rate can be fabricated but the 1) power consumption 2) good delivery, and 3) amount of loan can represent the real GDP growth rate better. [↑](#footnote-ref-2)