UNIVERSITY OF NOTTINGHAM

Empirical Studies on Environment, Economic growth and FDI in China

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10/29/2019

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Introduction

This thesis contains three independent empirical chapters regarding environment, economic growth and FDI in China.

The first chapter is an empirical study on the relationship between economic development and environment in China during 2001-2012, which investigates environmental Kuznets curve using industrial pollution index. The augmented EKC model is estimated using a panel data of 30 provinces in China for the period from 2001 to 2012. The objective of this chapter is to answer the following questions: Does EKC exist in China? What is the turning point? How many regions have passed the turning point? This study evaluates China's current efforts on environmental improvement, investigates the environmental effect of growth through scale, composition, and technical mechanisms and also considers the impact of environmental regulation.

This study makes three contributions to existing EKC literature. First, it uses panel data set which can reveal the current relationship between development and environmental degradation in China. Second, it introduces three comprehensive pollution indices to measure industrial wastewater pollution, waste gas pollution and solid waste pollution, respectively. They are different from and improve on the previous EKC studies which have used a single environmental indicator to measure the emission or concentration of a specific pollutant. Third, an augmented EKC model is adopted in this paper. This model allows us to separately examine the impact of the three mechanisms of economic development on the environment, namely scale, composition and technique effects, which were aggregately measured by GDP per capita in previous literature. Additionally, this research takes a first step in incorporating education standards to measure public environmental awareness.

Empirical results show that EKC trajectory exists in the cases of industrial wastewater and air pollution with turning points in a range between RMB 20,024 - 21,298 for wastewater and RMB 23,584 - 26,517 for waste gas, respectively. However, the relationship between industrial solid wastes pollution and economic development adheres a U-shaped curve, and the stationary point is between RMB 23,646 and RMB 26,084 GDP per capita. Almost regions passed the turning points for all three pollution indices by the end of 2012. Thus, in near future, the industrial wastewater and air pollution will reduce, but solid pollution will increase along with economic growth.

The composition effect, measured by the shares of secondary- and tertiary industry in GDP, is confirmed as a pollution reducing factor for solid wastes pollution. The negative coefficient of secondary industry possibly implies the improvement in energy efficiency and success of pollution abatement actions. The evidence is found that technique effect significantly reduces industrial wastewater and air pollution but increases solid waste emission. Expenditure on industrial pollution abatement, urban population density and education are all driving forces for environmental degradation. FDI inflow has a significant negative impact on water pollution but positive on air and solid waste pollutions.

The second chapter empirically examines the effects of geographic, culture and economic distances on FDI location choice on sub-national level. How MNEs make investment decisions has been a dominate topic in the area of international business research over the past decades. The mainstream of research, focusing on country-specific factors, has influenced the flow, distribution, and entry mode of FDI across the world. As a result, it overlooks the effects of relational factors between the source and recipient regions of investment. Some recent studies investigated how distance between countries impacts the flow of economic activity across borders (Kogut and Singh, 1998; Slangen, Fortanier, and Tulder, 2007; Tsang and Yip, 2007). However, there are few studies on the influence of distance factors at a sub-national level.

A growing number of empirical studies implies that MNEs make equal considerations regarding sub-national locational advantages offered by multi-level local governments when they are selecting a proper site for investment (Nielsen, Asmussen, and Weatherall, 2017). Accurate and comprehensive attention paid to sub-national locational characters is particularly critical for MNEs who are going to join a large market. Prior empirical literature on sub-national location choices of FDI in China used aggregated FDI inflow data, which failed to reveal a difference in location choice among various source countries (Chen, 1996; Cheng Kwan, 2000; Sun Tong and Yu, 2002). However, some empirical studies found that location choice strategy differs among home countries and is changing over time (Pan, 1997). Therefore, we want to examine FDI location choice, considering the characteristics of both home and host regions. In addition, we focus on the distance and linkage between the home country and host destination.

Our study uses novel FDI data, which is sorted by both home country and recipient region and covers the period from 2000 to 2012. Besides the dependent variable, we also introduce distance as an independent variable, which is widely used in national-level studies but rarely in sub-national location choice studies. This study contributes to the literature in two distinct aspects. First, although recent studies found the distance between countries to be significant on economic activities across countries, they did not consider the influence of distance on sub-national level investment decisions. This study aims to fill this gap by estimating a gravity model with distance proxies between the FDI's home country and the host region in China. Second, differing from FDI location choice studies in China, this study estimates a gravity model with a novel dependent variable, FDI flow by home country and host region over time, to explore the effects of both home and host regions, rather than just a unilateral effect. The empirical results imply that a gravity model can explain FDI flow in China; FDI increases with market size on both sides of the investment but decreases with geographic distance, and FDI prefers to locate in a culturally close but economically dissimilar region. Additionally, economic standards in both host and home regions, the R&D level in the home country, and a bonded area in the host region are contributing factors to FDI flow.

The last chapter investigates how the intensity of environmental regulation impacts employment. In response to the continuous degradation of the environment, many national states around the world are making efforts towards pollution abatement through the tightening of environmental regulations. China, as a developing country, is in the initial stage of seeking a way to balance economic development with requirements to undertake the environmental issues.

Beginning in 2001, the central government began to place an emphasis on environmental protection and first introduced an environmental target, as opposed to economic development, as the main objective of the 10th Five-Year Plan. Regrettably, the objective of a 10% reduction of SO_2 emissions was not achieved by 2005. However, the central government did not abandon faith in environmental governance. The 11th and 12th Five-Year Plans increasingly emphasize environmental regulation.

There is a 30% objective in the 11th Five-Year Plan relating to green development, and the 12th Five-Year Plan encompasses China's first full-fledged green development plan containing both qualitative and quantitative objectives for a wide range of ecological and environmental targets.

However, alongside the betterment of China's environmental regulatory system are concerns about the negative impacts of environmental regulation. One such concern is that the intensity of environmental regulation will lead to a reduction in employment. This concern has prompted debate around the country's environmental policies, especially because there are 450 million rural workers who are expected to migrate to urban areas within the next two decades, which will generate challenges for the government in creating jobs and promoting rapid economic development (Liu et al., 2017).

Popular thinking is that environmental regulation will cause a reduction in labour demand in the directly regulated sectors. The economic perspective behind this claim is that higher standards for pollution abatement increase production costs, which then further raise prices and reduce demand for output, thus reducing employment. However, according to a neoclassical microeconomic analysis, Berman and Bui (2001) demonstrated that environmental regulation can also be a labour-enhancing factor. To comply with new environmental regulations, plants need to hire extra workers to install and maintain pollution treatment equipment or modify production processes to reduce pollution, which may lead to a rise or decline in labour demand than the previous production process. Consequently, the impact of the intensity of environmental regulation on the employment of regulated enterprises cannot be predicted by standard neoclassical microeconomic theory. Thus, it remains inconclusive and needs to be examined empirically.

In response to the doubts about how environmental regulations will impact employment in the regulated sectors in China, this study extends the existing empirical analyses by investigating the relationship between the intensity of environmental regulation and employment using industrial level data from China's industrial sector during the period 2001 to 2015, which covers three of China's Five-Year Plans (the 10th, 11th, and 12th). This paper is potentially the first empirical study on the effect of environmental regulation on employment in China using a longer time period from an industry-level data set. Benefited by this relatively long period covered by the data set, this study makes contributions to the existing literature on three points. First, it examines the continuous effect of environmental regulation on employment over a long period of time. Second, this study uses empirical regression for sub-samples of three different Five-Year Plan periods to investigate the differences in the impact of environmental regulation among the various periods. Third, this study also checks the heterogeneity of the relationships between environmental regulation and employment across enterprises with different ownership structures.

The empirical results lead to three conclusions. First, environmental regulations, especially water pollution control regulations, promoted employment in industrial enterprises between 2001 and 2015. In addition, water pollution regulations dominated the environmental regulation effect rather than gas pollution regulations. The effects of gas pollution regulations became apparent beginning in the 12th Five-Year Plan period. Second, the environmental regulation effect on industrial employment changed over time. It transferred from being a labour-enhancing factor in the 10th Five-Year Plan to being a labour-reducing factor in the 11th and 12th Five-Year Plan periods. Additionally, the impacts of the intensity of environmental regulation on employment in industrial enterprises were heterogeneous across different ownership structures. In general, this impact is positive in state-owned industrial enterprises, negative in privately owned enterprises, and insignificant in foreign-owned enterprises.

Chapter 1: Empirical study on the relationship between economic development and environment in China during 2001-2012: Investigating environmental Kuznets curve using industrial pollution index

1. Introduction

In the past three decades, China has experienced a rapid economic development associating an increasing of GDP at 7.9% per year (NBS, 2013). On the other hand, although China achieved significant economic advance, it has paid a considerable price of environmental degradation and natural resource depletion. From 2001 to 2013, wastewater emission grew by 3.5 times and industrial SO_2 emission increased by 1.3 times (NBS, 2001; 2013). Environmental degradation is estimated to cost around 8% to 12% of China's annual GDP (Economy, 2004).

It is certain that economic growth with environmental degradation is unable to be deemed as a success. First, environmental degradation involving water and air pollution directly jeopardises people's health. However, protecting people's health and improving life quality are important compositions of social welfare, which is expected to be enhanced through economic development. Second, environmental degradation restrains future productivity because over consumption of energy and natural resources destroys the prospects for sustainable development. For developing countries like China, economic development is still crucial, even as the most prior objective of development, which contributes to the elimination of poverty and improvement of people's life standard. Thus, achieving environmental amenity should not be associated with economic decline. It is urgent to find a proper and effective strategy for maintaining economic growth without environment degradation.

To examine the relationship between economic development and the environmental quality, Grossman and Krueger (1991) found that economic growth damages the environment at the initial stage but improves environmental quality after reaching a turning point (or inverted U-shaped). Does this indicate that the environmental degradation at the initial stage of development is temporary, or that a country like China can follow the grow first clean up later approach and expect that environmental degradation would be alleviated automatically along with economic development? The answer is absolute No. An extensive amount of literature has confirmed that there is nothing inherent or inevitable for environmental improvement (Grossman and Krueger, 1994; Shafik and Bandyopadhyay, 1992; Lopez, 1994; Stokey, 1998; Brock and Taylor, 2010). Therefore, it is unreasonable to expect that the environmental deterioration rate spontaneously passes the turning point of EKC and then gradually decreases without any environmental improving effects.

According to previous empirical studies, the shape of EKC is sensitive to the selection of data, implying that development strategy and policy making of a country profoundly impact on EKC trajectory. And the nexus between development and environment is different not only across regions but also over time in any particular area due to the dynamic economic growth, industrial structure and policy implication (Panayotou, 1993). Besides economic development and industrialisation in recent years, China made notable progress on environmental regulation.

The concept of environmental protection emerged in China in 1975, when the first Environmental Protection Ten-Year Plan for the period 1976-1985 was enacted. However, environmental protection in China was just a concept on paper and an inessential matter at that time in contrast to the priority issue of economic development. In 2000, the central government started to enhance environmental protection regulation and for the first time stipulated explicit emission standards for six pollutants in its 10th Five Years Plan for China's Environmental Protection. Afterwards, the 11th Five Years Plan, for the period 2006 to 2010, strictly stated the objectives of a 10% reduction in SO2 emission and Chemical Oxygen Demand (COD) by 2010. The 12th Five Years Plan expanded the targets to an 8% reduction of SO2 emission and COD and a 10% reduction of NO_X emission by 2015. The tightened environmental regulation potentially changed the relationship between economic growth and environmental degradation. Therefore, although there is considerable existing literature have examined the environmental effect of development for China (Shen, 2006; He, 2008; Song, Zheng and Tong, 2008; Gao, 2011; Liu, 2012), whether China's economic growth can enhance environmental quality is still uncertain. It depends on China's future development trajectory, the effectiveness of any applied environmental regulations, and technology upgrades. Thus, an empirical study with the updated data set is expected to reveal the economy effect on the environment, and it is valuable and helpful for China's policy making.

The previous EKC studies for China mainly used single pollutant to measure environmental degradation (Jalil and Mahmud, 2009; Du, Wei and Cai, 2012; Chen and Chen, 2015). However, a specific indicator is only a small fraction of environmental degradation, and it insignificantly captures environmental situation (Wang *et al.*, 2015). To improve this issue, Li, Yang and Sheng (2011) constructed a comprehensive environmental pollution index for thirty regions in China from 2003 to 2008. Unfortunately, they only ranked the pollution index to compare pollution level among these thirty regions but did not use this index to explore the relationship between economic development and the environment. Thus, this study adopts the structure of this pollution index developed by Li, Yang and Sheng (2012) to construct dependent variables for EKC model and considering the availability of data splits the comprehensive index to industrial wastewater, gas and solid pollution indices separately.

Most previous EKC literature for China was estimated on reduced model, and they used income level to measure three or two of scale, composition and technique effects. An advantage of reduced form model is that the environmental effect of development is directly estimated. However, this approach fails to reveal the reason why the estimated relationship exists (Bruyn, Bergh, and Opschoor, 1998). Hence existing literature with reduced model only reports a descriptive result but does not interpret the underlying factors of EKC. For policy makers, descriptive conclusions are not enough since they need to make policy decision with the knowledge that what mechanisms help to achieve pollution reduction. Therefore, an augmented model with various interpretations is more practical and useful for policy making.

The purpose of this study is to explore the relationship between environmental degradation and economic development in China based on the EKC model and to deduce environmental policy implications. This chapter aims to answer the following questions: Does EKC exist in China? What is the turning point? How many regions have passed the turning point? This study also evaluates China’s current efforts on environmental improvement. It investigates the environmental effect of growth through scale, composition, and technical mechanisms and also considers the impact of environmental regulation.

The augmented EKC model is estimated using a panel data of 30 provinces in China for the period from 2001 to 2012. The results from the fixed effect estimation confirm that EKC valids for industrial water and gas pollution in China. And the relationship between GDP per capita and industrial solid pollution adheres U-shape curve. Composition effect helps to reduce industrial pollution. Urban population density and education are pollution increasing factors. The environmental effects of technology process, inflow FDI, and environmental policy are inconsistent across three pollution indicators.

This study makes three contributions to existing EKC literature. First, it uses an undated panel data set which can reveal the relationship between development and environmental degradation in China. Second, it introduces three comprehensive pollution indices to measure industrial wastewater pollution, waste gas pollution and solid waste pollution, respectively. They are different from and improve on the previous EKC studies which have used a single indicator measuring the emission or concentration of a specific pollutant. Third, an augmented EKC model is adopted in this paper. This model allows us to separately examine the impact of the three mechanisms of economic development on the environment, namely scale, composition and technique effects, which were aggregately measured by GDP per capita in previous literature. Additionally, this research takes a first step in incorporating education standards to measure public environmental awareness.

The remainder of this paper is structured as follows. Next section reviews previous literature on EKC, including both theoretical and empirical studies. Section three provides the methodology used in this chapter including the construction of pollution index, description of data, and model specification. Section four reports the empirical results and the following section five is a critical discussion on the empirical results. The final section concludes.

2. Literature review

From the 1970s, the academic world began to pay attention on the relationship between economic development and the environment. Before that, there was a belief that growth in the economy would expand the consumption of natural resources at the same rate. In the early 1970s, the environmental economists of the Club of Rome raised the *Limits to Growth* view which states that the limits of raw materials, energy and natural resources will block future economic growth, and they predicted that immoderate economic development may cause an ecological crisis (Meadows, Goldsmith and Meadow, 1972). However, the following empirical studies found that the consumption rate of some natural resources began to decline in certain developed countries in the 1970s (Malenbaum, 1978). Auty (1985) then issued the *intensity-of-use hypothesis* which indicates the relationship between metal consumption and economic growth as an inverted-U shape.

Kuznets (1955) used the inverted-U curve to explain the relationship between income per capita and income inequality. Known as Kuznets Curve, it indicates that income inequality will increase as economic growth and then declines after a threshold level of income per capita. In the early 1990s, Kuznets Curve was applied in the environmental economics area to present the nexus between pollution and economic growth, with Panayoutou (1993) being the first to name it as the Environmental Kuznets Curves (EKC). Then numerous economists contributed to the prosperity of EKC literature through both theoretical and empirical aspects.

This section reviews some existing literature on the EKC. It narrates the emergence and development of EKC hypothesis in the 1990s firstly，then reviews empirical studies after 2000, finally presents some evidence of EKC in China. Reviewing these previous studies helps to identify the research gaps of existing literature and provides a guideline for research methodology.

2.1 Emergence and development of EKC in 1990s

In the 1990s, two significant studies laid the foundation for the prosperity of EKC research in the following period. The first one was conducted by Grossman and Krueger (1991), which explored the potential environmental effect of North American Free Trade Agreement (NAFTA) in Mexico. The empirical results demonstrated an inverted-U shape between environmental degradation and income. The other one was Shafik and Bandyopadhyay (1992) published in the 1992 World Development Report (International Bank for Reconstruction and Development, 1992). As a background study for the World Development Report, Shafik and Bandyopadhyay (1992) estimated the EKC model using ten pollution indicators and confirmed the existence of EKC. From then on, various studies followed aiming to find the theoretical explanation and empirical evidence for EKC.

Grossman and Krueger (1991) explained that the environmental effect of economic development could be divided into three mechanisms: scale effect, technique effect and composition effect. Scale effect refers to the process of economic activity expansion that accompanies with increasing natural resource input and pollution emission. In this way, scale effect increases energy and natural resource consumption and reduces environmental quality. Technique effect refers that as economic grows, R&D investment may increase and stimulate technology upgrading from dirty and polluted technology to clean and environmentally friendly technology. Thus, technique effect is beneficial to environmental quality. Composition effect is the environmental effect caused by the transformation of industry structure. At the early stages of economic development, industrial structure transits from agriculture to industry. This process of industrialisation will raise the pressure on resource depletion and produce more pollution. However, when industrial structure begins to upgrade from energy intensive industry to services and technology intensive industry, composition effect will change from negative to positive for environment. To explain EKC through the perspective of these three mechanisms, the scale effect and early negative composition effect dominate in the initial stages of economic development; as the economy expands, technique effect and positive composition effect will exceed scale effect. Hence, environmental quality degrades as the economy takes off then improves after a threshold level.

To examine the impact of economic growth on the environment, Grossman and Krueger (1991) used the data published by the World Health Organization (WHO) for a group of cities from various countries during the period 1977-1988. They estimated a quadratic function of purchasing power parity on three air quality indicators, including the concentrations of SO2, dark matter, and suspended particles. They also controlled the location characteristics using some dummy variables, for example whether the city is coastal or inland, and whether the measurement point is within 100 miles to desert. Their empirical results confirmed the existence of EKC, i.e. an inverted-U shaped relationship between economic growth and the pollution, and obtained the turning point of SO2 concentration and dark matter in the range between $4,000 and $5,000. One limitation in Grossman and Krueger (1991) is that they used concentration of air pollutants as environmental degradation indicator which may heavily be influenced by geographical location, atmospheric situation and dispersion compared with the indicators measured by emission volumes (Panayotou, 1993). Even Grossman and Krueger (1991) controlled several dummy variables to clarify the location characters, the estimated model failed to eliminate noisy influences embedded in concentration data.

Gale and Mendez (1998) re-examined Grossman and Krueger's study using same data set. Gale and Mendez doubted that it was not significant that Grossman and Krueger used one variable, income per capita, to capture both scale and technique effects. Thus, they introduced a new indicator; national GDP divided by the city's share of the national population to capture scale effect separately. The results were consistent with Grossman and Krueger’s findings which supported EKC hypothesis. However, when they adopted national GDP divided by the city’s share of the national population to control scale effect, the pollution changed along with income per capita continuously rather than following the inverted-U curve.

Shafik and Bandypoadhyay (1992) explored the environmental effects of GDP per capita for ten environmental degradation indicators including lack of clean water, lack of urban sanitation, ambient levels of suspended particulate matter, ambient sulfur oxides, carbon emission per capita, change in forest area, deforesting rate, river dissolved oxygen, river faecal coliforms, and average municipal waste. They estimated linear, quadratic and cubic function for each indicator. The results were different across indicators. Income increasing relieves the lack of clean water and lack of urban sanitation consistently. River quality negatively relates in a linear way to income per capita. And neither the forestation indicator has a significant relationship with income growth. However, the results of both air pollutants supported the EKC hypothesis with a turning point between $3,000 and $4,000 income per capita.

Following the studied of Grossman and Krueger (1991) and Shafik and Bandyopadyay (1992), Panayotou (1993) further demonstrated the existence of EKC through both theoretical and empirical perspectives and was the first to name the inverted-U relationship between economic growth and environmental degradation as EKC. Panayotou (1991) stated that development level was a function constituted by the transition in economic and industrial structure, demand for an enjoyable environment, technology progress and environmental regulation. Since the environmental effects of these factors are changing as development process, it is reasonable to hypothesise a non-linear nexus. Then Panayotou provided empirical evidence for EKC with estimating a quadratic function of GDP per capita for air pollutant emission including SO2, NOX, suspended particulate matter, and deforestation. Based on cross-section data in 1985, Panayotou confirmed the existence of EKC for all environmental degradation indicators with the turning point between \$800- &1,200 for deforestation rate and \$3,800- \$5,500 for air pollution emissions.

However, there were several embed limitations mainly due to the data limit. Firstly, net deforestation rate measured by the differences between reforestation and deforestation is not a reliable indicator of environmental degradation. Since the commercial value of forestation resource heavily depends on the age of the forest, it is not reasonable to make an assume that reforestation can compensate deforestation activities. On the other hand, deforestation rate is not reliable to present natural resource consumption, especially in a modern industrialised world. The turning point of deforestation rate occurs much earlier than air pollution emission because deforestation generated by agriculture expansion happens in very early stage of economy development. As industrialisation deepens, deforestation’s influence on environmental quality became more and more insignificant. The most serious shortcoming of Panayotou’s study is that the air pollutant emission data for developing regions was estimated from fuel consumption (Stern, Common and Barbier, 1996). Hence, the estimated emission data failed to capture various energy efficiencies and pollutant purification skills across countries.

Selden and Song (1994) investigated the influence of economic growth on air quality using cross-countries panel data reported by the Global Environment Monitoring System. They used pollutant emission data including suspended particulate matter, sulphur dioxide, oxides of nitrogen, and carbon monoxide. They estimated a quadratic function of real GDP per capita and firstly introduced population density as a site variable. Through pooled cross-sections, fixed effect, and random-effect estimators, Selden and Song (1994) confirmed the EKC hypothesis for all environmental degradation indicators. The aggregated emissions of NO_X and CO models had various turning points with different estimations. The turning point for suspended particulate matter and sulphur dioxide was over $8,000, which is higher than those in Grossman and Krueger (1991). This may be due to differences between concentration data and emission data. Air pollution concentration presents more urban air quality and directly relates to public health. Thus, people and governments may make more efforts on concentration reduction rather than emission abatement. Therefore, it is reasonable that air pollution concentration data has a lower turning point than emission data. Moreover, population destiny is confirmed to be negatively related to pollutants emission. Hence, Selden and Song (1994) further predicted that the turning point of a country with a large population is probably lower than a country with a small population.

Arrow et al. (1995) raised a theoretical debate on EKC. They queried the robustness of EKC studies and claimed economic growth was not the determinate solution for environmental degradation. They illuminated the limitations for EKC hypothesis application mainly through four points. Firstly, EKC was only confirmed for local and short-term pollutants like SO_2 but not global or long-term pollutants such as CO_2. Secondly, EKC concept does not include any variable presenting natural resource stock that is also an important indicator of environmental quality. Thirdly, a reduction of effluent possibly is a result of the economic system-wide transition. For instance, the industrialised countries may shift the pollution on to developing countries through importing or foreign direct investment (FDI). Fourthly, according to the experiences from advanced regions, institutional reform associated with adoption of strict environmental regulation was the primary measure to attain environmental improvement.

To respond the question issued by Arrow et al., Grossman and Krueger (1996) published a comment on their initial finding in 1992. They identified that the emergence of EKC was not inevitable or automatic. Besides composition effect and technique effect, they illuminated that institutional reform was another crucial factor contributing to emission reduction. When people achieve a particular living standard, they will desire a better environment and pay more attention to environmental quality (Pezzey 1990). Moreover, Selden and Song (1994) announced that high level of education and public environmental awareness were also causes of the eventual downturn of EKC. With a more profound awareness of the environment, people may be more willing to spend a share of their income on environmental clean-up activities, including purchasing environmentally friendly products, donating to environmental protection organisations, and so on (Dinda, 2004). In this way, public awareness of environmental protection stimulates producers to adopt cleaner technologies and explore green product options. Referring to institutional reform, public demand for environmental amenity drives a government to increase environmental expenditures and to apply stricter environmental regulations.

Moreover, International trade seems to play a crucial role in ECK. According to the scale effect of economic development, trade may damage the environment by increasing export volume; however, trade may benefit the environment by transferring advanced technology to developing countries, strengthening their technology effect, and stimulating industry composition changing to service and technology insensitive industry. Meanwhile, some economists argued that the environmental improvement in a mature economy was caused by migrating dirty industry to developing regions (Hettige, Lucas and Wheeler, 1992; Copeland and Taylor, 1994; Suri and Chapman, 1998). Under this assumption, FDI will be attracted by lax environmental regulations in the developing countries, and move energy and pollution-intensive industry to these developing countries (Hettige, Lucas and Wheeler, 1992). Developing countries, therefore, become pollution haven for developed areas, which is called the Pollution Haven Hypothesis (PHH) presently (Antweiler, Copeland and Taylor, 2001). As a result, FDI and international trade may lead developed countries into the improving process of EKC and entangle developing countries in environmental degradation.

The literature in the early phases mainly focused on local pollutants such as SO_2 and NO_X. Subsequent studies tend to be concerned about global air pollutant CO_2 emissions. For example, Roberts and Grimes (1997) conducted an empirical study on carbon intensity. They used the cross-country panel data from 1962 to 1991 and estimated EKC for each single year. The results suggested that the relationship between economic development and CO_2 emission transferred from linear in 1965 to strongly curvilinear in 1990. The quadratic term of GDP per capita became statistically significant from 1982. Then they classified countries as high, middle and low-income countries and plotted the trend of average carbon intensity for each group countries from1965 to 1990. Only high-income countries presented a significant improvement in CO_2 intensity. Hence, they diagnosed that the emergence of EKC for carbon dioxide emission intensity should be attributed to a few developed countries becoming more efficient from 1970, whereas the majority countries would not ever reach the hypothesised “turning point” since the efficiency of environmental regulation implementation in middle- and lower- income countries were usually disappointed. Roberts and Grimes (1997) was criticised by McNaughton and Lee (1998) regarding two limitations in model selection and empirical analysis. Firstly, the ordinary least squares (OLS) regression should be either standard quadratic form or natural log-transformed, but the model in Grimes and Robert (1997) was hybrid. Secondly, cross-section analyses for environment-development nexus were time dependent, and therefore, Grimes and Roberts could not obtain the descriptive conclusion from their OLS regression result. Also, Sun (1999) argued that the existing evidence for CO_2 EKC naturally reflected the relationship between energy consumption and economic development because the data sources of CO_2, used in previous studies (Roberts and Grimes, 1997; Unruh and Moomaw, 1998), were derived from energy consumption.

Due to the validity of data, most previous EKC studies in the 1990s used cross-country data under the assumption that all the countries adhere to the same EKC. However, the results of cross-country may only discover the present or historical relationship between environmental degradation and economic development but have little value on policy implementation. The sustainable development trajectory invariably depends on the policy-makers; therefore, there is no convincing evidence that all developing countries will or have to replicate the experiences of developed countries or follow the same EKC estimated basing on cross-country data (Unruh and Moomaw, 1998). Also, the turning pointed obtained from cross-country studies fails to reveal the actual turning point for an individual country (Bruyn, Bergh and Opschoor, 1998).

From the end of the 1990s, some economists tried to detect the EKC for an individual country or a specific group of countries. For example, List and Gallet (1999) estimated EKC for state-level data in the US from 1929-1994. They explored the economic growth per capita emission of sulphur dioxide and nitrogen oxide relationship specifically in the case of the US. The fixed effect estimator results confirmed the existence of EKC for NOx in 38 of the 47 states and SO_2 in 37 states. However, the turning point of the EKC for the NO_x was higher than previous studies, and that for the SO_2 was lower.

By the end of the 1990s, numerous economists have successfully built the foundation of EKC hypothesis. Although there is no certain explanation for the emergence of EKC, two points have been universally accepted: (1) environmental degradation – economic development nexus does not inevitably or inherently adhere EKC; (2) environmental improvement is a result of some specific factors which could be regulation implementation, technology upgrading, industrial structure transition or international trade freedom. Unfortunately, empirical evidence in the 1990s only revealed the descriptive relationship between income per capita and environmental degradation but not how each of the three potential mechanisms of economic development influences the environment. Also, EKC studies in the 1990s lacked focus on a particular country. The cross-country studies have no reference value for environmental policy formulation. These two defects have been addressed in the studies in the 2000s.

2.2 EKC study in 21st century

Different from the basic EKC model that only included income per capita and its squared term, research in the 2000s was widely applied for kinds of environmental degradation indicators e.g. carbon dioxide and aggregate environmental measurement and comprehensive environmental index.

Carbon dioxide is an important and popular environmental degradation indicator in resource economic area. Probably since global warming, to what greenhouse gas significantly contributes, is one of the most serious environmental issues. More and more EKC study made efforts on investigating how was CO_2 emission (or energy consumption) influenced by economic development in recent years.

For example, in the study on carbon dioxide emission in Sweden in 1870-1997, Lindmark (2002) divided the period into three sub-periods. From 1870 to World War

I, economic growth increased CO2 emission but at a decreasing rate. During the period of World War I to 1960s, CO2 emission increased extremely as economic development. In the last phase, the 1960s to 1977, economic development helped to reduce CO2 emission.

Lantz and Feng (2006) investigated the macroeconomic factors underlying CO_2 emissions in Canada. They utilised provincial level panel data from 1970 to 2000. And the findings suggested income level was unrelated to carbon dioxide. Additionally, they introduced two variables to capture population and technology respectively. They found a significant relationship between CO_2 emission and population/technology effects, implying the environmental impacts of population growth and technology will change after a threshold level.

Bilgili et al. (2016) examined the validity of the EKC hypothesis for CO_2 emissions with potential impact of renewable energy consumption on environmental degradation. They employed a panel data set of 17 OECD countries for the period from 1977 to 2010 and applied panel FMOLS and panel DOLS estimators. Their results supported EKC hypothesis and suggested renewable energy consumption has a negative effect on CO_2 emissions.

In summary, the CO_2 emission studies in recent years obtained various results due to different databases and statistic estimators. Some found a monotonous linear relationship between economic development and CO_2 emission (Zoundi 2017; López-Menéndez, et al., 2014; Begum, et al., 2015); some confirmed EKC hypothesis (Ahmed and Long, 2012; Tiwari, et al., 2013; López-Menéndez, et al., 2014; Tan, Lean and Khan, 2014; Shahbaz, et al., 2014; Heidari, Katircioğlu and Saeidpour, 2015; Ahmad et al., 2017; Sencer Atasoy, 2017); some obtain an inverted N-shape curve (Martinez-Zarzoso and Bengochea-Morancho, 2004; Onafowo-ra and Owoye, 2014; Ozokcu and Ozdemir, 2017); and some suggested income growth unrelated to CO_2 emission (Lantz and Feng, 2006; Azlina, Law and Mustapha, 2014). Table 3.1 provides a summary of some recent studies on CO2 emission.

Table 2.1 Summary of EKC literature focusing on CO_2 emission

Author	Year	Region	Data	Independent variables	Estimator	Findings
Martinez-Zarzoso and Bengochea-Morancho	2004	22 OECD countries	Panel data 1975-1998	GDP/capita	Pooled mean group	Inverted N-shape curve for the CO2-i relationship
Lantz and Feng	2006	Canada	5 region panel data 1970-2000	GDP/capita; population density; technology change	Pooled and fixed-effects	GDP/capita unrelated to CO2; Inverted-U relationship with population; U-shape with technology
Ahmed and Long	2012	Pakistan	Time series data 1971-2008	Economic growth; energy consumption, trade liberalization, population density	Auto Regressive Distributed Lag bounds testing	Support EKC; trade improve environment; population and energy consumption contribute to pollution
Tiwari et al.	2013	India	Time series data 1966-2011	GDP/capita; coal consumption/capita; trade openness	Auto Regressive Distributed Lag bounds testing	Find EKC in both short and long run; coal consumption and openness contribute to CO2 emission
Azlina, Law and Mustaph	2014	Malaysia	Time series data 1975-2011	GDP/capita; structural changes; renewable energy use/ energy consumption in transport section	Granger causality test	EKC is not valid; relationship between GDP and CO2 emission is unidirectional
López-Menéndez et al.	2014	27 countries of EU	Panel data 1996-2010	GDP/capita; renewable energy use	Fixed-effects; random-effects	Only four countries support EKC, 22 correspond to increasing patterns, 9 show a decreasing path and 3 lead to U-shaped curve; with renewable energy use as independent variables EKC exists

Tan Lean and Khan	2014	Singapore	Time series data 1975-2011	GDP/capita	Granger causality test	Support EKC and Singapore passed turning point about 2010-2011
Shahbaz et al.	2014	Tunisia	Time series data 1971-2010	GDP/capita; energy consumption/capita; trade openness	Auto Regressive Distributed Lag bounds testing; Innovative accounting approach; vector error correction model	Confirm EKC hypothesis by vector error correction model and innovative accounting approach
Onafowo-ra and Owoye	2014	Brazil; China; Egypt; Japan; Mexico; Nigeria; South Korea; South Africa	Panel data 1970-2010	GDP/capita; energy consumption/capita; trade openness; population intensity	Auto Regressive Distributed Lag bounds testing	Japan and South Korea confirm EKC hypothesis in long run; other countries follow an inverted N-shaped trajectory
Heidari Katircioğlu and Saeidpour	2015	Indonesia; Malaysia; Philippines; Singapore; Thailand	Panel data 1980-2008	GDP/capita	Panel smooth transition regression	Supports EKC with turning point at $4,686

Begum et al.	2015	Malaysia	Time series data 1970-2009	GDP/capita; population growth; energy consumption/capita	Dynamic ordinary least squared and Sasabuchi-Lind-Melham U test	EKC is not valid, CO2 emission linearly positively relates to GDP/capita and energy consumption/capita; population growth insignificantly relates to CO2 emission
Bilgili et al.	2016	17 OECD countries	Panel data 1977-2010	GDP/capita; renewable energy consumption	Panel FMOLS; panel DOLS	Support EKC; renewable energy consumption reduces CO_2 emission
Zoundi	2017	25 selected African counties	1980-2012	GDP/capita; renewable energy consumption/capita; primary energy consumption/capita; population growth	Panel cointegration	EKC is not valid, CO2 emission linearly positively relates to GDP/capita, renewable energy consumption has negative effect on CO_2 emission but this effect is overweighed by primary energy consumption in both short and long run
Ahmad et al.	2017	Croatia	1992-2011	GDP	Autoregressive Distributed Lag and VECM method	EKC is valid in Croatia in long run
Sencer Atasoy	2017	50 states in United State	1960-2010	GDP per capita; energy consumption per capita; population growth	Augmented Mean Group estimator (AMG); Correlated Effects Mean Group Estimator (CCEMG)	AMG estimator validates EKC hypothesis in 30 of 50 states with turning points between $1,292 and $48,597 per capita; CCEMG estimator validates EKC hypothesis in 10 of 50 states with turning points between $2,457 and $14,603 per capita

Ozokeu and Ozdemir	2017	26 OECD countries; 50 emerging countries	1980-2010	GDP per capita	Driscoll Kraaay Standard Errors technique	N-shape curve for the CO2-income relationship

Besides the EKC studies focusing on a single measurement of pollution as an environmental degradation indicator, some studies tried to utilise environmental index, such as the Ecological Footprint (EF) to measure comprehensive environmental quality (Caviglia-Harris, Chambers and Kahn, 2009; Usama, et al., 2014). EF was created by Rees (1992) and developed in Wackernagel and Rees (1996) to investigate the influence of human consumption on the environment. It captures the natural resource, namely biological productivity, and input for a consumption area including food, services, transportation, consumer goods and housing. Caviglia-Harris, Chambers and Kahn (2009) estimated the EKC for a panel EF database including 146 countries and covering 40 years from 1961 to 2000. The empirical results rejected the EKC hypothesis only when the energy components were removed from the EF. The EF/economic growth relationship showed an inverted-U shape with a turning point of about $652 at the 2000 price. This result implied that energy consumption is the main determinant for the EKC relationship.

Usama, et al., (2014) used the EF database of 93 countries from 1980 to 2008 to test the EKC hypothesis but obtained a different conclusion. They categorised the sample countries by income, and found substantial evidence for the EKC existence in upper middle- and high-income countries but not in the low and lower middle-income countries since low and lower-income regions were in the early stage of economic development. Therefore, they believed that the inverted-U relationship between EF and income only occurs in the country where economic growth can lead to clean technology development, increase energy efficiency and promotion of the use of green energy. Besides income level, Usama et al. (2014) further examined the effects of urbanisation, trade openness and financial development. For middle and high-income countries, urbanisation and trade openness cause an environmental damage however financial development alleviates environmental degradation.

Besides innovation of environmental indicator selection, some economists attempted to examine the environmental effect of other potential variables. For instance, Thompson (2012) introduced a variable representing water resource stock into EKC model for water pollution. Although the empirical results seem to be suspicious as there was a huge difference in calculated turning points between the model with income per capita only and the model including water abundance variable, this study indeed is so heuristic for future EKC research direction that natural resource stock is a potential factor underlying EKC.

Additionally, Merleveda, Verbeke and Clercq (2006) conducted an empirical study to address the environmental effect of the average firm size of a country. They utilised SO_2 concentration to capture environmental degradation, income per capita to present scale, technique and composition effects, and total employees divided by numbers of establishments to measure firm size. Their findings suggested that firm size significantly related to the environment but not in a monotonous way. Firstly, firm size may positively correlate to environmental degradation through composition-channel. Some literature demonstrated that most of the industrial pollution was produced by large plants (Dasgupta et al. 2002). Thus, it is plausible that large firm size country discharges more effluents than small firm size. Secondly, cost/benefit ratio of environmental regulation in large firm size country is greater. Small size firms are harder to be managed and regulated than large, whereas large firms' marginal transition cost on administration is lower. Hence, a country whose economy is consisted by small numbers of large enterprises can achieve certain environmental standards much more easily. To conclude, large firm countries initially suffer a higher level of environmental degradation but can more rapidly achieve environmental improvement at the advanced stage of economic development thanks to the higher efficiency of environmental regulation implementation.

To sum up, after 2000, numerous economists made considerable efforts looking for evidence supporting EKC hypothesis. EKC was estimated on various kinds of databases with different variables. To a certain extent, the EKC studies in this period indeed filled up some shortcomings of the studies in the 1990s. Firstly, some updated environmental indicators were applied to ECK model such as carbon dioxide and Ecological Footprint, which spread the scope of application of EKC hypothesis. Secondly, more and more studies utilised data from a single country or a specific group of countries rather than broad cross-countries. These supplementary studies offered more customised and practical suggestions on environmental regulation making than cross-country studies. Thirdly, some new explanatory variables such as population, openness, financial development, resource stock, and firm size, have been incorporated into EKC model. The accession of these new independent variables further revealed the underlying mechanisms of ECK trajectory. However, there is one aspect need to be improved for future research, which is to split income level into scale, composition and technique effects. In the previous studies, income level captured the collective impact from three mechanisms (scale, composition and technique). Thus, existing literature fails to demonstrate separate role these three mechanisms play in EKC.

2.3 Evidence from China

As China became the second largest economy in the world, its worsened environmental problems in recent years have attracted a lot of attentions from public and academics. Prolific EKC studies on China emerged in the past decade. These empirical studied can be sorted by the type of database, namely provincial panel data, municipal panel data and time series data.

Most EKC studies on China have employed provincial level panel data (Shen, 2006; He, 2008; Song, Zheng and Tong, 2008; Gao, 2011; Liu, 2012). He (2008) tested the EKC hypothesis using a data of SO_2 emission in China from 1992 to 2002 and found a turning point at around 10,000 yuan. He (2008) also illustrated a negative impact of openness and technological process on SO_2 emission. Wang et al. (2016) investigated the impacts of economic growth and urbanization on SO_2 emission with provincial level panel data set for the period from 1990 to 2012. Basing on semi-parametric panel fixed effects regression, they found strong EKC evidence for EKC relationship between economic growth and SO_2 emission, but little evidence for urbanization.

Additionally, Song, Zheng and Tong (2008) investigated the effect of economic development on the emissions of wastewater, waste gas and solid wastes using a cointegration approach. They confirmed the EKC hypothesis indicating that some highly developed regions in China had passed the turning point.

Regarding the relationship between CO_2 emission and economic development in China, EKC has been confirmed by some existing studies. For example, Chen and Chen (2015) explored the relationship between CO_2 emissions and economic development among 31 regions from 1985 to 2010 using a nonparametric method. The inflection point is at around RMB 49,813 and only three regions Beijing, Shanghai and Tianjin have passed the threshold. Yin, Zheng and Chen (2015) also found evidence to support the existence of EKC for CO_2. Their findings suggested that everything else equal, five-year lagged R&D expenditure had significant and negative effect on CO2 emission, indicating that long term positive technique effect of economic growth. Furthermore, they found that the effect of environmental regulation on CO2 emission was not linear. Yin, Zheng and Chen (2015) explained that due to economic and institutional inequalities among east, west and central China, the implication of strict environmental regulation in east China would force pollution intensive industries to relocate their productions to the west and central China. Since the regulatory enforcement in western and centre was relatively lax, the relocated industries would produce and discharge more pollution. Therefore, the national overall pollution increased. Along with regional integration, the differences in environmental regulation implementation would decrease. Then, the adoption of stricter policy would lead to the CO_2 reduction. Recently, Wang et al. (2017) used provincial level panel data for the period 2000-2013 to investigated the impacts of economic growth and urbanization on industrial CO_2 emissions in electricity, heat production and manufacturing sectors respectively. The empirical results from semi-parametric panel fixed effects regression suggested a validity of EKC hypothesis for economic growth in electricity and heat production sectors, and for urbanization in manufacturing sector.

Besides, Yang, Lan and Zheng (2013) used a dynamic objective evaluation method to construct pollution emission index based on the overall differences-vertical and horizontal scatter degree, for the 28 provinces in China from 1995 to 2010. The fixed effect regression results suggested that at the national level, economic development would cause more pollution emission whereas energy efficiency, energy prices and trade were negatively related to pollution discharge, *ceteris paribus*. These findings suggested improving energy efficiency and building market mechanism for the energy resource price were efficient methods for pollution reduction. Interestingly, for east and central China, the correlation coefficient of economic growth variable and pollution index was negative, which means that pollution emission was decreasing with economic growth in relatively high-income regions.

Besides provincial level studies, a few literature employed municipal panel data. Shaw et al. (2010) investigated the impact of economic growth on air quality in 99 Chinese cities from 1992 to 2004. They utilised the emissions of sulfur dioxide and nitrogen oxides to capture air quality and further introduced some additional explanatory variables that include population density, the ratio of the secondary industry of total GDP, policy measurement, and regional dummies. According to their results, EKC only emerged in the case of SO_2 emission with a peak point at around RMB 17,923 in 2000 price. Population density and policy measurement were confirmed to have significant positive and negative impact on air pollution, respectively. Secondary industry to GDP does not have significant impact on the environmental indicators, indicating ambiguous composition effect of growth. Shaw et al. (2010) claimed that they successfully controlled the endogeneity of economic growth using the instrumental variables approach. However, their selection of instrumental variables was inappropriate. The instrumental variable is supposed to be directly related to economic growth but having no influence on the dependent variable of environmental indicators, otherwise, it would lead some statistical bias. Shaw et al. (2010) adopted FDI, fixed capital investment and so on as instrumental variables, but these instruments might be potential determinants of air pollution according to some PHH theory.

Cole, Elliott and Zhang (2011) estimated the EKC hypothesis using six industrial pollutant indicators based on a dataset of 112 cities between 2001 and 2004. Different from Shaw et al. (2010), Cole, Elliott and Zhang found a monotonous increasing relationship between per capita GDP and air pollution. Only industrial water pollution adhered EKC trajectory with a turning point between RMB 32,577 and RMB 35,098 for wastewater discharge and between RMB 17,233 and RMB 23,866 for petroleum-like matter. Although Cole, Elliott and Zhang (2011) contributed to municipal-level panel data studies on EKC for China with relatively significant numbers of cities, the examined period was only four years. Such short-term data was insufficient to reveal historical pattern of China's EKC.

Furthermore, there were considerable numbers of studies focused on a particular region or city using time-series data (Liu et al., 2007; Diao et al., 2009; Li and Fang, 2011; Shao et al., 2011; Shi Zhao and Zhang, 2011; Wang et al., 2012; Song, Zhang and Wang, 2013; Wang et al. 2015). For instance, Song, Zhang and Wang (2013) estimated EKC model for each provincial region in China and attempted to obtain a turning point for each region. The results implied that EKC trend varied across regions. EKC exist in the majority regions except Liaoning, Anhui, Fujian, Hainan and Qinghai. By the end of 2012, only five regions, Shanghai, Tibet, Guizhou, Jilin and Beijing, have passed their turning points separately; the other regions needed another seven years to reach the top of EKC. Another example is Wang et al. (2015), which explored the nexus between environmental quality and income level in Gansu province during 1980-2012. Using Bayesian time series model, they verified the EKC hypothesis, and the results implied that technical effect and environmental policy make considerable contribution to improving environmental quality compared with scale effect and composition effect. Table 3.2 is a summary of the EKC studies on a particular region in China.

Table3.2: Summary of EKC literature focussing on Chinese regions

Authors	Year	Region	Data	Environmental indicators	Findings
Liu et al.	2007	Shenzhen	1989-2003	Air and water	Production-induced pollutants fit EKC; Consumption-induced pollutants do not fit EKC
Shi, Zhao and Zhang	2011	Tangshan	2000-2009	Industrial water, gas, solid and dark matter emission; industrial solid produce	Support EKC in case of industrial dark matter emission; industrial water and solid waste would continue to rise
Wang and Lu	2011	Zhejiang (Rural)	2001-2010	Water (NSP)	No significant relationship
Li and Fang	2011	Suzhou	2002-2009	Water disposal	Inverted-N shape
Han, Zhang and Liu	2011	Shandong	1981-2008	SO_2; soot waste water; waste solid	Turning point at RMB 5,536 for SO_2; Turning point at RMB 1,998 for soot; Waste water and solid not fit to inverted-U
Wang et al.	2011	Beijing	1997-2010	CO_2 emissions	Does not fit EKC; continuing to rise
Shao et al.	2011	Shanghai	1994-2009	CO_2 emission	Inverted-N shape
Shu et al.	2012	Guangdong	1990-2009	Waste water	Shenzhen, Heyuan and Huizhou: no significant relationship
Song, Zhang and Wang	2013	31 provincial level regions	1993-2010	Industrial waste gas emission	Shanghai, Tibet, Guizhou, Jilin and Beijing have overstepped their inflection points; Liaoning, Anhui, Fujian, Hainan and Qinghai do not have inflection points

Wang et al.	2015	Gansu	1989-2010	Ecological environment quality	Verified EKC; technique effect and regulation improve environment
Zhang, Yi and Li	2015	Beijing	1980-2003	Carbon emission	Inverted-U shaped relationship
Jiang et al.	2019	Guangdong	1995-2004	CO_2 emission	CO_2 – economic growth relationship varied by time

In conclusion, there is no agreed EKC trajectory for all the countries and nothing inherent or invisible existing in the economic development-environment nexus. The most EKC studies in the early period explored the effect of growth based on cross-country data set. However, the environment and economy nexus heavily depends on the national development strategy and environmental policy. In the other word, the individual characters of each country are critical in shaping the environment and economy relationship. Therefore, the findings from cross-country analysis cannot be directly applied to China, and research designed particularly for China is needed to reveal its growth-environment nexus using up-to-date data.

The existing studies on EKC in China have focused on one or a group of pollutant indicators, and the results are sensitive to the selection of data. None of them considered using a comprehensive environmental index to proxy overall environmental degradation. This Ph.D. study fills this gap in the literature through constructing three comprehensive indices to measure industrial water pollution, air pollution and solid wastes pollution. Previous EKC studies used per capita GDP to capture two or three mechanism effects of economic development so that it is difficult to distinguish one from the others. This study hence fills this gap by splitting the three mechanism effects using GDP per capita to measure scale effect, output share of secondary and tertiary industries to capture composition effect, and expenditure on R&D activity to present technique effect.

3. Methodology

This section firstly introduces the methods of constructing comprehensive environmental pollution indices (EPIs). It then discusses the model specification and justifies the variables used in the model. Next, it presents details of data and descriptive statistics of variables. Finally, it explores the methodological issues related to the model and how they are addressed in the regressions.

3.1 The dependent variable: Environmental Pollution Index (EPI)

The environmental degradation indicators of the most previous EKC studies were the single pollutant that has embedded a shortage that fails to represent comprehensive environmental degradation. Li, Yang and Sheng (2011) constructed a new comprehensive environmental pollution index reflecting the entire status of environmental pollution. Then they ranked the 30 provinces of China according to that index. However, this index may make noise in a research of EKC using econometric methods as it contains 23 environmental indicators from 6 dimensions including wastewater, waste gas, solid wastes, and household wastes, energy consumption and city air quality. The pollutants of different dimensions are measured by different scales and units. Therefore, it is not proper or accurate to use one indicator, which is a combination of pollutants from various dimensions, as the dependent variable in EKC.

Thus, this study makes an adjustment by splitting the index into industrial wastewater pollution index, industrial waste gas pollution index, and industrial solid wastes pollution index. Table 3.1 shows the structures and data sources of the EPIs.

Table 3.1 Structure of EPIs

EPI dimension	Data Source	Environmental indicator	Number
Industrial water pollution index	China Statistical Yearbook	Industrial wastewater emission per capita	3
		COD in the industrial wastewater emission per capita	
		Volume of ammonia Cal and nitrogen in industrial waste water	
Industrial gas pollution index	China Statistical Yearbook	Industrial waste gas emission per capita	3
		Industrial waste SO_2 emission per capita	
		The sum of industrial waste Soot and Dust emission per capita	
Industrial solid pollution index	China Statistical Yearbook	Industrial waste solid emission per capita	2
		Industrial waste solid utilized per capita*	

*Note: Most are pollution emission indicators and * denotes pollution utilisation indicator. The volumes of SOOT and dust emission were reported separately before 2010. After 2011 they were reported together as a sum volume in the China Statistical Yearbook.*

Source: China Statistical Yearbook 2001-2013

The EPI for this study is calculated according to Equation (1), (2), and (3).

$$EX_{ijt} = (X_{ijt} - X_{itmin})/ (X_{itmax} - X_{itmin}) \quad (1)$$

$$EX_{ijt} = (X_{itmax} - X_{ijt})/(X_{itmax} - X_{itmin}) \quad (2)$$

$$EPI_{ijt} = 1/n \sum_{i=1}^{n} EX_{ijt} \quad (3)$$

where EPI_{jt} refers to relative environmental pollutant index of the location *j*, dimension *i*, and year *t*; EX_{ijt} presents the environmental index of location *j*, pollutant *i* and year *t*. X_{jit} is emission per capita for location *j*, pollutant *i*, and year *t*. For each pollution indicator, an environmental index (EX) is calculated using equation (1) and only the amount of Industrial waste solid utilised per capita which are presented with * in Table 3.1 is calculated using equation (2). X_{itmax} and X_{itmin} stand for the maximum and minimum value of the pollutant *i* emission in year *t*. After that, EPI is achieved using equation (3), which is the mean of EXs.

EX_{ij} makes different pollution indicators additive. Then EPI_{it} integrates all pollutants in dimension *i* into one index. It ranges from 0 to 1. A region has index 0 in one dimension indicates that all the pollution indicators of that region ranked the last of the 30 regions meaning this region is the least polluted region in this pollution dimension. In opposite, index 1 means that region is the most polluted regions since all the pollution indicators of it ranked the first place of the 30 regions.

All the pollution indices are reported in appendix 1. Tables 3.2-3.4 report the statistical summary for three environmental pollution indices respectively.

Table 3.2 Statistical summary of water pollution index

	Mean	**Median**	**Standard Deviation**	**Minimum**	**Maximum**	**Count**
Overall	0.2824	0.2476	0.1848	0.0000	0.9703	360
2001	0.2514	0.2326	0.1659	0.0134	0.6695	30
2002	0.2870	0.2417	0.1843	0.0117	0.8234	30
2003	0.2868	0.2474	0.1871	0.0151	0.8228	30
2004	0.3101	0.2961	0.1898	0.0197	0.8929	30
2005	0.2819	0.2342	0.1991	0.0000	0.9703	30
2006	0.3195	0.2857	0.1961	0.0025	0.9332	30
2007	0.3319	0.2947	0.2045	0.0024	0.9584	30
2008	0.3001	0.2743	0.1899	0.0046	0.9186	30
2009	0.3004	0.2745	0.1852	0.0033	0.9575	30
2010	0.2507	0.2176	0.1842	0.0011	0.9517	30
2011	0.2158	0.1704	0.1613	0.0000	0.9105	30
2012	0.2532	0.2272	0.1644	0.0000	0.9220	30

Source: manually calculated by author with data collected from China Statistical Yearbook 2001-2013.

The overall mean of wastewater pollution index is 0.282, and the median is 0.248. In 2001, the most industrial wastewater polluted regions were Ningxia and Zhejiang whose water pollution indices both were greater than 0.65 and the smallest indices were found in Guizhou and Qinghai with 0.013 and 0.027, respectively. Ningxia and Zhejiang were also the most polluted regions in 2012, the index of Ningxia increased to 0.92, but that of Zhejiang declined to 0.45. The indices of Guizhou and Qinghai grew to 0.08 and 0.09 but still ranked last two and three respectively. From 2011 to 2012, the least industrial water polluted region was Beijing with an index of 0 for both years, which means all of the three industrial water pollution indicators, namely industrial wastewater emission per capita, COD in the industrial wastewater emission per capita and volume of ammonia Cal and nitrogen in industrial waste water per capita, of Beijing were the lowest among the 30 regions in 2011 and 2012. That implies Beijing archived significant success on water pollution treatment after 2010 when the local government issued a regulation on the prevention and control of water pollution for Beijing in Nov 2010.

Table 3.3 Statistical summary of gas pollution index

	Mean	**Median**	**Standard Deviation**	**Minimum**	**Maximum**	**Count**
Overall	0.286	0.219	0.213	0.000	1.000	360
2001	0.302	0.262	0.185	0.009	0.813	30
2002	0.282	0.226	0.193	0.071	0.840	30
2003	0.280	0.220	0.208	0.000	0.849	30
2004	0.289	0.245	0.205	0.000	0.911	30
2005	0.315	0.244	0.232	0.012	0.973	30
2006	0.293	0.227	0.209	0.004	0.895	30
2007	0.298	0.227	0.221	0.000	0.893	30
2008	0.293	0.214	0.228	0.005	0.916	30
2009	0.289	0.219	0.219	0.000	0.917	30
2010	0.234	0.163	0.211	0.003	0.971	30
2011	0.270	0.190	0.229	0.003	1.000	30
2012	0.284	0.197	0.244	0.004	1.000	30

Source: manually calculated by author with data collected from China Statistical Yearbook 2001-2013.

The average overall index is 0.286, and the median is 0.219. The most air polluted regions in 2001 were Shanxi and Ningxia with indices of 0.812 and 0.792, respectively. In 2012, the index of Ningxia increased to 1 and ranked the first place as the most air-polluted regions. Shanxi ranked the third place with an index of 0.724. Inner Mongolia, of which the index was 0.849, leapt to the second place for waste gas pollution in 2011. The least air-polluted regions in 2001 were Hainan and Jiangxi. Both indices were lower than 0.1 especially for Hainan, which was only 0.009. However, in 2011 Beijing (0.003) surpassed Hainan (0.022) the least industrial air polluted region and the index was 0.003. Jiangxi dropped to the twelfth place with an index of 0.174.

Table 3.4 Statistical summary of solid pollution index

	Mean	**Median**	**Standard Deviation**	**Minimum**	**Maximum**	**Count**
Overall	0.3971	0.4084	0.1430	0.0002	0.9549	360
2001	0.3706	0.3902	0.1549	0.0002	0.6342	30
2002	0.3668	0.1394	0.1394	0.0002	0.5867	30
2003	0.3707	0.3809	0.1209	0.0888	0.6135	30
2004	0.3741	0.3881	0.1130	0.1124	0.5642	30
2005	0.3606	0.3741	0.1264	0.1142	0.5682	30
2006	0.3518	0.3581	0.1389	0.0453	0.6604	30
2007	0.3990	0.4055	0.1213	0.0151	0.6176	30
2008	0.4146	0.4187	0.1210	0.1937	0.8009	30
2009	0.3913	0.3953	0.1760	0.0404	0.8900	30
2010	0.4094	0.4054	0.1539	0.0198	0.9183	30
2011	0.4822	0.4784	0.1538	0.0108	0.9549	30
2012	0.4741	0.4685	0.1374	0.0025	0.9334	30

Source: manually calculated by author with data collected from China Statistical Yearbook 2001-2013.

The overall mean of solid wastes pollution indices is 0.397, and the median is 0.408. The most solid polluted regions in 2001 were Guizhou and Shanxi, of which the indices were both over 0.6. Shanghai was the least solid polluted region with an index approaching zero. Fujian was also good at solid pollution controlling, with an index of 0.076 in 2001. Shanxi seems to make considerable efforts to abate solid wastes pollution during 2001-2012. Its solid wastes pollution index decreased to 0.414 in 2012, and its ranking dropped from the second place in 2001 to twenty sixth in 2012. Xinjiang leapt to the first place of the most solid wastes polluted region in 2012 with an index of 0.933. And the least polluted region is Qinghai, with an index of 0.003.

3.2 Model specification

According to the EKC hypothesis and the prior literature on the subject as reviewed above, an augmented EKC model is used for regression:

$$\boldsymbol{EPI_{it} = \alpha_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 S_{2it} + \beta_4 S_{3it} + \beta_5 R_{it-1} + \beta_6 F_{it} + \beta_7 I_{it} + \beta_8 P_{it} + \beta_9 E_{it} + \varepsilon} \quad \textbf{(4)}$$

where subscripts *i* and *t* indicate region *i* and year *t* separately; EPI_{it} is the environmental pollution index of location *i* in year *t*; Y is GDP per capita; S_2 and S_3 present the output share of second and third industries respectively; R is real expenditure on technology innovation and development per capita; F is FDI inflow per capita; I is real completed in treatment of industrial pollution per capita, P presents urban population density, and E is percentage of high-level educated population. Moreover, α_i is region intercepts.

Equation (4) is estimated using a dataset of 30 Chinese provinces (Tibet is excluded due to data availability of some variables) from 2000 to 2013. This project considers both linear and quadratic relationships between GDP per capita and EPI. Thus, Y_{it} is introduced in the first place, and then the quadratic term Y_{it}^2 is added.

GDP per capita (Y) represents economic standard and measures scale effect. If the EKC hypothesis exists in China, the EPI should increase as GDP per capita grows and then decreases after a particular point. Thus, the graph portrays an inverted-U shaped curve. In this case, the expected sign of quadratic term β_1 is positive and β_2 is negative. If there is no evidence supporting the EKC hypothesis, linear regression may show an environmental effect of GDP per capita is positive or negative. In this case, the sign of β_1 is uncertain.

Second and tertiary industry output shares (S2 and S3) are used to measure composition effect. Environmental quality will be worsened due to increasing industrial pollution emissions in the transition from agriculture production to industrial production, and then improve when the industry is dominated by service and technology incentivised industry (Shafik and Bandyopadhyay, 1992; Shen, 2006). In other words, the secondary industry contributes to environmental degradation and the growth of the tertiary industry leads to a better environment. Sometimes, the secondary industry may reduce industry pollution if it is dominated by high technology and clean industries. Therefore, β_3 is expected to be positive or negative.

The tertiary industry is service, information and technology intensive, which requires less energy consumption and generates less by-product comparing with agriculture and the secondary industry. Therefore, β_4 is expected to be negative.

To split technique effect from income per capita, this project introduces R&D expenditure (R) following Zeng and Eastin (2011). The high-income regions may make more investment in R&D activities. Technique effect is supposed to increase energy efficiency and reduce pollution. Hence, the expected effect of R&D expenditure on environmental degradation, which is indicated by β_5, is negative.

The environmental effect of FDI (F) is uncertain. According to the PHH, FDI may be attracted by lenient environmental regulations and have the incentive to move the dirty industry from home country to host country (Chakraborty and Mukherjee, 2013; Lee, 2013). However, as the main source of advanced technology for developing countries, FDI may improve environmental quality through introducing clean technology to China (Zheng, Kahn and Liu, 2010). Therefore, the expected sign of β_5 is ambiguous.

The investment in environmental activity (I) measures the stringency of environmental regulations (Merlevede, Verbeke, and Clercq, 2006; Diao et al., 2009). It is supposed to reduce pollution emission effectively so β_6 is expected to be negative.

Population density (P) is designed to represent public demand in liveable environments (Selden and Song, 1994; Brajer, Mead and Xiao, 2009; Park and Lee, 2011). Higher population density is assumed to have a higher public requirement on environmental quality, which promotes enactment and enforcement of strict environmental regulations. However, increasing population leads more demands on products and service, which requires more resource input and discharges more pollution. Therefore, the impact of population density on environmental pollution (β_7) is expected to be negative or positive.

Education level was used to measure the character of the state in a cross-countries EKC study conducted by List and Gallet (1999). This study introduces education level (E) to proxy public awareness on environmental protection. This study assumes that a highly educated population have strong environmental awareness. They are more willing to pay a specific share of income for ecological products or donate to environmental organisations. That profound awareness will be conducive to favourable effects on the environment. Hence, β_8 is expected to be negative. Table 3.5 lists all the expected signs of coefficients in Equation (4).

Table 3.5: Excepted sings for estimated coefficients in Equation (6)

Coefficients	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9
Expected signs	+ +/-*	-	+/-	-	-	+/-	+/-	-	-

*Note: * denotes the sign for linear regression*

3.3 Data description

Table 3.6 reports the variable definitions, measurement, units and data sources. The investment in environmental activity is presented by investment completed in the treatment of industrial pollution per GDP. And population density is the number of persons in per kilometre square of the urban area. The high education rate is calculated according to the data obtained from China's Annual National Sample Survey on Population Changes. The sampling fraction is around 0.8%-1%. The ratio is equal to the number of persons who achieved college or higher-level education over total surveyed population aged 6 and over.

Besides FDI, all other data is collected from the China Statistical Yearbooks 2001-2014. All data covers the year from 2001 to 2012 for 30 provinces in China. Tibet is not included in the dataset due to unavailability of some key variables. The GDP per capita is transferred from the current price to 2000 prices using GDP deflator published by the World Bank.

FDI data is mainly obtained from the Statistical Yearbook of each province. Moreover, FDI in Hebei and Gansu provinces is obtained from the National Economy and Social Development Statistical Bulletins, which are released by each province annually. The FDI value is transferred from US dollar into RMB based on annual average exchange rate reported by China Statistical Yearbook and deflated in 2000 prices.

Table 3.7 reports the descriptive statistics of variables and Table 3.8 reveals the correlation coefficients among variables.

Table 3.6 Definitions and Data sources for independent variables

Variable	**Definition**	**Source**
Y	GDP per capita (Yuan at 2000 price)	China Statistical Yearbook
S2	Share of GDP contributed by secondary industry	China Statistical Yearbook
S3	Share of GDP contributed by third industry	China Statistical Yearbook
R	Expenditure on R&D activity per capita (Yuan at 2000 price)	China Statistical Yearbook
F	Actual use FDI inflow per capita (Yuan at 2000 price)	Province Statistical Yearbook, and National Economy and Social Development Statistical Bulletin for Hebei and Gansu
I	Investment completed in treatment on industrial pollution per capita (Yuan at 2000 price)	China Statistical Yearbook
P	Urban population density (Persons per km2)	China Statistical Yearbook
E	Ratio of the population graduate from Junior College and about	China Statistical Yearbook

Table 3.7 Descriptive statistics for all the variables

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Y	360	20851.77	16335.37	14851.87	3319.978	80273.08
S2	360	47.4629	48.7202	7.574519	20.4	61.5
S3	360	39.43346	38.3	7.368911	28.6	76.45631
R	360	45.22997	27.82	88.0807	2.052097	690.3865
F	355	712.0748	331.95	913.3129	5.5019	5779.055
I	360	30.32913	22.34	26.37738	1.428699	178.6342
P	360	2154.632	1937.5	1403.231	56	6307.376
E	360	0.0737644	0.0578	0.0550069	0.00981	0.3735028

Note: FDI of Yunnan in 2001, 2003, 2005, 2007, and 2009 are missing.

Table 3.8 Correlations among the independent variables

	Y	S2	S3	R	F	I	P	E
Y	1.0000							
S2	0.0763	1.0000						
S3	0.5835	-0.5949	1.0000					
R	0.7236	-0.1951	0.6380	1.0000				
F	0.8058	0.0736	0.4913	0.5378	1.0000			
I	0.3480	0.3523	0.0772	0.1340	0.3808	1.0000		
P	0.0956	0.1389	-0.0994	0.0709	-0.0087	0.0005	1.0000	
E	0.7182	-0.1715	0.6598	0.5475	0.5966	0.2736	0.0467	1.0000
Water Index	-0.0330	0.3916	-0.1936	-0.1367	-0.0897	0.4437	-0.1817	-0.0099
Gas Index	-0.1531	-0.2576	0.0054	0.0438	-0.2623	-0.2532	0.2559	-0.1085
Solid Index	0.1959	-0.0694	0.2590	0.0960	0.1525	0.1019	-0.0050	0.2593

3.4 Methodological issues

To correct the positive skewing of independent variables and reduce the noisy impact of error term, equation (4) is estimated logarithmically and a logarithmic transformation model. Also, logarithmic transformation can increase the reality of the regression result. The curve of a general quadratic function is symmetrical which means on any two symmetrical points, the dependent variable increase and decrease at the same rate. Moreover, the dependent variable may decline quickly below to zero. Those tow phenomena rarely happen in real world.

Another concern is the endogeneity of economic growth referring to GDP per capita in this project. In EKC hypothesis studies, the exogeneity of economic growth is challenged by the potential two-way causation between economic growth and pollutants emission. On the one hand, economic development generates pollution. On the other hand, increasing pollutant emission restraints economic growth at the same time. To control the potential endogeneity, this study applies the instrument estimator for Equations (4). A two stage least square estimation with instrumental variables is used. Since it is hard to find variables that have an impact on GDP per capita but not related to the environment, two- and three-year lagged GDP per capita are used as instrumental variables. A Hausman test is employed after the 2SLS estimation to check the endogeneity of GDP per capita and a Sargan test for the validity of instrumental variables.

Besides, FDI is replaced by trade intensity as an alternative measure of openness to test the stability of empirical results.

4. Results

To confirm the robustness of regression result, this study applied fixed effect and random effect estimators. In most models, the random effect estimator is rejected by Huasman test, which suggests fixed effect is more appropriate and efficient in this study. The Hausman test on endogeneity suggests that GDP per capita is exogenous so that 2SLS with IVs are not needed. Hence, this section only reports fixed effect regression results. Empirical results with random effect are reported in Appendix 2.

Tables 4.1- 4.3 report the quadratic, logarithmic result based on fixed effect estimator for industrial wastewater index, industrial waste gas index, and industrial solid waste index, respectively.

The results for wastewater pollution index and waste gas pollution index confirm the EKC hypothesis. However, the relationship between solid waste pollution index and GDP per capita exhibits "U" shape.

4.1 Result for industrial wastewater pollution index

Table 4.1 reports the results for industrial wastewater index based on fixed effect estimator. According to the results, the sign of the coefficient on Y is positive, and that on Y2 is negative, indicating an inverted-U shaped relationship between income and pollution, i.e. the existence of EKC. The turning point is between RMB 20,024 and 21,298.[1] According to Figure 1 which represents real GDP per capita for each region in each year with Water TP standard line at value of RMB 20,024, most of the regions have passed the turning point by 2012. Shanghai, Beijing and Tianjin are the first three regions that arrived the turning point in 2001, followed by Zhejiang, which reached the turning point in 2004, and then Jiangsu and Guangdong in 2005. During the period from 2005 to 2010, Liaoning, Fujian, Inner Mongolian, Shandong and Jilin entered to the declining side of EKC. And another 17 regions passed the peak point in the most recent years. So far, only three regions' GDP per capita are still below the turning points. They are Yunnan, Guizhou, and Gansu, where all in the western of China.

[1] The tuning point is calculated basing on the symmetry of quadratic function that the middle line is equal to -2a/b. The reported range of turning point comes from column (6)- (9).

Technique effect of economic development, the expenditure on R&D activity (R) is negatively associated with the industrial wastewater index at 10% significance level. The coefficient in Column 9 suggests that a 1% increasing in expenditure on R&D activity will reduce the wastewater pollution index by 0.025 units everything else equal.

Regarding composition effect, neither the shares of secondary or tertiary industries in GDP (S2 and S3) has been found to have a significant impact on the wastewater pollution index.

For other control variables, columns 4-7 show that the coefficient on FDI (F) is negative and statistically significant. A 1% increase in inward FDI flows will lead the wastewater pollution index to decline by about 0.04 units, *ceteris paribus*.

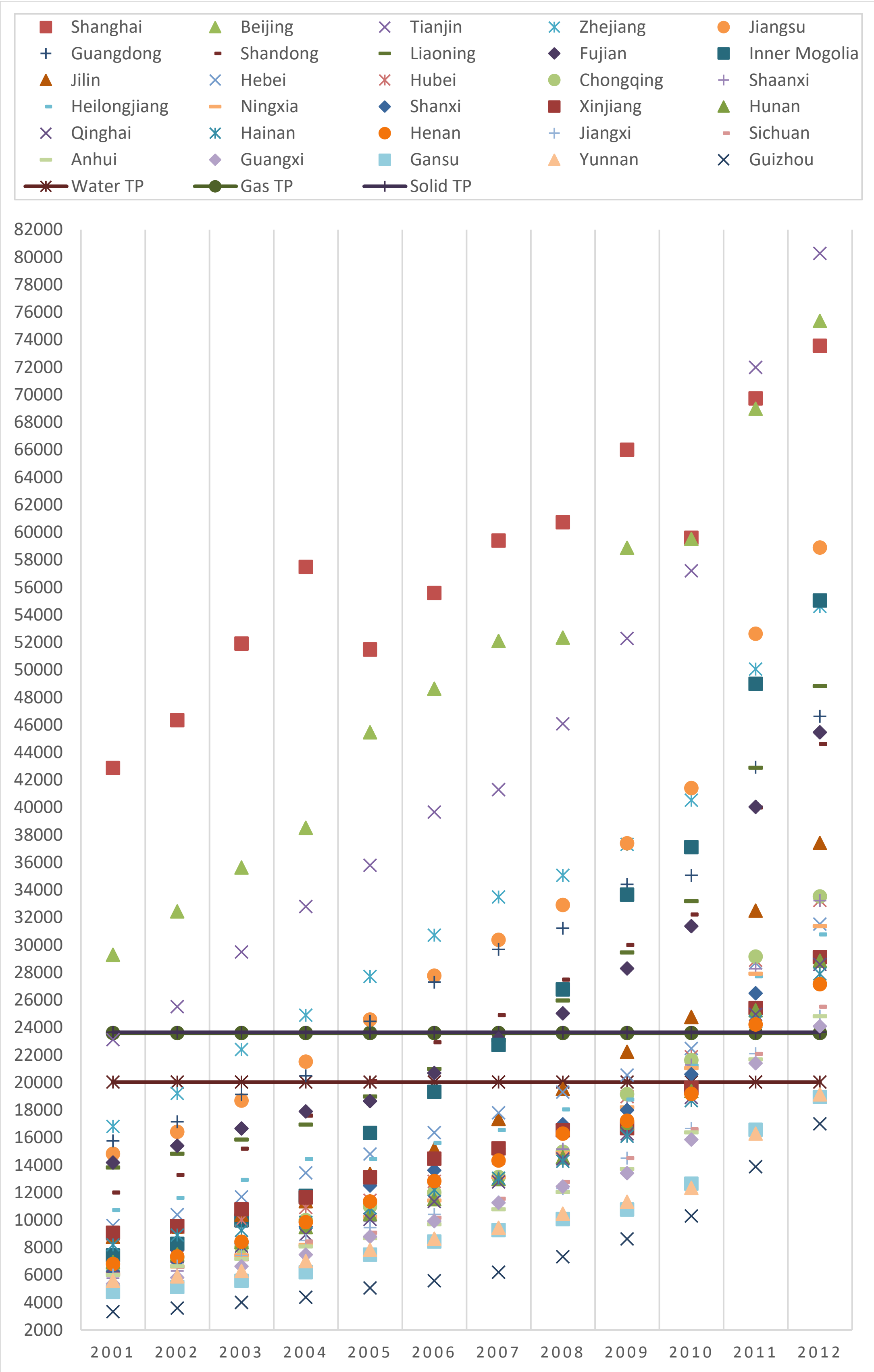
The expenditure on pollution abatement (I) and urban population density (P) are found to have significant and positive impacts on wastewater pollution index. Their coefficients are about 0.019 and 0.0167, respectively.

Table 4.1 Fixed effect result for industrial wastewater index

VARIABLES	(1) WATER	(2) WATER	(3) WATER	(4) WATER	(5) WATER	(6) WATER	(7) WATER	(8) WATER	(9) WATER
Y	-0.0198**	1.353***	1.322***	1.404***	1.425***	1.634***	1.483***	1.346***	1.351***
	(0.00991)	(0.198)	(0.215)	(0.227)	(0.227)	(0.230)	(0.238)	(0.245)	(0.246)
Y2		-0.0709***	-0.0695***	-0.0732***	-0.0730***	-0.0817***	-0.0744***	-0.0679***	-0.0682***
		(0.0102)	(0.0110)	(0.0115)	(0.0114)	(0.0115)	(0.0119)	(0.0122)	(0.0122)
S2			0.0222	-0.0753	-0.0838	-0.0457	-0.0965	-0.0891	-0.0842
			(0.0600)	(0.107)	(0.106)	(0.105)	(0.107)	(0.106)	(0.107)
S3				-0.122	-0.107	-0.0985	-0.124	-0.122	-0.118
				(0.110)	(0.111)	(0.109)	(0.109)	(0.108)	(0.108)
R					-0.0144	-0.0134	-0.0144	-0.0163*	-0.0158*
					(0.00894)	(0.00881)	(0.00876)	(0.00876)	(0.00882)
F						-0.0445***	-0.0409***	-0.0416***	-0.0422***
						(0.0109)	(0.0109)	(0.0109)	(0.0109)
I							0.0199**	0.0195**	0.0187**
							(0.00879)	(0.00874)	(0.00884)
P								0.0166**	0.0167**
								(0.00766)	(0.00767)
E									0.00528
									(0.00941)
Constant	0.475***	-6.133***	-6.062***	-5.684***	-5.885***	-7.008***	-6.027***	-5.456***	-5.483***
	(0.0965)	(0.957)	(0.977)	(1.034)	(1.039)	(1.067)	(1.145)	(1.169)	(1.171)
Observations	360	360	360	360	355	355	355	355	355
Number of regions	30	30	30	30	30	30	30	30	30
R-squared	0.012	0.138	0.139	0.142	0.149	0.191	0.204	0.216	0.217
Turning point	N/A	13927	13504	14620	15009	22026	21298	20163	20024

*Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Figure 1. Real GDP per capita by regions (RMB Yuan in 2000 price)



Source: China Statistical Yearbooks 2001-2013

4.2 Result for industrial waste gas pollution index

Table 4.2 represents the fixed effect results for industrial waste gas pollution index. The signs of coefficients on Y and Y2 are positive and negative respectively, supporting EKC hypothesis with a turning point between RMB 23,584 and 26,517, which is slightly higher than the turning point of wastewater curve. According to Figure 1, Beijing and Shanghai were the first two regions that arrived the turning point (indicated by Gas TP line in Figure 1) in 2001, followed by Tianjin in 2003, Zhejiang in 2005, Jiangsu in 2006, and Guangdong in 2007. By 2012, only Guizhou, Gansu and Yunnan have not passed the turning point.

Expenditure on R&D (R) is negatively related to industrial waste gas index at 10% significant level. And the coefficient in column 9 is bigger than that of wastewater results. A 1% rising in expenditure on R&D will reduce 0.0425 units of industrial waste gas pollution index.

To coefficient on investment on pollution abatement (I) is significant and positive at 5% significant level. It is 0.0177 in column 9, indicating 1% increased expenditure on pollution treatment leads 0.0177 units adding to waste gas pollution index.

However, different to the findings using wastewater index, the coefficients on FDI and urban population density are not statistically different from zero. And high-educated population rate has no significant impact on industrial waste gas pollution, either. Figure 1. Real GDP per capita by regions and years

Table 4.3 Fixed effect result for industrial air pollution index

VARIABLES	(1) GAS	(2) GAS	(3) GAS	(4) GAS	(5) GAS	(6) GAS	(7) GAS	(8) GAS	(9) GAS
Y	-0.00512	1.155***	0.922***	1.018***	1.076***	1.043***	0.893***	0.872***	0.884***
	(0.00906)	(0.183)	(0.195)	(0.206)	(0.199)	(0.207)	(0.214)	(0.222)	(0.222)
Y2		-0.0600***	-0.0487***	-0.0530***	-0.0525***	-0.0512***	-0.0439***	-0.0429***	-0.0439***
		(0.00944)	(0.00999)	(0.0104)	(0.0101)	(0.0104)	(0.0107)	(0.0111)	(0.0110)
S2			0.170***	0.0555	0.0323	0.0232	-0.0272	-0.0261	-0.0124
			(0.0546)	(0.0969)	(0.0936)	(0.0948)	(0.0961)	(0.0963)	(0.0964)
S3				-0.144	-0.102	-0.102	-0.127	-0.127	-0.114
				(0.100)	(0.0972)	(0.0980)	(0.0977)	(0.0979)	(0.0978)
R					-0.0393***	-0.0397***	-0.0407***	-0.0410***	-0.0395***
					(0.00786)	(0.00793)	(0.00788)	(0.00793)	(0.00795)
F						0.00968	0.0132	0.0131	0.0113
						(0.00981)	(0.00983)	(0.00985)	(0.00987)
I							0.0197**	0.0197**	0.0177**
							(0.00790)	(0.00792)	(0.00797)
P								0.00252	0.00258
								(0.00694)	(0.00692)
E									0.0145*
Constant	0.335***	-5.250***	-4.707***	-4.263***	-4.812***	-4.633***	-3.659***	-3.573***	-3.645***
	(0.0882)	(0.883)	(0.889)	(0.940)	(0.914)	(0.961)	(1.030)	(1.058)	(1.056)
Observations	360	360	360	360	355	355	355	355	355
Number of regions	30	30	30	30	30	30	30	30	30
R-squared	0.001	0.110	0.136	0.141	0.203	0.206	0.221	0.221	0.228
Turning point	N/A	15139	12915	14821	28215	26517	26130	25930	23584

*Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

4.3 Result for industrial solid wastes index

The results of industrial solid waste index in Table 4.3 are extremely different from those for wastewater and waste gas indices. There is no evidence to support the EKC hypothesis. The signs of Y and Y2 are negative and positive, respectively, indicating a U-shaped relationship between GDP per capita and solid wastes emission. The turning point is between RMB 23,646 and RMB 26,084. The industrial solid wastes pollution declines with GDP per capita increasing then rises after passing the lowest point. And according to Figure 1 most of the regions of China are currently in the increasing process.

Moreover, the output share of secondary industry (S2) behaves as a hindering factor in industrial solid waste pollution. For every 1% expansion in secondary industry share in GDP, the industrial solid wastes pollution declines 0.23 units.

Expenditure on R&D (R) is confirmed to be significantly and positively related to industrial solid waste pollution index. A 1% increasing in R&D investment generates around 0.05 units of industrial solid pollution index.

FDI (F) has significant and positive impact with the coefficient at 0.457 in column 9. Thus, 1% growing in inflow FDI leads 0.457 units increasing in solid waste pollution index.

Additionally, urban population density has a significant and positive effect on industrial solid wastes pollution. And the coefficient is 0.0324.

The results of other variables, including the share of tertiary industry in GDP, expenditure on pollution abatement, and high education rate are not statistically significant.

Table 4.3 Fixed effect results for industrial solid index

VARIABLES	(1) SOLID	(2) SOLID	(3) SOLID	(4) SOLID	(5) SOLID	(6) SOLID	(7) SOLID	(8) SOLID	(9) SOLID
Y	0.0587***	-1.551***	-1.271***	-1.248***	-1.330***	-1.561***	-1.544***	-1.811***	-1.804***
	(0.0110)	(0.218)	(0.233)	(0.246)	(0.234)	(0.236)	(0.246)	(0.248)	(0.248)
Y2		0.0832***	0.0696***	0.0686***	0.0678***	0.0775***	0.0767***	0.0893***	0.0887***
		(0.0112)	(0.0119)	(0.0125)	(0.0118)	(0.0118)	(0.0123)	(0.0124)	(0.0124)
S2			-0.204***	-0.232**	-0.199*	-0.236**	-0.230**	-0.216**	-0.207*
			(0.0650)	(0.116)	(0.110)	(0.108)	(0.110)	(0.108)	(0.108)
S3				-0.0346	-0.0929	-0.0950	-0.0921	-0.0894	-0.0817
				(0.120)	(0.114)	(0.111)	(0.112)	(0.109)	(0.110)
R					0.0555***	0.0549***	0.0550***	0.0513***	0.0522***
					(0.00924)	(0.00902)	(0.00904)	(0.00886)	(0.00891)
F						0.0484***	0.0480***	0.0468***	0.0457***
						(0.0111)	(0.0113)	(0.0110)	(0.0111)
I							-0.00223	-0.00309	-0.00426
							(0.00907)	(0.00885)	(0.00894)
P								0.0324***	0.0324***
								(0.00775)	(0.00775)
E									0.00881
Constant	-0.174	7.574***	6.924***	7.031***	7.806***	9.014***	8.904***	10.01***	9.970***
	(0.107)	(1.052)	(1.058)	(1.123)	(1.075)	(1.092)	(1.182)	(1.183)	(1.184)
Observations	360	360	360	360	355	355	355	355	355
Number of regions	30	30	30	30	30	30	30	30	30
R-squared	0.080	0.211	0.234	0.235	0.311	0.353	0.353	0.387	0.388
Turning point	N/A	11169	9234	8921	181893	23646	23510	25335	26084

*Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

5. **Robustness check**

Tables in Appendix 2 report the results using random effect estimator and Tables in Appendix 3 are the results using trade intensity as a measure of openness. All the results are similar to main findings and prove the robustness of this study.

With considering potential endogeneity of GDP per capita, this study applies 2SLS using 2- and 3- year lagged GDP per capita as instruments. However, Hausman test suggests GDP per capita is exogenous. Thus, the IV estimator result will not be reported.

5.1 Random effect

With random effect estimator, the existence of EKC is confirmed in the cases of water and air pollution with turning points RMB 19,287 and RMB 22,855 from column 9 separately. The relationship between solid pollution and income is U-shape, similar to the fixed effect results, having a turning point at RMB 26,968. In comparison with fixed effect results, the turning points from random effect are slightly lower. The sign of secondary industry share changes from negative in fixed effect results to positive in random effect but not statistically significant across the specifications of industrial waste gas pollution index. Other results are same as fixed effect.

5.2 Estimated model with trade intensity

Trade intensity has been incorporated to replace FDI inflow. EKC is found for water and air pollution indices, but a U-shape curve for solid wastes pollution. However, the turning points largely vary across different model specifications. The signs of coefficient trade intensity are the same to those of FDI for all three pollutions, meaning trade will lead to less wastewater pollution but more waste gas pollution. That finding may be related to the structure of trade, particularly export. China may export more air pollution intensive industrial products.

6. Discussion

By comparing the empirical results of this study with previous literature and combining with China's reality, this discussion section will explore the deeper facts contained in the statistical results.

6.1 Evidence for EKC hypothesis

The evidence supporting EKC was founded in case of industrial wastewater pollution and waste gas pollution. Song, Zheng and Tong (2008), Cole, Elliott and Zhang (2011), and Gao (2011) also validated EKC for industrial water pollution in China. However, the turning point obtained by Cole, Elliott and Zhang (2011) is between RMB 32,577 and RMB 35,098, which is much higher than this study between RMB 22,700 and RMB 23,266. The examined period of Coles' study is from 2001 to 2004. A possible explanation of the lower inflection point in this study is that some effective measures on industrial water pollution reduction might have been taken in recent years.

The results for industrial waste gas index are similar to the findings in previous literature. Some cross-country studies conducted by Grossman and Krueger (1991), Panayotou (1993), and Selden and Song (1994) proved the existence of EKC relationship between air pollution and economic development. And in the case of China, some studies also found inverted-U shaped relationship for air pollution indicators (He, 2008; Shaw et al., 2010). However, the inflection point obtained in this study is between RMB 26,700 and RMB 28,800 in 2000 price, which is much higher than previous studies, such as RMB 10,000 in He (2008) and RMB 5,536 in Han, Zhang and Liu (2011).

This difference on turning point is potentially caused by the application of gas pollution index. The turning point in previous studies for China was mainly obtained from SO_2 emission data. However, this study adopted waste gas pollution index that reveals the joint EKC for SO_2, NO_x, and Soot and Dust emission. Selden and Song (1994) found a turning point for SO_2 about 9000 US dollars and a higher turning point for NO_x about 1,2000 US dollar in their study, indicating that NO_x emissions are more costly than SO_2. This might explain why the inflection point obtained from waste gas pollution index is higher than those obtained in previous SO_2 emission studies.

Different from Han, Zhang and Liu (2011) who found no evidence suggesting a significant relationship between industrial solid emission and economic growth, this study confirmed a U-shape curve for solid pollution index-economy nexus with a turning point between RMB 25,400 to RMB 26,600.

6.2 Composition effect

The Shares of secondary and tertiary industries in GDP capture composition effect of economic growth on environmental degradation. On one hand, for developing country secondary industry is hypothesized as a promoting factor for industrial pollution, since the increasing in secondary industry, especially heavy industry, leads more natural resource inputting and pollutant discharge (Grossman and Krueger, 1991), which means the correlation coefficient of S2 is supposed to be positive. On the other hand, secondary industry expanding may reduce industrial pollutant discharging when it's structure transiting towards clean industries (Yang, Lan and Zheng, 2013). In this study, a negative coefficient appears for secondary industry share, but it is not statistically significant. Positive but insignificant results may be led by the two opposite effects of composition. It depends on the structure of the industry. Different regions have different industrial structure, some have more high-tech, some have more pollution-intensive.

The sign of coefficient on S3 is negative but not statistically significant. Contribution from tertiary industry on GDP is an environmental improving factor in EKC hypothesis. Because tertiary industry is service, information and technology intensive, which requires less energy consumption and generates less by-product comparing with agriculture and secondary industry. Empirical results in this study are consistent with the hypothesis and previous literature (Zhou, Zhang and Li; 2013).

6.3 Technique effect

Technique effect is measured by expenditure on R&D activity intensity. The empirical results for technique effect are mixed. It is positively related to wastewater and waste gas pollution indices but negatively related to solid wastes pollution index at significant level of 1% or 10%. In comparison with previous literature, Zhuo, Zhang and Li (2013) found no significant relationship between technical progress and CO_2 emission. However, Yin, Zheng and Cheng (2015) illustrated that R&D activity reduced CO_2 emission in China, and R &D input was not perceptible immediately until five years later.

On one hand, technique effect indeed benefits China's environmental quality by reducing wastewater and waste gas emission. That may be a result of the increasing on R&D expenditure intensity. In 2001, the spending on technology development only accounted 3.28% of GDP, which is more than doubled in 2012 to 8.58%. The results that variable R is significant negatively related to wastewater and gas pollution indices are suggestive that technique effect contributed to emission reduction in the examined period. Thus, for China's government, a policy increasing input on R&D activity is an effective method to control industrial pollution, especially for wastewater and gas.

On the other hand, the positive sign of variable R for solid pollution is consistent with previous literature Ma et al. (2008), who found that utilisation of energy intensive technology increased energy intensity in China from 1995. This phenomenon possibly reflects "rebound effect" of technical process. Technology upgrading, which accompanies with application of new energy technology and improvement of energy efficiency, always leads energy price decline. Then, reduction in energy price stimulates energy consumption, and "rebound effect" will occur if the increased energy depletion is greater than the energy saving (Sanders, 2000; Yin, Zheng and Chen, 2015). Therefore, when technology upgrading causes "rebound effect", technique effect plays as an increasing factor for environmental degradation. Once "rebound effect" weakens, the improving effect of technique effect on environment will be more perceptible. Based on this assumption, it requests future research considering that the environmental effect on technique is potential nonlinear rather than monotonous.

6.4 Impact of FDI

The impact of FDI on environment in China is various across different pollution indices. For industrial water pollution index, empirical results suggest that FDI has significant negative effects, meaning FDI facilitates water pollution reduction and improvement in environment amenity. This finding is opposite to the PHH but suggests that FDI can reduce pollution by inducing innovative technology (Letchumanan and Kodama, 2000) and environment friendly product (Perkins and Neumayer, 2009) to the host country. On the other hand, the signs of FDI variable for waste gas and solid waste pollution indices are positive, supporting the existence of PHH. FDI seems to allocate air- and solid waste-polluted industries into China and to exacerbate industrial waste gas and solid wastes pollution. These findings are opposite to those in Zhou, Zhang and Li (2013), who found FDI helped to reduce CO_2 emission in China. They are also different from some empirical studies on the relationship between openness (trade) and environment in China (Yang, Lan and Zheng, 2011; Onafowora and Owoye, 2014).

The environmental effect of FDI is ambiguous, for the following reasons. The first one refers to difference in local environmental policy standard among regions. Panayoutou (2000) asserted that environment regulation had a feedback influence on FDI, meaning FDI can reduce pollution in strictly regulated regions and discharges more pollutant in laxly regulated regions. Due to disparity in economic development levels, the environmental regulation in coastal regions is expected to be stricter than inland China. Thus, FDI in coastal provinces may contribute more on environmental improving than the inland. Additionally, the main source regions of industrial water pollution allocate along coast of China. According to the data for 2012, the top four regions discharging most wastewater were Guangdong, Jiangsu, Shandong and Zhejiang. All these four regions are coastal regions, and their sum of wastewater emission accounts 34.13% of total China. And the top four regions discharging most waste gas pollution were Hebei, Shanxi, Inner Mongolian and Shandong; they totally account 27.78% China’s waste gas emission. Expect Shandong; other three regions locate in inland China. That may provide the reason that FDI facilities the reduction of industrial wastewater pollution but not waste gas or solid wastes pollution. Secondly, FDI originating from a variety of countries might have different environmental performance. For example, Cole, Elliott and Zhang (2011) clarified FDI by origin regions: FDI sourcing from Hong Kong, Taiwan, and Macau or other regions. Their empirical result suggested for a particular pollutant, these two groups of FDI own different environmental performance. It is detected that environmental effect of FDI may vary due to its some specific characters such as origin country and business strategy. This issue of FDI will be further examined in next chapter.

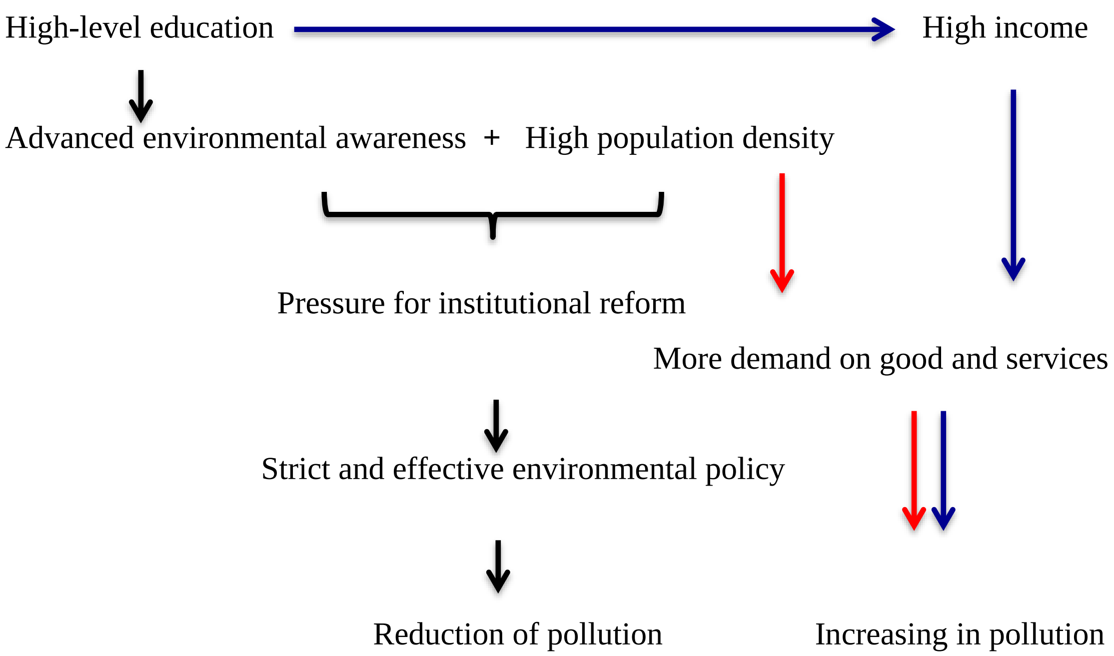
6.5 Policy, Population and Education

The effect of environmental regulations is measured by completed investment in the treatment of industrial pollution in this study. Unexpectedly, there is significant evidence that expenditures on environment promote wastewater and waste gas discharges but insignificantly reduce solid wastes emission. This finding is different from previous literature that local environmental policy had improving effect on air quality (Shaw et al., 2010). The expenditure on environmental protection from China's central and local government extremely increased in recent years. The total expenditure was 1.3297 million in 2005, 19.3404 million in 2009 and 29.6346 million in 2012 (NBSC, 2004; 2010; 2013). However, the regulation is not effective enough to ease environmental tension in China despite the input in environmental improvement increased over 20 times. Due to the administrative decentralisation structure, local government own strong power to formulate and implement local environmental policy rather than to obey the central government. And in reality, economic development still takes precedence over everything else for local government (Zhou, Zhang and Li, 2013).

The empirical results suggest that urban population density significantly contributes to environmental degradation in China， which is consistent with past literature (Lantz and Feng, 2006; Saka, 2014). From 2001 to 2012, the share of urban population in China grew from 37.66% to 52.57% and the total urban population increased from 480.64 million to 711.82 million. Increasing in urban population is associated with expanding demand for goods and services. Thus, the population integration into urban area remits the pressure on rural environment, but it leads industrial growth accompanied with more energy consumption and pollutant emission (World development report, 1992).

In this study, education standard presents public awareness on environmental protection. However, the ratio of population receiving higher education has found an unexpected positive coefficient, meaning that higher education increases industrial pollution in China. It is suggestive that, high education experience does not give Chinese people advanced environmental awareness but probably more ability to achieve luxuriant material lives. Pursuing material consumption leads increasing demand for goods and services, contributing to more industrial pollution (Israel and Levinson, 2004).

Additionally, the effect of education on the environment is not direct but is levered by environmental policy. The process and relationship among environmental policy, population density and education can be described as follows (Black, blue and red line indicate three separate processes):



Following the process presented by black line, under the assumption that high-educated people possess advanced environmental awareness (Selden and Song, 1994), higher level education combining with higher population density who asks for environmental amenity will create pressure on government for institutional reform. Then strict and efficient environmental policy will be applied to reduce pollution and to improve environment quality. Every element of this process takes a crucial role and may affect the environmental effect of education. Empirical studies have already suggested the improving effect of population density on industrial pollution (Lantz and Feng, 2006) and ineffectiveness of environmental policy in China (Zhou, Zhang and Li, 2013). Therefore, this consecutive operation that education reduces pollution is interrupted.

Overall, the relationship between income level and industrial water and waste gas pollution adhere EKC trajectory. And most of the regions have already passed the turning point. The curve for industrial solid waste pollution exhibits a U-shape, indicating solid wastes pollution will worsen in near future. Underlying these non-linear nexuses, the pollution reducing factors are composition effect, and increasing factors are environmental policy, urban population density and education. Environmental effects of FDI and technique effect are ambiguous.

7. Conclusions

With concern about the serious environmental degradation, this study has explored the nexus between economic development and industrial pollution in China using a panel data set that covers 30 provincial level regions during 2001- 2012. The environmental effects of secondary industry and tertiary industry, FDI inflows, expenditure on R&D activity and pollution abatement, urban population density and education are also evaluated.

Empirical results show that EKC trajectory exists in the case of industrial wastewater and air pollution with turning points in a range between RMB 20,024 – 21,298 for wastewater and RMB 23,584 – 26,517 for waste gas, respectively. However, the relationship between industrial solid wastes pollution and economic development adhere a U-shaped curve, and the stationary point is between RMB 23,646 and 26,084 GDP per capita. Almost all regions passed the turning points for all three pollution indices in 2012. Thus, in near future, the industrial wastewater and air pollution will reduce, but solid pollution will increase along with economic growth.

The composition effect, measured by the shares of secondary- and tertiary industry in GDP, has been confirmed as a pollution reducing factor for solid wastes pollution. The negative coefficient of secondary industry possibly implies the improvement in energy efficiency and success of pollution abatement actions. The evidence is found that technique effect significantly reduces industrial wastewater and air pollution but increase solid waste emission. Expenditure on industrial pollution abatement, urban population density and education are all driving forces for environmental degradation. FDI inflows have a significant negative impact on water pollution but positive on air and solid waste pollutions. The inconsistency of FDI's effect is probably due to the lack of investigation on different type of FDI.

Although some of the empirical results are ambiguous and insignificant, they do have meaningful policy implications. It is important for the government at different levels to promote R&D, innovation and technology upgrading which are crucial for the water and air quality. Also, it is necessary to improve the efficiency of environmental policy through stricter environmental regulations, to ensure the investment in environmental abatement to have more effective impact on pollution reduction. Additionally, Government should attach great importance to environment education to increase public awareness, which should be worked together with stricter environmental regulations.

A limitation of this study is lack of examination of environmental effects of different kinds of FDI. Environmental performance of FDI may vary due to its some specific characters such as origin country and business strategy.

Appendices

Appendix 1: Water, Gas and Solid Pollution Indices from 2001-2012

Appendix 1.1 Water pollution index

REGION	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia
2001	0.24	0.27	0.33	0.2	0.15
2002	0.12	0.35	0.37	0.24	0.24
2003	0.07	0.37	0.34	0.24	0.27
2004	0.07	0.42	0.42	0.29	0.31
2005	0.05	0.42	0.31	0.2	0.29
2006	0.03	0.35	0.39	0.31	0.26
2007	0.02	0.37	0.38	0.37	0.21
2008	0.01	0.3	0.3	0.31	0.23
2009	0.01	0.26	0.29	0.32	0.26
2010	0	0.19	0.23	0.25	0.25
2011	0	0.17	0.2	0.15	0.27
2012	0	0.2	0.25	0.21	0.29

REGION	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu
2001	0.39	0.21	0.14	0.49	0.4
2002	0.38	0.24	0.18	0.47	0.46
2003	0.34	0.23	0.2	0.42	0.45
2004	0.33	0.24	0.19	0.37	0.49
2005	0.43	0.24	0.18	0.26	0.45
2006	0.4	0.29	0.22	0.27	0.49
2007	0.39	0.26	0.24	0.26	0.45
2008	0.34	0.25	0.23	0.2	0.4
2009	0.33	0.24	0.18	0.2	0.42
2010	0.26	0.22	0.15	0.15	0.38
2011	0.22	0.17	0.14	0.15	0.31
2012	0.27	0.23	0.21	0.22	0.41

REGION	Zhejiang	Anhui	Fujian	Jiangxi	Shandong
2001	0.66	0.18	0.25	0.1	0.23
2002	0.66	0.19	0.3	0.11	0.26
2003	0.62	0.17	0.36	0.14	0.25
2004	0.65	0.19	0.44	0.17	0.28
2005	0.52	0.14	0.39	0.14	0.22
2006	0.62	0.22	0.42	0.2	0.26
2007	0.66	0.27	0.43	0.25	0.28
2008	0.57	0.21	0.42	0.2	0.25
2009	0.56	0.23	0.45	0.22	0.26
2010	0.49	0.16	0.36	0.21	0.26

2011	0.34	0.12	0.43	0.2	0.16
2012	0.45	0.14	0.37	0.22	0.22

REGION	Henan	Hubei	Hunan	Guangdong	Guangxi
2001	0.22	0.33	0.28	0.12	0.42
2002	0.24	0.35	0.43	0.19	0.55
2003	0.23	0.32	0.35	0.2	0.68
2004	0.3	0.35	0.42	0.24	0.89
2005	0.23	0.23	0.32	0.26	0.71
2006	0.3	0.29	0.39	0.27	0.75
2007	0.32	0.32	0.44	0.29	0.83
2008	0.29	0.3	0.35	0.23	0.78
2009	0.29	0.29	0.35	0.22	0.64
2010	0.23	0.23	0.22	0.19	0.61
2011	0.15	0.22	0.23	0.17	0.26
2012	0.19	0.24	0.26	0.23	0.36

REGION	Hainan	Chongqing	Sichuan	Guizhou	Yunnan
2001	0.05	0.38	0.26	0.01	0.08
2002	0.08	0.41	0.31	0.01	0.1
2003	0.08	0.44	0.32	0.02	0.09
2004	0.07	0.5	0.32	0.02	0.11
2005	0.07	0.38	0.19	0	0.07
2006	0.08	0.48	0.24	0	0.09
2007	0.07	0.43	0.26	0	0.1
2008	0.07	0.38	0.23	0	0.1
2009	0.08	0.37	0.22	0	0.09
2010	0.05	0.21	0.18	0	0.08
2011	0.07	0.11	0.08	0.06	0.14
2012	0.09	0.12	0.09	0.08	0.15

REGION	Shaanxi	Gansu	Qinghai	Ningxia	Xinjiang
2001	0.08	0.24	0.03	0.67	0.12
2002	0.13	0.2	0.02	0.82	0.19
2003	0.14	0.18	0.02	0.82	0.23
2004	0.15	0.23	0.03	0.54	0.27
2005	0.14	0.19	0.24	0.97	0.22
2006	0.16	0.32	0.28	0.93	0.27
2007	0.23	0.22	0.34	0.96	0.29
2008	0.23	0.22	0.35	0.92	0.31
2009	0.24	0.29	0.4	0.96	0.34
2010	0.19	0.12	0.38	0.95	0.3
2011	0.16	0.23	0.3	0.91	0.37
2012	0.17	0.24	0.37	0.92	0.4

Appendix 1.2 Gas pollution index

REGION	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia
2001	0.28	0.49	0.41	0.81	0.48
2002	0.21	0.52	0.38	0.81	0.52
2003	0.17	0.53	0.36	0.8	0.74
2004	0.15	0.33	0.41	0.8	0.91
2005	0.14	0.47	0.46	0.84	0.97
2006	0.12	0.41	0.46	0.75	0.89
2007	0.11	0.34	0.51	0.79	0.89
2008	0.05	0.3	0.4	0.75	0.92
2009	0.04	0.26	0.43	0.73	0.92
2010	0.02	0.2	0.25	0.56	0.74
2011	0.01	0.23	0.47	0.73	0.78
2012	0	0.24	0.45	0.72	0.85
REGION	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu
2001	0.47	0.21	0.19	0.54	0.32
2002	0.42	0.18	0.16	0.51	0.28
2003	0.41	0.16	0.17	0.45	0.27
2004	0.37	0.18	0.17	0.42	0.27
2005	0.61	0.23	0.18	0.41	0.29
2006	0.55	0.22	0.18	0.29	0.25
2007	0.54	0.21	0.2	0.27	0.22
2008	0.66	0.22	0.22	0.23	0.21
2009	0.48	0.25	0.23	0.18	0.21
2010	0.31	0.17	0.16	0.11	0.15
2011	0.39	0.24	0.17	0.15	0.21
2012	0.43	0.19	0.21	0.15	0.22
REGION	Zhejiang	Anhui	Fujian	Jiangxi	Shandong
2001	0.3	0.11	0.11	0.1	0.35
2002	0.27	0.08	0.08	0.08	0.3
2003	0.28	0.1	0.12	0.12	0.28
2004	0.28	0.11	0.13	0.16	0.26
2005	0.27	0.12	0.17	0.15	0.29
2006	0.23	0.13	0.15	0.16	0.23
2007	0.23	0.14	0.17	0.15	0.24
2008	0.21	0.17	0.16	0.18	0.23
2009	0.22	0.17	0.17	0.17	0.22
2010	0.14	0.13	0.14	0.14	0.17
2011	0.16	0.17	0.14	0.17	0.22
2012	0.16	0.18	0.16	0.17	0.21
REGION	Henan	Hubei	Hunan	Guangdong	Guangxi
2001	0.21	0.19	0.19	0.18	0.34
2002	0.19	0.17	0.17	0.16	0.3
2003	0.18	0.15	0.16	0.15	0.3
2004	0.2	0.18	0.18	0.15	0.37
2005	0.25	0.17	0.18	0.14	0.34
2006	0.21	0.17	0.18	0.12	0.29

2007	0.2	0.13	0.19	0.11	0.3
2008	0.19	0.14	0.2	0.12	0.29
2009	0.19	0.14	0.22	0.1	0.33
2010	0.15	0.1	0.15	0.08	0.26
2011	0.17	0.14	0.1	0.07	0.2
2012	0.16	0.13	0.1	0.07	0.21

REGION	Hainan	Chongqing	Sichuan	Guizhou	Yunnan
2001	0.01	0.3	0.24	0.29	0.11
2002	0.11	0.26	0.21	0.25	0.07
2003	0	0.22	0.17	0.18	0.09
2004	0	0.27	0.19	0.19	0.1
2005	0.01	0.24	0.15	0.16	0.1
2006	0	0.28	0.14	0.27	0.11
2007	###	0.28	0.18	0.29	0.11
2008	0.01	0.27	0.1	0.21	0.11
2009	0	0.32	0.09	0.19	0.11
2010	0	0.21	0.12	0.18	0.09
2011	0	0.17	0.1	0.23	0.18
2012	0.02	0.17	0.1	0.27	0.19

REGION	Shaanxi	Gansu	Qinghai	Ningxia	Xinjiang
2001	0.29	0.24	0.25	0.79	0.23
2002	0.26	0.23	0.22	0.84	0.2
2003	0.24	0.25	0.27	0.85	0.22
2004	0.27	0.23	0.35	0.75	0.29
2005	0.26	0.24	0.43	0.84	0.3
2006	0.25	0.21	0.45	0.77	0.31
2007	0.26	0.19	0.48	0.85	0.35
2008	0.28	0.18	0.59	0.82	0.41
2009	0.27	0.2	0.6	0.77	0.46
2010	0.22	0.19	0.51	0.97	0.4
2011	0.27	0.24	0.51	1	0.45
2012	0.27	0.25	0.6	1	0.64

Appendix 1.3 Solid pollution index

REGION	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia
2001	0.21	0.17	0.23	0.61	0.4
2002	0.24	0.18	0.23	0.51	0.39
2003	0.26	0.24	0.24	0.5	0.36
2004	0.29	0.23	0.11	0.5	0.39
2005	0.33	0.14	0.11	0.5	0.15
2006	0.31	0.15	0.13	0.51	0.05
2007	0.41	0.28	0.21	0.62	0.02
2008	0.45	0.29	0.24	0.5	0.23
2009	0.44	0.29	0.12	0.39	0.04
2010	0.47	0.33	0.19	0.36	0.02
2011	0.49	0.45	0.4	0.42	0.29
2012	0.49	0.46	0.41	0.41	0.39

REGION	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu
2001	0.19	0.36	0.22	0	0.28
2002	0.13	0.37	0.2	0	0.28
2003	0.16	0.37	0.25	0.09	0.29
2004	0.21	0.38	0.29	0.15	0.29
2005	0.18	0.37	0.31	0.18	0.25
2006	0.17	0.33	0.29	0.21	0.24
2007	0.26	0.38	0.37	0.33	0.34
2008	0.19	0.4	0.37	0.34	0.35
2009	0.15	0.35	0.34	0.34	0.33
2010	0.28	0.37	0.38	0.39	0.38
2011	0.43	0.46	0.49	0.47	0.46
2012	0.47	0.46	0.46	0.48	0.46

REGION	Zhejiang	Anhui	Fujian	Jiangxi	Shandong
2001	0.37	0.3	0.08	0.4	0.21
2002	0.37	0.3	0.29	0.4	0.18
2003	0.37	0.32	0.28	0.39	0.22
2004	0.37	0.35	0.29	0.39	0.22
2005	0.37	0.34	0.27	0.39	0.2
2006	0.36	0.32	0.26	0.35	0.17
2007	0.4	0.37	0.34	0.41	0.28
2008	0.41	0.34	0.33	0.42	0.29
2009	0.4	0.3	0.24	0.4	0.24
2010	0.43	0.35	0.31	0.43	0.31
2011	0.48	0.44	0.48	0.49	0.43
2012	0.48	0.44	0.43	0.47	0.44

REGION	Henan	Hubei	Hunan	Guangdong	Guangxi
2001	0.38	0.36	0.45	0.45	0.41
2002	0.39	0.35	0.46	0.46	0.37
2003	0.38	0.35	0.44	0.44	0.4
2004	0.39	0.38	0.44	0.44	0.45
2005	0.38	0.37	0.43	0.44	0.44
2006	0.36	0.37	0.42	0.45	0.4

2007	0.4	0.41	0.44	0.47	0.41
2008	0.4	0.42	0.47	0.47	0.42
2009	0.37	0.4	0.44	0.47	0.4
2010	0.41	0.4	0.46	0.48	0.42
2011	0.46	0.5	0.49	0.49	0.48
2012	0.47	0.47	0.48	0.5	0.47

REGION	Hainan	Chongqing	Sichuan	Guizhou	Yunnan
2001	0.5	0.51	0.48	0.63	0.57
2002	0.5	0.5	0.46	0.59	0.54
2003	0.5	0.5	0.43	0.61	0.46
2004	0.5	0.49	0.41	0.5	0.42
2005	0.5	0.55	0.41	0.48	0.45
2006	0.5	0.55	0.41	0.5	0.45
2007	0.5	0.62	0.51	0.5	0.47
2008	0.5	0.8	0.42	0.53	0.44
2009	0.5	0.89	0.42	0.6	0.47
2010	0.5	0.92	0.43	0.55	0.47
2011	0.5	0.57	0.49	0.56	0.88
2012	0.5	0.53	0.49	0.58	0.73

REGION	Shaanxi	Gansu	Qinghai	Ningxia	Xinjiang
2001	0.51	0.49	0.47	0.38	0.5
2002	0.5	0.51	0.45	0.36	0.49
2003	0.49	0.47	0.5	0.32	0.52
2004	0.47	0.48	0.49	0.33	0.56
2005	0.46	0.49	0.46	0.32	0.57
2006	0.42	0.5	0.39	0.34	0.66
2007	0.45	0.48	0.41	0.34	0.57
2008	0.47	0.49	0.42	0.37	0.66
2009	0.42	0.5	0.38	0.27	0.86
2010	0.43	0.48	0.39	0.24	0.72
2011	0.49	0.49	0.01	0.41	0.95
2012	0.48	0.46	0	0.38	0.93

Appendix 2.1 Random effect results for water pollution index

VARIABLES	(1) WATER	(2) WATER	(3) WATER	(4) WATER	(5) WATER	(6) WATER	(7) WATER	(8) WATER	(9) WATER
Y	-0.0183*	1.351***	1.288***	1.316***	1.340***	1.530***	1.376***	1.256***	1.263***
	(0.00979)	(0.197)	(0.213)	(0.222)	(0.221)	(0.225)	(0.233)	(0.242)	(0.242)
Y2		-0.0707***	-0.0677***	-0.0689***	-0.0689***	-0.0767***	-0.0693***	-0.0636***	-0.0640***
		(0.0102)	(0.0109)	(0.0112)	(0.0112)	(0.0113)	(0.0116)	(0.0121)	(0.0121)
S2			0.0446	0.00881	-0.00154	0.0269	-0.0293	-0.0144	-0.0122
			(0.0571)	(0.0982)	(0.0983)	(0.0976)	(0.0997)	(0.0991)	(0.0996)
S3				-0.0459	-0.0342	-0.0217	-0.0531	-0.0406	-0.0391
				(0.103)	(0.103)	(0.102)	(0.103)	(0.102)	(0.102)
R					-0.0144	-0.0144	-0.0154*	-0.0170*	-0.0165*
					(0.00887)	(0.00876)	(0.00870)	(0.00878)	(0.00883)
F						-0.0397***	-0.0363***	-0.0357***	-0.0365***
						(0.0103)	(0.0104)	(0.0103)	(0.0104)
I							0.0210**	0.0210**	0.0203**
							(0.00873)	(0.00876)	(0.00885)
P								0.0125	0.0126*
								(0.00765)	(0.00765)
E									0.00490
									(0.00946)
Constant	0.460***	-6.134***	-5.986***	-5.831***	-6.026***	-7.057***	-6.021***	-5.588***	-5.607***
	(0.100)	(0.952)	(0.973)	(1.034)	(1.038)	(1.066)	(1.142)	(1.176)	(1.176)
Observations	360	360	360	360	360	360	360	360	360
Number of id	30	30	30	30	30	30	30	30	30

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 2.2 Random effect results for gas pollution index

VARIABLES	(1) GAS	(2) GAS	(3) GAS	(4) GAS	(5) GAS	(6) GAS	(7) GAS	(8) GAS	(9) GAS
Y	-0.00489	1.149***	0.887***	0.944***	1.007***	0.986***	0.816***	0.802***	0.815***
	(0.00898)	(0.182)	(0.194)	(0.203)	(0.196)	(0.205)	(0.212)	(0.222)	(0.221)
Y2		-0.0596***	-0.0469***	-0.0495***	-0.0493***	-0.0484***	-0.0402***	-0.0395***	-0.0406***
		(0.00938)	(0.00994)	(0.0103)	(0.00993)	(0.0103)	(0.0106)	(0.0110)	(0.0110)
S2			0.188***	0.117	0.0905	0.0909	0.0459	0.0535	0.0689
			(0.0529)	(0.0921)	(0.0894)	(0.0905)	(0.0919)	(0.0921)	(0.0921)
S3				-0.0899	-0.0551	-0.0507	-0.0722	-0.0666	-0.0534
				(0.0962)	(0.0935)	(0.0944)	(0.0943)	(0.0945)	(0.0945)
R					-0.0386***	-0.0387***	-0.0396***	-0.0396***	-0.0380***
					(0.00782)	(0.00793)	(0.00792)	(0.00802)	(0.00805)
F						0.00531	0.00825	0.00773	0.00577
						(0.00949)	(0.00952)	(0.00954)	(0.00957)
I							0.0216***	0.0217***	0.0197**
							(0.00795)	(0.00800)	(0.00807)
P								0.000725	0.000737
								(0.00699)	(0.00698)
E									0.0156*
									(0.00862)
Constant	0.333***	-5.223***	-4.603***	-4.312***	-4.848***	-4.767***	-3.727***	-3.708***	-3.786***
	(0.0952)	(0.879)	(0.886)	(0.939)	(0.913)	(0.963)	(1.038)	(1.073)	(1.072)
Observations	360	360	360	360	360	360	360	360	360
Number of ID	30	30	30	30	30	30	30	30	30

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 2.3 Random effect results for solid pollution index

VARIABLES	(1) SOLID	(2) SOLID	(3) SOLID	(4) SOLID	(5) SOLID	(6) SOLID	(7) SOLID	(8) SOLID	(9) SOLID
Y	0.0427***	-1.401***	-1.150***	-1.072***	-1.180***	-1.257***	-1.182***	-1.514***	-1.512***
	(0.0108)	(0.222)	(0.236)	(0.239)	(0.225)	(0.232)	(0.241)	(0.244)	(0.244)
Y2		0.0746***	0.0623***	0.0591***	0.0592***	0.0623***	0.0587***	0.0745***	0.0741***
		(0.0114)	(0.0121)	(0.0122)	(0.0114)	(0.0117)	(0.0121)	(0.0122)	(0.0122)
S2			-0.168***	-0.295***	-0.269***	-0.274***	-0.252***	-0.233***	-0.226**
			(0.0579)	(0.0929)	(0.0886)	(0.0895)	(0.0922)	(0.0896)	(0.0903)
S3				-0.179*	-0.228**	-0.232**	-0.222**	-0.203**	-0.196**
				(0.101)	(0.0963)	(0.0971)	(0.0979)	(0.0950)	(0.0955)
R					0.0639***	0.0648***	0.0656***	0.0604***	0.0611***
					(0.00926)	(0.00928)	(0.00932)	(0.00910)	(0.00913)
F						0.0130	0.0103	0.0117	0.0117
						(0.00991)	(0.00997)	(0.00968)	(0.00975)
I							-0.00874	-0.00860	-0.00980
							(0.00933)	(0.00904)	(0.00913)
P								0.0377***	0.0376***
								(0.00784)	(0.00783)
E									0.00994
									(0.00987)
Constant	-0.0183	6.934***	6.298***	7.001***	7.911***	8.319***	7.856***	9.171***	9.159***
	(0.107)	(1.073)	(1.085)	(1.166)	(1.096)	(1.139)	(1.232)	(1.224)	(1.222)
Observations	360	360	360	360	360	360	360	360	360
Number of ID	30	30	30	30	30	30	30	30	30

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 3.1 Model with trade intensity for water pollution index

VARIABLES	(1) WATER	(2) WATER	(3) WATER	(4) WATER	(5) WATER	(6) WATER	(7) WATER	(8) WATER	(9) WATER
Y	-0.0198**	1.353***	1.322***	1.404***	1.425***	1.413***	0.800***	0.753***	0.752***
	(0.00991)	(0.198)	(0.215)	(0.227)	(0.227)	(0.226)	(0.271)	(0.273)	(0.274)
Y2		-0.0709***	-0.0695***	-0.0732***	-0.0730***	-0.0717***	-0.0459***	-0.0434***	-0.0434***
		(0.0102)	(0.0110)	(0.0115)	(0.0114)	(0.0114)	(0.0130)	(0.0131)	(0.0131)
S2			0.0222	-0.0753	-0.0838	-0.112	-0.162	-0.155	-0.154
			(0.0600)	(0.107)	(0.106)	(0.108)	(0.106)	(0.106)	(0.107)
S3				-0.122	-0.107	-0.119	-0.162	-0.160	-0.158
				(0.110)	(0.111)	(0.111)	(0.109)	(0.109)	(0.109)
R					-0.0144	-0.0134	-0.0246***	-0.0249***	-0.0247***
					(0.00894)	(0.00894)	(0.00920)	(0.00919)	(0.00925)
T						0.0134	-0.0792***	-0.0715***	-0.0717***
						(0.00857)	(0.0250)	(0.0257)	(0.0257)
I							0.102***	0.0941***	0.0940***
							(0.0259)	(0.0266)	(0.0266)
P								0.0100	0.0100
								(0.00776)	(0.00777)
E									0.00185
									(0.00937)
Constant	0.475***	-6.133***	-6.062***	-5.684***	-5.885***	-5.792***	-1.829	-1.725	-1.722
	(0.0965)	(0.957)	(0.977)	(1.034)	(1.039)	(1.039)	(1.432)	(1.432)	(1.435)
Observations	360	360	360	360	360	360	360	360	360
Number of id	30	30	30	30	30	30	30	30	30
R-squared	0.012	0.138	0.139	0.142	0.149	0.155	0.194	0.198	0.198

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 3.2 Model with trade intensity for gas pollution index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS
Y	-0.00512	1.155***	0.922***	1.018***	1.076***	1.057***	1.237***	1.209***	1.204***
	(0.00906)	(0.183)	(0.195)	(0.206)	(0.199)	(0.197)	(0.241)	(0.243)	(0.242)
Y2		-0.0600***	-0.0487***	-0.0530***	-0.0525***	-0.0505***	-0.0581***	-0.0566***	-0.0568***
		(0.00944)	(0.00999)	(0.0104)	(0.0101)	(0.00997)	(0.0115)	(0.0117)	(0.0116)
S2			0.170***	0.0555	0.0323	-0.0140	0.000649	0.00455	0.0163
			(0.0546)	(0.0969)	(0.0936)	(0.0938)	(0.0944)	(0.0945)	(0.0944)
S3				-0.144	-0.102	-0.123	-0.110	-0.109	-0.0971
				(0.100)	(0.0972)	(0.0963)	(0.0967)	(0.0967)	(0.0966)
R					-0.0393***	-0.0377***	-0.0344***	-0.0346***	-0.0332***
					(0.00786)	(0.00778)	(0.00818)	(0.00818)	(0.00819)
T						0.0221***	0.0494**	0.0541**	0.0529**
						(0.00747)	(0.0222)	(0.0229)	(0.0228)
I							-0.0300	-0.0347	-0.0353
							(0.0230)	(0.0236)	(0.0236)
P								0.00614	0.00598
								(0.00691)	(0.00688)
E									0.0147*
									(0.00830)
Constant	0.335***	-5.250***	-4.707***	-4.263***	-4.812***	-4.660***	-5.827***	-5.763***	-5.736***
	(0.0882)	(0.883)	(0.889)	(0.940)	(0.914)	(0.905)	(1.273)	(1.275)	(1.271)
Observations	360	360	360	360	360	360	360	360	360
Number of id	30	30	30	30	30	30	30	30	30
R-squared	0.001	0.110	0.136	0.141	0.203	0.224	0.228	0.230	0.237

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix 3.3 Model with trade intensity for solid pollution index

VARIABLES	(1) SOLID	(2) SOLID	(3) SOLID	(4) SOLID	(5) SOLID	(6) SOLID	(7) SOLID	(8) SOLID	(9) SOLID
Y	0.0587***	-1.551***	-1.271***	-1.248***	-1.330***	-1.320***	-1.501***	-1.649***	-1.653***
	(0.0110)	(0.218)	(0.233)	(0.246)	(0.234)	(0.234)	(0.287)	(0.283)	(0.282)
Y2		0.0832***	0.0696***	0.0686***	0.0678***	0.0668***	0.0744***	0.0824***	0.0821***
		(0.0112)	(0.0119)	(0.0125)	(0.0118)	(0.0119)	(0.0137)	(0.0136)	(0.0136)
S2			-0.204***	-0.232**	-0.199*	-0.175	-0.190*	-0.170	-0.159
			(0.0650)	(0.116)	(0.110)	(0.112)	(0.112)	(0.110)	(0.110)
S3				-0.0346	-0.0929	-0.0826	-0.0951	-0.0878	-0.0771
				(0.120)	(0.114)	(0.114)	(0.115)	(0.112)	(0.113)
R					0.0555***	0.0547***	0.0514***	0.0506***	0.0518***
					(0.00924)	(0.00925)	(0.00973)	(0.00952)	(0.00955)
T						-0.0112	-0.0385	-0.0142	-0.0153
						(0.00888)	(0.0265)	(0.0266)	(0.0266)
I							0.0300	0.00561	0.00504
							(0.0274)	(0.0275)	(0.0275)
P								0.0318***	0.0316***
								(0.00803)	(0.00802)
E									0.0135
									(0.00967)
Constant	-0.174	7.574***	6.924***	7.031***	7.806***	7.728***	8.895***	9.224***	9.249***
	(0.107)	(1.052)	(1.058)	(1.123)	(1.075)	(1.075)	(1.514)	(1.484)	(1.482)
Observations	360	360	360	360	360	360	360	360	360
Number of id	30	30	30	30	30	30	30	30	30
R-squared	0.080	0.211	0.234	0.235	0.311	0.315	0.317	0.349	0.353

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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Chapter 2: Does Distance Matter in FDI Sub-national Location Choice? Evidence from China

1. Introduction

How MNEs make investment decisions has been a dominate topic in the area of international business research over the past decades. The mainstream of research, focusing on country-specific factors, has influenced the flow, distribution, and entry mode of FDI across the world. As a result, it overlooks the effects of relational factors between the source and recipient regions of investment. Some recent studies investigated how distance between countries impacts the flow of economic activity across borders (Kogut and Singh, 1998; Slangen, Fortanier, and Tulder, 2007; Tsang and Yip, 2007). However, there are few studies on the influence of distance factors at a sub-national level.

A growing number of empirical studies implies that MNEs make equal considerations regarding sub-national locational advantages offered by multi-level local governments when selecting a proper site for investment (Nielsen, Asmussen, and Weatherall, 2017). Accurate and comprehensive attention paid to sub-national locational characteristics is particularly critical for MNEs that are going to join a large market, since, in a geographically wide market, the regional disparity is tremendous. That regional disparity includes differences in language, culture, climate, economic development, and government administration, which are determinative factors in MNEs' location choices.

China is a particularly good case for exploiting the location patterns of FDI at a sub-national level. It is, geographically, the third-largest country with the biggest population in the world. Due to its vast territory, diverse climate, and natural environment, the culture, economy, and institutions differ across various regions. Thus, it is not reasonable to measure the distance between the home country of the FDI and China as a whole. In terms of geographic distance, the straight-line distances across China are 5,500 kilometres from the north to the south and 5,200 kilometres from the east to the west. Due to such a large territory, a particular country may be at distinct distances from different regions in China. The vast land area has created enormous regional differences in the economy. Transportation and communications in the eastern region are well-developed, and many cities in that region possess considerable technical know-how. Moreover, the middle and western regions have the advantage of being well-endowed with natural resources. Thus, MNEs will face a business environment proprietary to a particular host region in China. That regional disparity makes location choice more strategically important for MNEs.

Prior empirical literature on sub-national location choices of FDI in China used aggregated FDI inflow data, which failed to reveal a difference in location choice among various source countries (Chen, 1996; Cheng Kwan, 2000; Sun Tong and Yu, 2002). However, some empirical studies found that location choice strategy differs among home countries and is changing over time (Pan, 1997). Additionally, according to the eclectic OLI (O-ownership; L-location; I-international) theory, MNEs' ownership advantages highly depend on country specific characteristics, but crucially determine the destination of foreign investments (Dunning, 1980). Thus, MNEs, who source from different countries, are supposed to have various considerations and standards regarding location choice, since they have diverse ownership advantages. Therefore, we want to examine FDI location choice, considering the characteristics of both home and host regions. In addition, we focus on the distance and linkage between the home country and host destination.

Our study uses novel FDI data, sorted by home country at a regional level, from 2000 to 2012. Besides the dependent variable, we also introduce distance as an independent variable, which is widely used in national-level studies but rarely in sub-national location choice studies. This paper contributes to the literature in two distinct aspects. First, although recent studies found the distance between countries to be significant on economic activities across countries, they did not consider the influence of distance on sub-national level investment decisions. We aim to fill this gap by estimating a gravity model with distance proxies between the FDI's home country and the host region in China. Second, differing from FDI location choice studies in China, we estimate a gravity model with a novel dependent variable, FDI flow by home country and host region over time, to explore the effects of both home and host regions, rather than just a unilateral effect. The empirical results imply that a gravity model can explain FDI flow in China; FDI increases with market size on both sides of the investment but decreases with geographic distance, and FDI prefers to locate in a culturally close but economically dissimilar region. Additionally, economic standards in both host and home regions, the R&D level in the home country, and a bonded area in the host region are contributing factors to FDI flow.

The rest of the paper is organised as follows: The next section reviews relevant theoretical and empirical literature in terms of how distance impacts FDI location choice. Section 3 outlines the methodology, including the model estimate, data description, and estimate selection. Section 4 presents and discusses the empirical results. And, the final section is a summary and conclusion.

2. Literature Review

2.1 Determinants of FDI: The Eclectic Paradigm

The eclectic paradigm or OLI theory, developed by Dunning (1980), is widely used to explain international production or FDI. It embraces both internalisation theory and trade theory. Dunning proclaims that FDI is preferred when there are simultaneous ownership advantages (O), location advantages (L), and internalisation advantages (I). Generally, an enterprise has several possible approaches for achieving growth. It can develop horizontally, which means creating new product lines, or vertically, into new activities, such as supplying or after-sales service. Also, it can expand market share by acquiring existing enterprises or exploiting foreign markets. If it chooses the latter route to becoming an international enterprise, it must have more ownership advantages than domestic competitors in the host country, and those ownership advantages must significantly outweigh the risks and costs of servicing an unfamiliar market (Hirsch, 1976). An enterprise that invests abroad has to be able to afford the cost of acquiring information due to cultural and language differences.

In 2006, Mathews extended the eclectic paradigm from the OLI to an alternative LLL (linkage, leverage, and learning) framework, introducing the roles of network and interfirm linkage. In terms of internationalisation, the new/latecomer prefers a joint venture rather than a wholly owned business, to obtain cooperation with a host partner and access local knowledge and networks.

Based on the LLL perspective, Buckley, Forsans, and Munjal (2012) introduced the linkage between the host and home countries into the eclectic paradigm as an institutional asset. They reconstructed the eclectic paradigm theory with the idea that the determinants of international business activities can be classified by country-specific ownership advantages (CSAs), host country-specific location advantages, and the distance and linkage between the home and host countries. Home country factors often significantly relate to outward FDI, since institutions and the macro-economic environment can be transferred to firms' competitive advantages in internationalised processes. Host country-specific location advantage refers to the host country's locational attractions. Cross-country distance or linkage captures the interactive effect of a pair of home and host countries, which impacts the flow between them. Buckley, Forsans, and Munjal (2012) believed that linkage variables improved the explanatory power of the eclectic paradigm and are shown to be an adjunct not an alternative.

2.2 Why Distance Matters? Liability of foreignness (LOF) and costs of doing business abroad (CDBA)

Defined by the OECD, FDI refers to a cross-national investment by a resident entity in one economy, aiming to obtain a lasting return and profit from an enterprise resident in another economy. The lasting return and profit leads to a long-term linkage existing between the investor and host region and considerable influence by the direct investor on enterprise operations. However, the long-lasting relationship or influence can be weakened by the conflicts generated by the dissimilarity and distance between home and host countries (Hymer, 1976), which is commonly defined as liability of foreignness (LOF; Berry et al., 2010; Johanson and Vahlne, 2009). According to Hymer (1976), cross-national distance leads to some LOF, which generates additional costs of investing abroad. Thus, MNEs may make strategy and location choices aiming to avoid or reduce LOF caused by such distance.

Hymer (1976) believed that foreign firms would afford the costs of doing business abroad (CDBA), since compared to domestic firms, they face disadvantages and barriers to integrating into the host market. CDBA were classified into four types by Hymer (1976). First, MNEs have an information disadvantage, which domestic firms do not have. The shortage of information makes MNEs incur set-up costs on initial information acquisition. Second, discriminatory treatment may exist. Foreign firms could be treated differently, or even worse, by the government, buyers, and suppliers, compared to domestic firms. Third, the government in the firm’s home country could also restrict firms’ internationalisation, for instance, by prohibiting the firms from carrying out specific activities or levying higher tax. Finally, foreign firms could face risks associated with exchange rate fluctuations, since receipts and payments of foreign currencies are not synchronised.

Zaheer (1995) built the foundation for empirical work on CDBA through exploring the patterns in trading rooms of U.S. and Japanese banks. LOF was categorised into four concepts: costs due to spatial distance (travel, transport, and coordination), unfamiliarity with the local environment, differential treatment by the host country, and costs imposed by the home country environment. She also argued that the concepts of CDBA and LOF were not the same. She announced that CDBA originated from an economic approach, whereas LOF came from socio-institutional analysis.

However, Eden and Miller (2004) held a different view: CDBA was a border concept, including LOF as a crucial component. They believed that LOF referred to social costs that were mainly raised by institutional distance (cognitive, normative, and regulatory), whereas CDBA covered both economic costs, which were driven by geographic distance related to economic activities (production, marketing, and distribution), and social costs.

Based on motivations for going abroad, FDI can be categorised into vertical FDI and horizontal FDI. Considering vertical FDI, for instance, exporting accounts form a great part of the total cost. Assuming the inputs of manufacturing are the same in all countries, exporting generates transport, insurance, communication, and exchange costs and trade barriers (tariffs and entry and license fees). And these costs are proportional to distance. Horizontal FDI sells products on the host country market instead of exporting, and so, the distance-related costs are lower. However, they need to pay the costs of adapting products to the local market and training local workers to use the MNE's technology. To cover various types of FDI, Eden and Miller (2004) defined economic costs as activity-based costs including transportation, communication, and trade barrier costs, which are mainly caused by the spatial distance between home and host markets.

LOF and social costs can be deconstructed into three hazards (Eden and Miller, 2004; Zaheer, 2002). Unfamiliar hazards refer to the costs driven by the lack of knowledge of, or experience in, the host country. This LOF is not determined by the age of the MNE, but rather by the cumulativeness of its business operating experience in the local economy. Unfamiliar hazards make MNEs spend additional time and money on obtaining knowledge to put them at a comparable level with local firms. The sources of information can be local production, investment in marketing, previous experiences in similar markets, cooperating with a local joint venture partner, and so on. These information gathering costs should reduce over time; however, Petersen and Pedersen

(2002) argued that they can exist in the long term if MNE managers comply with a standardised global strategy and do not proactively engage in local learning.

The second hazard is the discriminatory treatment of the foreign firm in the host country. MNEs could be treated differently by both the home or host government, consumers, or the general public in the host country. These costs are possibly caused by political hazards (Henisz and Williamson, 1999) or consumer ethnocentricity in the local market (Balabanis et al., 2001; Sumner, 1906). Eden and Miller (2004) argued that foreignness needs to be viewed both from the MNE's perspective of the host country (outside-inside) and from the host country's perspective of the MNE (inside-outside).

Kostova and Zaheer (1999) announced that discriminatory treatment occurs since the host country is unfamiliar with the foreign firm (an inside-outside approach), resulting in conventional and unfair regulation being imposed on MNEs. The MNEs' lack of integration into the host country, relative to local firms, leads to discriminatory treatment by host country stakeholders. Even if the host country promises equal treatment to foreign investors, MNEs may suffer informal discriminatory treatment if they are viewed as an outsider. In fact, this LOF should be redefined nowadays, as economic globalisation; FDI is widely accepted as an important driver of economic growth, and success in attracting FDI is a crucial economic objective for many countries, especially developing economies. Some host country governments provided preferable policies for FDI, including tax concessions, subsidies, and so on. Thus, the existence of discriminatory treatment from host country governments may vary across different host countries.

Every firm pays costs of organisation (Masten et al., 1991), whether in the form of internal organisational costs (intrafirm transactions) or external ones (external market transactions). For firms operating in unfamiliar economies, both sets of organisational costs are higher (Caves, 1971), since MNEs face both greater external and internal uncertainties than domestic firms. External uncertainty comes from the unpredictability and unfamiliarity of foreign environments, and internal uncertainty is led by the challenge of managing employees at a distance and from dissimilar cultures (Anderson and Gatignon, 1986). These uncertainties raise administrative costs of maintaining and communicating with parties involved in business abroad (Buckley and Casson, 1998; Henisz and Williamson, 1999), which are defined as relational hazards.

In terms of intra-organisational relations, geographic distance increases the difficulties of supervising and managing employees (Hennart, 2001). And, internationally diversified firms need to face high transaction costs (Hitt et al., 1997, p. 773) and deal with the conflicting lines of authority and multiple sources of value (Sundaram and Black, 1992). Cultural distance is a possible driver behind governance costs, since motivation and objectives differ among cultures (Calhoun, 2002). The routines of parent headquarters are also likely to be conveyed to subsidiaries (Kostova and Roth, 2002; Kostova and Zaheer, 1999). On the other hand, the additional cost of trust building with business partners and customers is an inter-organisational relational hazard. It includes costs of negotiating, monitoring, and dispute settlement. Trust is a crucial mechanism for reducing transaction costs in an uncertain environment (Doney et al., 1998), in contributing to maintaining long-term relationships between firms (Ring and Van de Ven, 1992), and in determining strategic alliance success (Gulati, 1995). Thus, considering the importance of trust, inter-organisational relation costs are inevitable.

According to the definitions of CDBA and LOF, made by Eden and Miller (2004), the source of economic costs can be clearly confirmed as geographic distance, whereas the source of social costs seems to be unfamiliarity generated by institutional distance. The institutional environment determines business activities, which means that different levels of institutional development and factor endowments lead to different aspects of business activities (North, 1990). Institutions have three aspects affecting LOF: regulatory, normative, and cognitive (Scott, 2008). The regulatory dimension represents the formal rules and regulations supervised and executed by the state (North, 1990). The normative dimension refers to legal and rationale means sanctioned by society to address legitimate objectives (Scott, 2008). The cognitive dimension is the mental concept, image, values, and beliefs held by people in society (DiMaggio and Powell, 1983). Institutional distance is defined as the extent of similarity or dissimilarity between two countries in regulative, normative, and cognitive aspects (Kostova and Zaheer, 1999). Greater institutional distance leads to more unfamiliarity, discrimination, and relational hazards as consequences of rising

LOF (Eden and Miller, 2004). DiMaggio and Powell (1983) argued that institution is the source of coercive, mimetic, and normative pressures on firms to become isomorphic. Thus, a similar institutional environment reduces that isomorphic pressure. Some scholars have found evidence that firms operating in institutionally dissimilar countries have more difficulties transferring administrative routines and capabilities (Kostova and Roth, 2002; Kostova and Zaheer, 1999), and adopting organisational structures that minimise LOF.

In conclusion, geographic and institutional distance caused LOF to MNEs during international expansion. Therefore, MNEs need to utilise their advantages or specific strategies to overcome this. Some studies suggest solutions for avoiding LOF through entry mode strategies. Additionally, the effects of distance on LOF may also leverage on location choice of FDI. In a specific range of choice, an MNE may choose a host country with less LOF over others. Consequently, being a shorter distance from the home country is a competitive advantage in attracting FDI.

2.3 Dimensions of Distance and Empirical Evidence

'Distance' is a broad and comprehensive concept in studying international business, rather than an absolute geographic distance. It was defined and classified in various ways by scholars; for instance, geographic distance, institutional distance, cultural distance, and psychic distance. Both similarity or overlap and difference exist among these various dimensions of distance. This section introduces some principal dimensions of distance in mainstream international business studies and explains how these distances impact on international business activity with supporting evidence from empirical studies.

2.2.1 Geographic distance

Geographic distance has been considered as an impeding factor of countries' linkage, since it is a source of friction between markets and associated with greater transaction costs. Studies on international trade found strong evidence of these assertions (e.g., Disdier and Head, 2008; Frankel and Rose, 2002). However, in terms of FDI (e.g., Hirsch, 1976; Horstmann and Markusen, 1987; Markusen and Venables, 1998), some suggest that if high transport costs prevent an arm's length transaction, then building up a subunit could avoid these problems. A contrasting view from Helpman (1984) argues that if the purpose of FDI is to reduce costs, it can be defined as vertical FDI, and the relationship is mainly interarm, then the effect of distance will be to reduce FDI. Buckley, Forsans, and Munjal (2012) also hypothesised a positive relationship between geographic distance and FDI, as MNEs will prefer FDI over exporting to avoid extra transportation costs due to distance.

Initially, geographic distance presents transport and communication costs, which relate to international trade, personal interaction, and information exchange. However, regarding economic globalisation, despite transport and communication costs declining, the impact of distance has not disappeared. According to most empirical studies, although transportation and communication technology has significantly improved, and, for instance, Internet telephony has reduced the ‘friction’ of distance to zero, geographic distance still significantly and negatively relates to FDI, even when the effects of colonial relations and the common language are controlled (Aleksynska and Havrylchyk, 2013; Choi et al,. 2016; Ghemawat, 2001). Also, some ‘gravity model’ studies in international business showed that absolute geographic distances still increase barriers to international business interaction (Evenett and Keller, 2002; Leamer and Storper, 2001; Rauch, 1999) and significantly affect both physical goods and information flow.

Ly et al. (2018) conducted an empirical study on capital flow among 71,309 pairs of FDI relationships from 2000 to 2012. Based on a framework of an extended gravity model, they found a significant and negative effect of geographic distance, and MNEs from high-income countries were more sensitive to distance than those from low-income countries. However, information flow, represented by language similarity, could diminish that negative influence.

A possible explanation for the distance puzzle appeared, which changed the focus from the perspective of transport and communication costs to information collection. In the globalisation era, geographic distance is a proxy for the cost of acquiring information (Rauch, 1999; Rauch and Trindade, 2002), and level of information asymmetry among business participators (Coval and Moskowitz, 1999).

Hakanson and Ambos (2010) revealed the negative effects of geographic distance on international flow, through the formation of psychic distance. Empirically, they conducted a survey study and found that geographic distance can increase, even accounting for the largest share of psychic distance perceptions.

2.2.2 Institutional distance

Institutional distance is a combined notion that relates to economic freedom, political influence, or FDI restrictions, affecting the location (Stoian, 2013). Berry et al. (2010) reviewed the concept of institutional distance and found that there are disparate proxies for institutional distance used in empirical studies. They broke institutional distance down into nine sub-dimensions, including economic, financial, political, administrative, cultural, demographic, knowledge, global connectedness, and geographic.

Choi et al. (2016) distinguished between general environmental institutional (GEI) distance and minority investor protection (MIP) institutional distance and made a hypothesis that these types of institutions have different impacts on international investment. By examining the effects of institutional distance on international M&A activities of U.S. firms from 1981 to 2008, they confirmed that a better GEI distance in the host country attracts FDI, while a better MIP institutional distance may deter it, because the latter reduces the potential benefits an acquiring firm can gain from an international acquisition in the host country.

In addition, some literature suggested administrative and political distance, which can be classified into institutional distance, as having an impact on international investment. Scholars argued that administrative components, such as colonial ties (Frankel and Rose, 2002), language (Brewer, 2007), religion (Ghemawat, 2001), or legal systems (Berry et al., 2010), affect MNEs' investment decisions. Political differences are defined as the dissimilarity in political systems (Delios and Henisz, 2003; Henisz and Williamson, 1999), democratic character (Jensen, 2003), and trade relationships (Brewer, 2007). Empirical studies on the effect of administrative and political distance on international investment show a consistent negative relationship (Berry et al., 2010; Brewer, 2007).

2.2.3 Cultural distance

Cultural distance, which is an often-cited factor in FDI studies, refers to the manner in which people interact with each other, companies and institutions, religion, language, and cultural norms (Ghamawat, 2001). It determines the managerial cost (Shenkar, 2001) and generates informational frictions impacting on knowledge transfer (Vachani, 1991). The most popular approach to measuring cultural distance is based on the work of Geert Hofstede, who built the system of cultural indexing with several key aspects (Berry et al., 2010). Kogut and Singh (1988) adopted Hofstede's cultural dimensions and found empirical evidence that MNEs are less willing to build a plant in host countries that are more culturally distant from their home country. Similarly, other studies found a negative relationship between cultural distance and foreign market entry (Berry et al., 2010; Hennart and Larimo, 1998).

Du et al. (2012) argued that cultural distance not only directly relates to FDI location choice but it can also impact the institutional effects of location choice. Differing from Choi et al. (2016), Du et al. (2012) separated the institutional effects into contract enforcement, government intervention, regional IPR protection, and corruption. Utilising a survey dataset containing 150,602 FIEs in 2001, they compared the sensitivity of the location choice of FDI from six major source countries/areas (Hong Kong, Taiwan, the U.S., the E.U., Japan, and Korea) toward the variation in the strength of economic institutions across China's regions. The results suggested that different cultural distances between China and the source areas determined the sensitivity of location choices to the variation in regional economic institutions. MNEs from countries culturally closer to mainland China preferred an economy highly inverted by the government, since they could effectively take advantage of government intervention and turn it into help, whereas MNEs from countries that were culturally farther away from China were less able to do so. Additionally, the MNEs from more culturally remote areas, such as the U.S. and the E.U., concerned more with property rights protection and contract enforcement than other sources of FDI.

However, some hold a different view, believing that the impact of cultural distance on international business activities is not homogenous. For instance, Dikava and Sahib (2013) hypothesised that the effect of cultural distance on international business activity is determined by the investors' experience in international business. Based on a database of 122 cross-border acquisitions conducted from 2009 to 2010, they found evidence that the interaction between cultural distance and cross-border acquisitions experience significantly contributes to acquisition performance. An experienced acquirer is more culturally sensitive and has more ability to deal with organisational incompatibilities caused by cultural distance (Morosini et al., 1998; Very et al., 1997). Thus, the negative effects of cultural distance on international business activity should be stronger for inexperienced participants than for those who are experienced. In addition, Popli et al. (2016) argued that the uncertainty of cultural distance impact is determined by the firm's industry context.

Bailey and Li (2015) investigated the relationship between cross-national distance and FDI from the demand-side perspective. The dataset was outward FDI flow from the U.S. to 110 destinations from 2006 to 2011. They found solid evidence that cross-national distance negatively relates to FDI; however, the host country's local demand diminishes the negative effects of geographic, cultural, and administrative distance and increases the political distance effect.

2.2.4 Psychic distance

Psychic distance primarily developed from cultural distance. It is a cognitive concept defined as the amount of knowledge and information individuals have (or believe they have) of other countries. Psychic distance determines the cost of collecting and utilising relevant information. Most literature used cultural distance as a proxy for psychic distance. However, Hakanson and Ambos (2010) suggested that the formation of psychic distance should also account for geographic distance, economic distance, and historical relation.

Habib and Zurawicki (2002) and Benassy-Quer et al. (2007) adopted the notion of psychic distance, which suggests that companies prefer a psychologically closer economy as an investment destination because these countries present lower levels of uncertainty, and psychic closeness contributes to learning from host countries. Based on this hypothesis, they found that a larger institutional distance negatively impacts FDI. And, Claessens et al. (2008) found similar evidence in their empirical study on FDI in banking industry.

As stated above, although there are different classifications and definitions of ‘distance’, various dimensions of distance have been widely and empirically confirmed to have effects on MNEs’ location choices. That can be explained because the distance between home and host regions leads to some additional economic and social costs for foreign firms compared with domestic firms, which MNEs need to minimise through location choice strategy.

3. Methodology

3.1 Model Selection: The Gravity Model

The empirical framework is estimated based on the traditional gravity model, which has been the workhorse of empirical applications in international economics research. The gravity model comes from Newton's law of gravitation, which declares that attractive force increases with the masses of two objects but reduces with the distance between them. It was widely used to explain economic flow, such as international trade and FDI, successfully, even before a theoretical basis was found. In addition, Ravenstein (1885) applied the gravity model to migration patterns in the nineteenth century in the UK. And, in the area of international business, Tinbergen and Hekscher (1962) were the first to use gravity to explain trade flows. In the context of the economy, the gravity model can be interpreted as the potential flow *Yij* between the supplied part *i* and the destination j, and it is positively determined by the masses of goods or labour or other factors in *i* and *j*, *Xi* and *Xj*, but negatively by the distance *Dij* between supplying and demanding parts. Strictly applying the analogy,

$$\boldsymbol{Y_{ij} = X_i X_j / D_{ij}} \qquad \textbf{(1)}$$

Although Tinbergen and Hekscher (1962) obtained solid evidence for a gravity factor on trade, the gravity model was not accepted by the mainstream of trade research until 1995. One of the main barriers is that gravity equations were more physics analogy rather than economic. Some economists made great efforts to explain the gravity model theoretically before the 1990s. For instance, Savage and Deutsch (1960) incorporated a multiplicative model of bilateral trade, published two years before Tinbergen and Hekscher’s work (1962). And, Anderson (1979) set a conventional and purely probabilistic economic model of gravity.

The year of 1995 was a turning point for gravity model research. Trefler (2002) pronounced the idea of “missing trade”, which meant that the HOV model predicted much higher trade flow than that actually observed. Although Trefler utilised “home bias” rather than geographic distance to explain missing trade, his work identified that it is crucial to explore the impediments to trade. Leamer and Levinsohn (1995) raised a doubt over the fact that the gravity model produced the clearest and most robust evidence in economics but had no influence on international economics. They thought it was probably because “human beings are not disposed toward processing numbers, and empirical results will remain unpersuasive if not accompanied by a graph". Thus, they produced a plot figure of export volumes in Germany using the export destination's GDP as the y-axis and the distance as the x-axis. Meanwhile, although the business press was proclaiming the concept of a "border-less world" and "world is flat", empirical research provided evidence of the opposite. McCallum (1995) utilised the gravity model with freshly exploited data on inter-provincial trade and demonstrated the economic relevance of national borders.

The gravity model's shortage of micro-foundations was overcome by the publications of Eaton and Kortum (2002) and Anderson and Van Wincoop (2003), which proclaimed that the gravity model was not only suitable for subsets of countries or industries neither based on imperfect competition or increasing returns. Moreover, Feenstra (2015) and Redding and Venables (2004) made it clearer that the importer and exporter fixed effects could be introduced to present the multilateral consistence term that was embodied in various theoretical models. These articles built the theoretical foundation for the gravity model to be rapidly admitted and adopted in empirical works due to its consistency with theory and easy implementation.

Following Linnemann (1961), the gravity model has been widely applied in empirical studies on trade flows and FDI (Brainard, 1997; Anderson and Wincoop, 2003). Although the gravity model was initially invented to describe bilateral flow, it is also suitable for one-directional flow data, which are the same as the data in this study. Therefore, it successfully explains how the interaction between the source and destination impacts on the flow and captures the effects of source and destination variables. Thus, the gravity model is also applied in some empirical studies on one-directional FDI flow data. For instance, Chenaf-Nicet and Rougier (2016) use the gravity model to estimate the FDI flowing from Europe and the Mediterranean region to the four main recipients of FDI in the Middle East and North Africa from 1985 to 2009, to investigate the effects of instability in source and host countries on FDI flow.

3.2 The Empirical Model

This study uses the traditional gravity model with some control variables. In existing literature, there were three main formations of the gravity model, since the masses of origin and destination of flow could be measured by various proxies. They can be expressed as seen below:

$$\boldsymbol{FLOW_{ij} = POP_{i/j}\ or\ GDP_{i/j} + GDPpc_{i/j} + Distance_{ij} + X} \quad \textbf{(2)}$$

where *POP* is population, *GDPpc* presents GDP per capita, *GDP* is *GDP* in origin *i* or destination *j* regions, Distance denotes the geographic distance between *i* and *j*, and *X* presents other related factors. A population variable is preferred to GDP in this study, since in the context of FDI, population presents the market size more accurately than GDP. Equations (2) and (3) are also estimated to check the robustness. Then, the regression equation is the following:

$$\boldsymbol{FDI_{ijt} = \alpha_1 POP_{it-1} + \alpha_2 POP_{jt-1} + \alpha_3 GDPpc_{it-1} + \alpha_4 GDPpc_{jt-1} + \alpha_5 DIST_{ij} + \alpha_6 COLO_{ij} + \alpha_7 SIMI_{ijt-1} + \alpha_8 RD_{it-1} + \alpha_9 BA_{jt-1} + \beta_t + \beta_{ij} + \varepsilon} \quad \textbf{(3)}$$

where *i* denotes home countries, *j* denotes host regions, and *t* is the year; β_{ij} is the time-invariant region-pair fixed effect and β_t is the time effect. All independent variables are one-year lagged, since the investment decision is made by MNEs based on the previous data.

3.2.1 The dependent variable

FDI_{ijt} is FDI flow from the home country *i* to the host region *j* in the year *t*. In FDI location choice studies, FDI stock and FDI flow are two usual measurements. In the empirical studies survey paper, which reviewed 153 quantitative studies on FDI location choice, conducted by Nielsen et al. (2017), there are 94 studies that predict FDI flow results and another 59 studies that focus on FDI stocks. The core question in FDI location choice studies is the decision to enter a particular location. Flow data directly reflect how FDI accesses a specific region at a given time, and stock data could possibly reveal the relationship between the FDI location and local characteristics, but not the entrance decision itself (Galan et al., 2007). Therefore, this study uses FDI annual inflow data as the dependent variable.

3.2.2 Independent variables

Population and GDP are both classic variables for measuring masses of parent and host regions in the gravity model in FDI studies. Some literature found that population is more important than the economic stage in explaining the possibility of being a recipient of foreign capital (Flores and Aguilera, 2007). Thus, this study uses population to measure the market sizes of source and host regions, as in previous studies (Cuervo-Cazurra, 2006; Henisz, 2000). According to the gravity model, the masses of both source and destination markets are promoting factors for bilateral flow. Thus, the expected signs of α_1 and α_2 are both positive.

GDP per capita of the supplier and demander are often estimated in a gravity equation. The assumption behind this is that higher income countries perform more expansion activities in foreign markets. From the perspective of the demanding side, a higher income level implies a more advanced infrastructure, a mature legal system, and abundant human resources, which are all pulling factors for investment. Thus, the expected signs of α_3 and α_4 are positive.

To measure geographic distance, I used the distance between the capital cities of the home and host regions, similar to in previous literature (e.g., Portes and Rey, 2005). The sign of this variable can be positive or negative. A great geographic distance creates high transporting costs, which encourages firms to conduct direct investment rather than export, implying a positive sign for the distance variable. On the other hand, greater distance is usually associated with unfamiliar language and culture, and higher transaction costs, which may detract from the FDI activities. Therefore, the sign of the distance variable is inconclusive.

$COLO_{it}$ is a dummy variable with the value 1 if a host region used to be colonised by a parent country or a concession belonging to a parent country, and the value 0 otherwise. It captures the administrative distance and cultural distance since that colonial linkage makes home and host regions culturally similar. Country-specific linkage is one of several effective proxies for institutional distance (Ghamawat, 2001). MNEs, sourcing from a home country that has political, social, or economic ties with the host country, have an extra competitive advantage compared to others. Referring to a sub-national level study, colonial tie is applied to capture the linkage between the home country and host region. A historical relationship creates a backdrop that is shared by the parent and host region pair, and this shared history may make it more likely that the parent invests in the host regions (Garrett, 2016). In addition, Rauch (1999) illustrated that colonial tie helps match the international buyers and sellers, since foreign firms have social network resources in a host region sharing past colonial relations. Therefore, the sign of this variable is supposed to be positive.

SIMI is a proxy that measures the distance or similarity of the economies in the home country and host regions. According to Egger and Pfaffermayr (2004), it is calculated by the following equation:

$$\boldsymbol{SIMI_{ijt} = 1 - \left[\frac{GDP_{it}}{(GDP_{it}+GDP_{jt})}\right]^2 - \left[\frac{GDP_{jt}}{(GDP_{it}+GDP_{jt})}\right]^2} \qquad \textbf{(4)}$$

The sign of SIMI could be positive or negative. According to theoretical trade literature, horizontal MNEs tend to be found in similarly endowed economies; however, vertical MNEs tend to occur in dissimilar economies (Egger and Pfaffermayr, 2004). MNEs, who mainly offer services locally, in the host market, and which rely on economies of experience, scale, and standardisation, will prefer regions that have similar economic profiles, since they have to replicate their mature business model to obtain a competitive advantage, which is hard to achieve in an economy where customer incomes are very different. On the other hand, in some particular industries, competitive advantage comes from economic arbitrage, the exploitation of cost and price differentials between markets.

R&D levels in home country are measured as the sum of medium and high-tech industry over manufacturing value added. Technology flow plays an important role as a driver of FDI flow in China. As a late developer, China imported technology from the advanced countries, which have become significant sources of know-how and investment. Technology flow exists with both horizontal and vertical FDI, but vertical FDI is more willing to transfer technology, since it results in production facilities that are tailored to the production environment of the host economy (Petri, 2012). As countries upgrade their technology, they obtain more competitive advantages in technological products and exports. Firms in technologically leading countries drive this pattern through technology flow to next stage producers, mainly by FDI. Their motivation is to utilise their technological assets as much as possible after their domestic production advantage fades away. Thus, it is more possible that FDI in China is driven by technology flow than by economies of scale or factor price differences. α_8 is hypothesised to be positive, which means that source countries with high scientific and technological achievements invest more in China than others.

The variable BA takes the value of 1 if a region has a bonded area, and, otherwise, it is 0. A bonded area is a special economic zone "inside the territory while outside the customs". It provides storage, export processing, and re-exporting services. Although the details of the preferential policy differ across various regions, a primary rule is that foreign goods imported from abroad into the bonded area are duty-free. This variable captures the attractive aspect of this policy for FDI. Therefore, the expected sign of α_9 is positive.

All data are deflated using 2010 as the base year and employing China's deflater from the World Bank for the host region variable. Table 3.1 presents the expected signs for each coefficient. Appendix 1 is a complete description of all variable definitions and sources. The raw data of home countries including GDP, GDP per capita, population, and R&D were collected from the World Bank database. China Statistical Yearbook (various years) provided data relating to host regions including GDP, GDP per capita, and population. The dependent variable, FDI flow was collected from Statistical Yearbook for various provinces separately. Because one-year lags are used for all independent variables in estimation, all independent variables of home and host regions are from 1999 to 2011. FDI flow data are from 2001 to 2012.

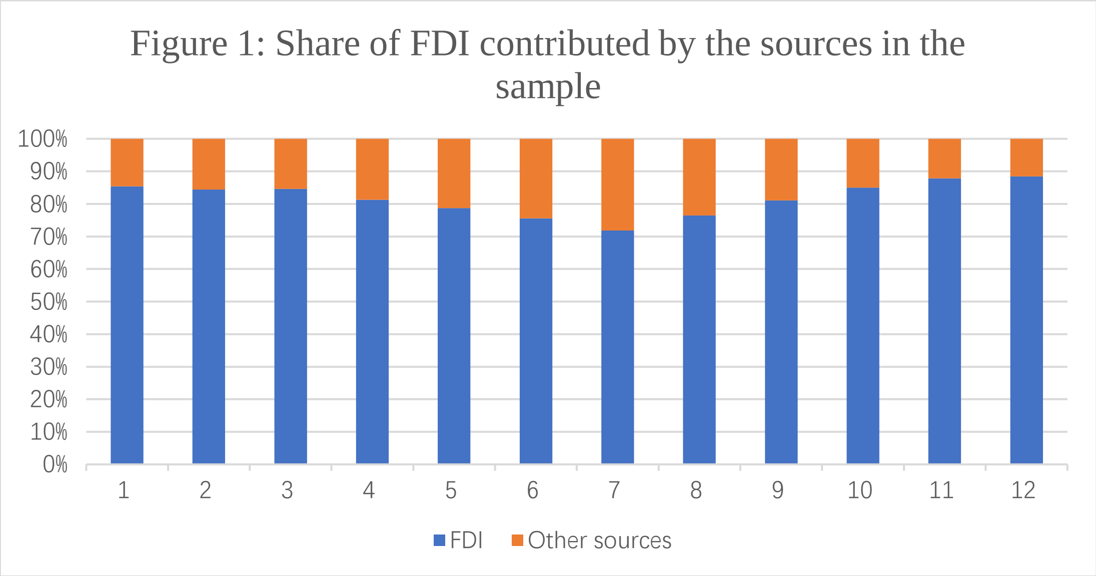
Table 3.1: Expected sign of coefficients

α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9
+	+	+	+	+/-	+	+/-	+	-

3.3 Data

The data of FDI inflow by source countries are only provided by some provincial governments. Thus, the data set we used covers 20 of 31 Chinese provincial level regions and the period from 2001 to 2012. Also, there are a few missing years for Shanxi, Shanghai, Hunan, Hainan, Ningxia, and Xinjiang. Appendix 2 shows the available observations for this study.

Although this data set did not include all the host regions or investment sourcing countries, the sample is fairly representative of the population of FDI in China. From the perspective of foreign investing countries, the main contributors to China's FDI inflow are included in this sample. Figure 3.1. represents the percentages of total FDI in China sourced from the sample countries from 2001 to 2012. The countries in the sample contributed over 80% of China's FDI in most of the years and over 70% in 2005, 2006, 2007, and 2008.



Data source: China Statistical yearbooks 2002-2013

From the perspective of host regions, the sample of 20 host regions in China is representative of the population of FDI destinations. According to the classification of the Report on Foreign Investment in China, distribution of FDI can be divided into the east, central, and west areas. The sample includes 9 of 11 provincial regions in the east area, 6 of 8 regions in the central area, and 5 of 12 regions in the west area. Figure 1 shows the distribution of the host region in the sample, and Appendix 3 presents the categories of regions in the east, the centre, and the west separately. Table 3.2 shows descriptive statistics for each variable. Table 3.3 is a correlations matrix of the variables.

Table 3.2: Descriptive statistics of the variables

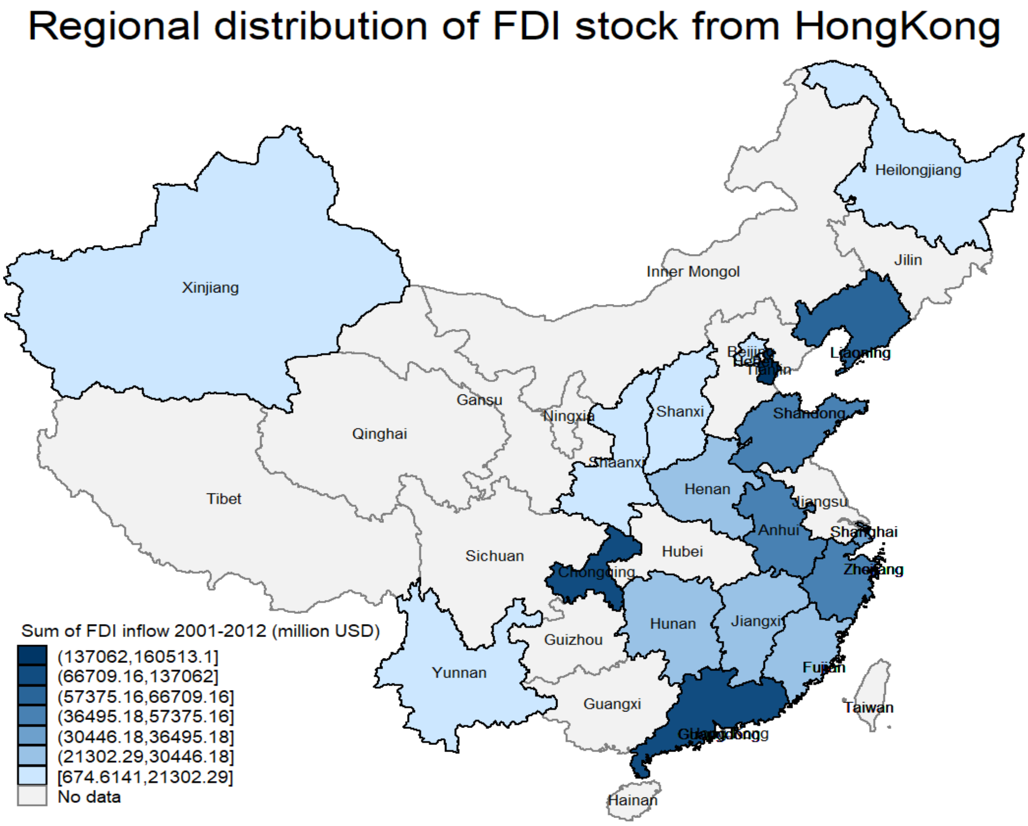
Variable	***Obs***	***Mean***	***Std. Dev.***	***Min***	***Max***
Ln (FDI+1)	5312	9.038776	5.995872	0	20.11528
lnPOPit-1	5003	9.715192	2.144528	3.027473	16.91907
lnPOPjt-1	5312	8.294276	0.625053	6.437752	9.268044
lnGDPpcit-1	4884	10.05865	1.059201	5.6022	11.62597
lnGDPpcjt-1	5312	9.936884	0.582789	8.882231	11.27454
lnDISTij	5312	8.567023	0.834816	4.779712	9.781406
COLOij	5312	0.034827	0.183358	0	1
SIMIijt-1	4831	0.222793	0.161057	0.00151	0.5
RDit-1	4643	0.390072	0.186056	0	0.88037
BAjt-1	5312	0.35128	0.477415	0	1

Table 3.3: Correlation of the independent variables

lnPOPit	***lnPOPit***	***lnPOPjt***	***lnGDPpcit***	***lnGDPpcij***	***lnDISTij***	***SIMIijt***	***RDit***
lnPOPit	1						
lnPOPjt	-0.0223	1					
lnGDPpcit	-0.3418	-0.06	1				
lnGDPpcjt-1	0.0079	-0.2114	0.1132	1			
lnDISTij	0.1283	-0.0312	0.2913	0.0074	1		
SIMIijt	-0.3704	0.0943	-0.2516	0.0862	-0.3421	1	
RDit	0.3855	-0.049	0.1125	0.0484	0.0778	-0.0006	1

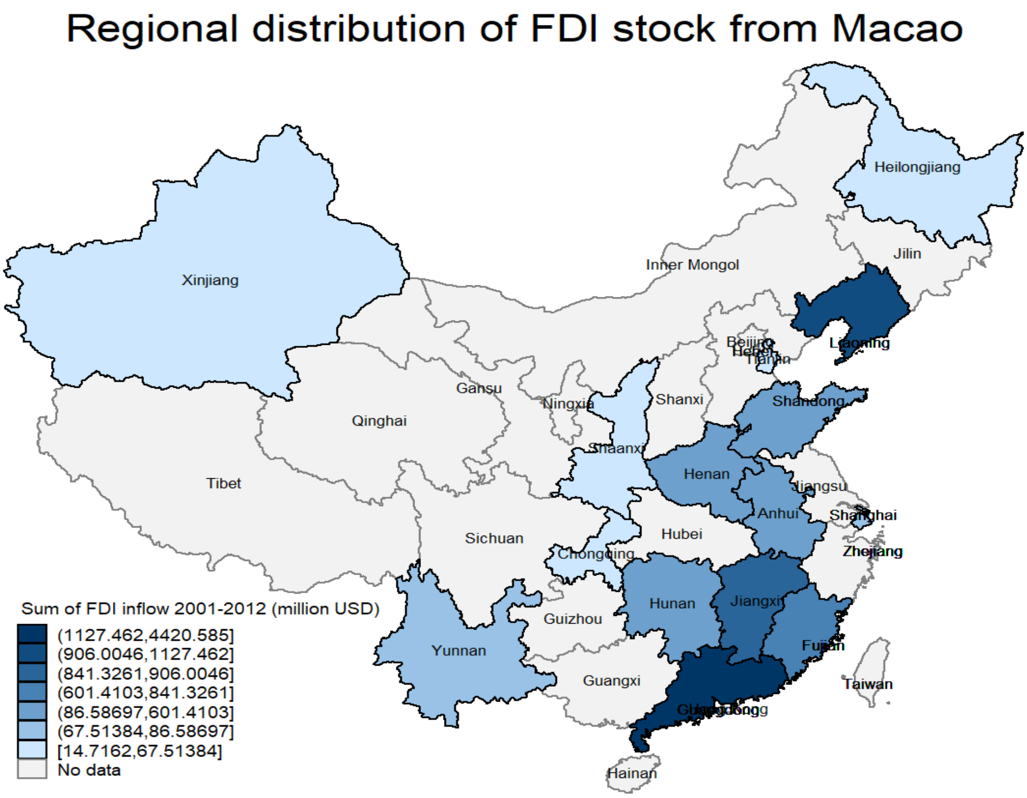
Figure 2- 12 show the regional distribution of total FDI inflow from 2001 to 2012 by some main source countries. Figure 2-4 are regional distribution of FDI stock contributed by Hong Kong, Macao and Taiwan. These three regions locate closely to mainland China and share strong cultural and historical tie and same language with some provinces in China. They are most important contributors of China's inflow FDI. Guangdong is preferred by all these three regions, Hong Kong and Taiwan highly intent to invest in Tianjin. Chongqing is another main destination of FDI from Hong Kong. And Macao allocated huge investment in Liaoning province.

Figure 2 Regional distribution of FDI stock from Hong Kong



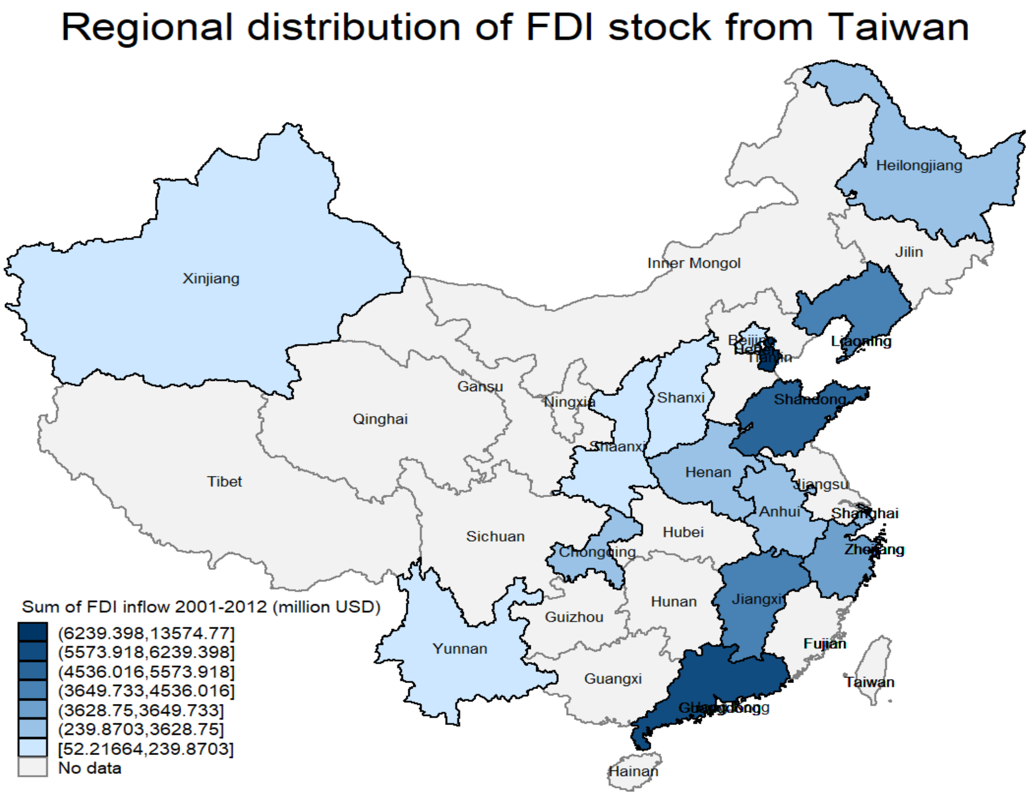
Data source: Statistical yearbooks of various provinces 2002-2013

Figure 3 Regional distribution of FDI stock from Macao



Data source: Statistical yearbooks of various provinces 2002-2013

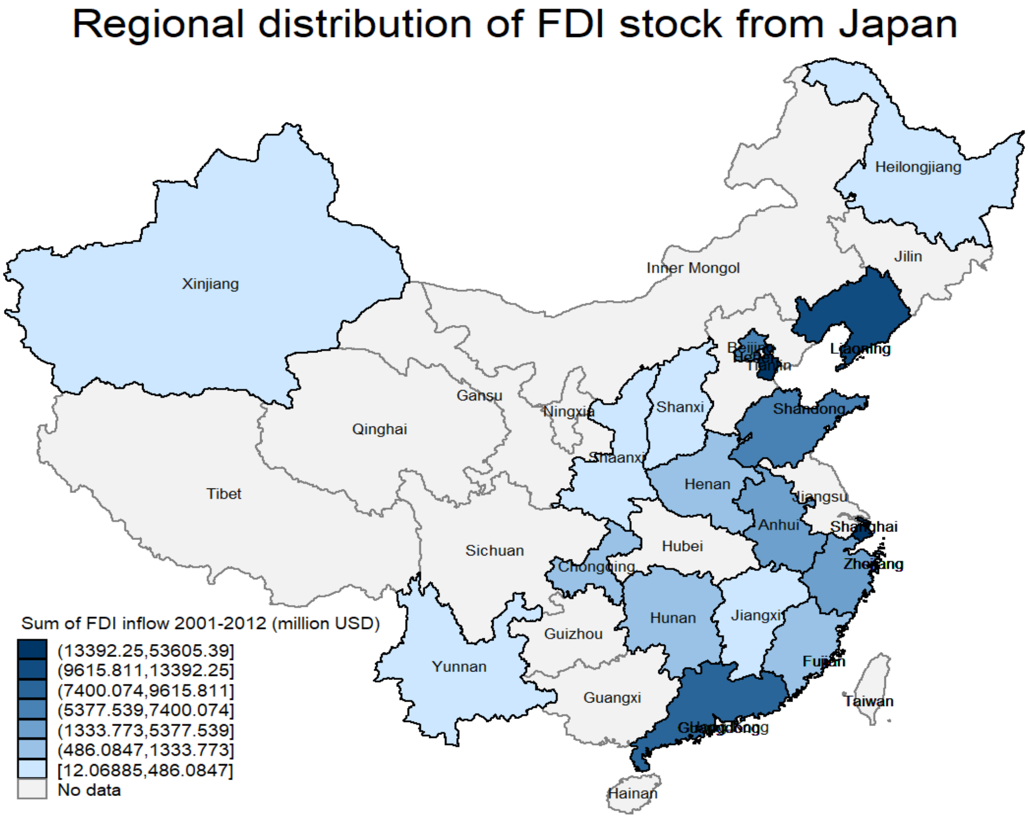
Figure 4 Regional distribution of FDI stock from Taiwan



Data source: Statistical yearbooks of various provinces 2002-2013

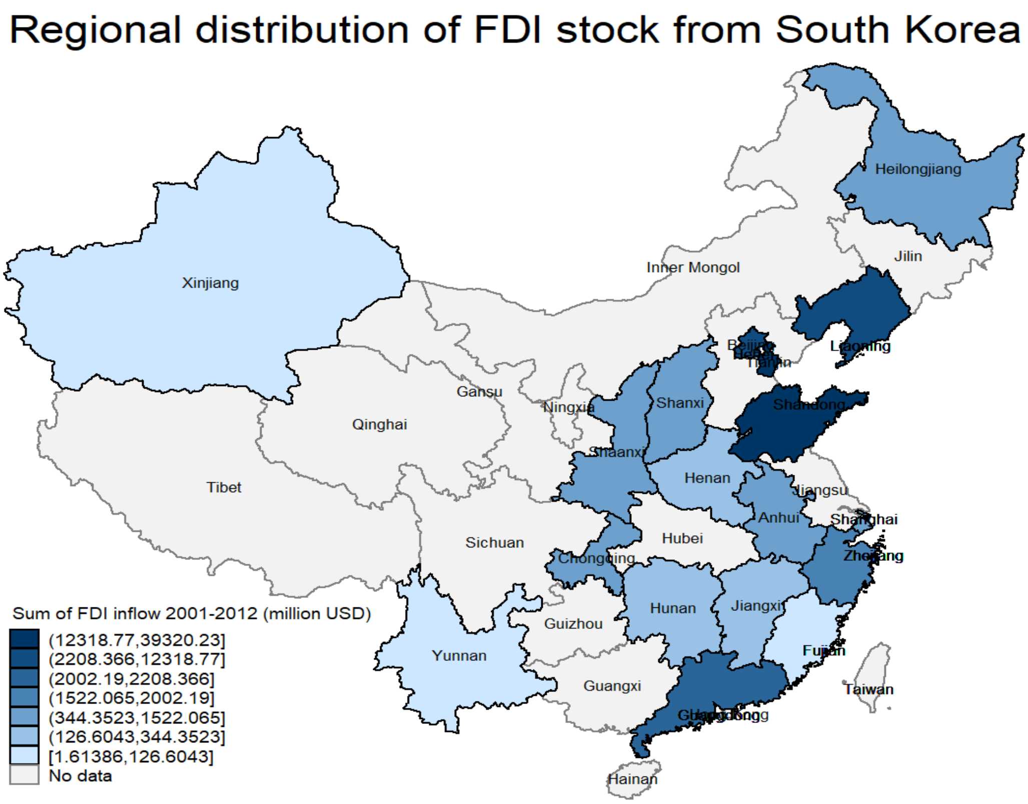
Figure 5 – 7 present the regional distribution of FDI stock from other Asian source countries, Japan, South Korea and Singapore. According to Figure 4 and 5, Liaoning and Tianjin are priority destinations of FDI sourcing from both Japan and South Korea, and South Korea also prefers to invest in Shandong province. That is possibly due to the short geographic distance between Liaoning and Japan/South Korea. Additionally, Japan invested considerable share in Shanghai where was colonized by Japan in 19th century. FDI sourcing from Singapore concentrated on China’s south coastal line and mostly allocates in Guangdong province.

Figure 5 Regional distribution of FDI stock from Japan



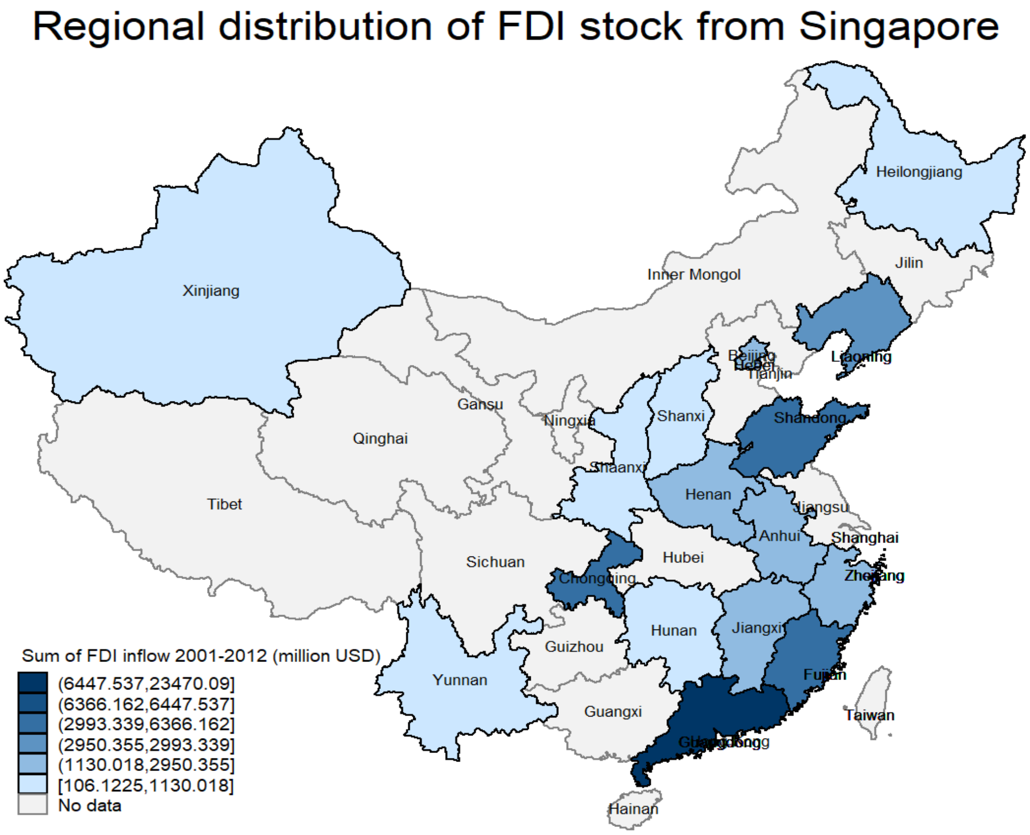
Data source: Statistical yearbooks of various provinces 2002-2013

Figure 6 Regional distribution of FDI stock from South Korea



Data source: Statistical yearbooks of various provinces 2002-2013

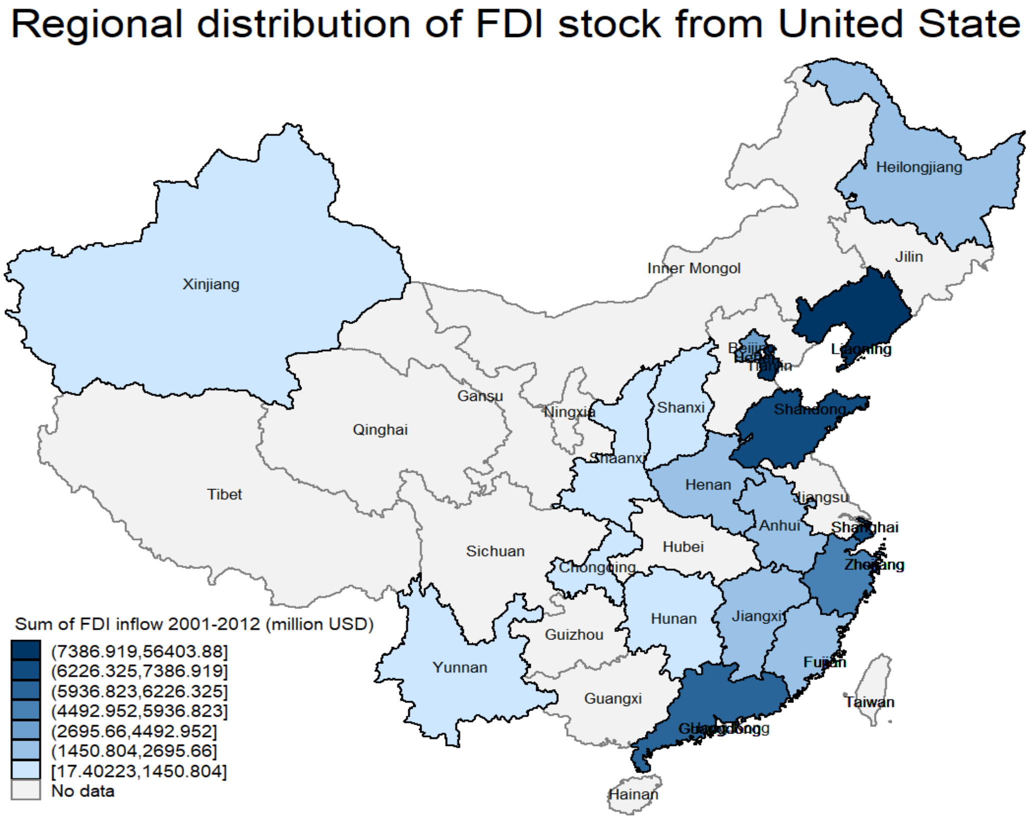
Figure 7 Regional distribution of FDI stock from Singapore



Data source: Statistical yearbooks of various provinces 2002-2013

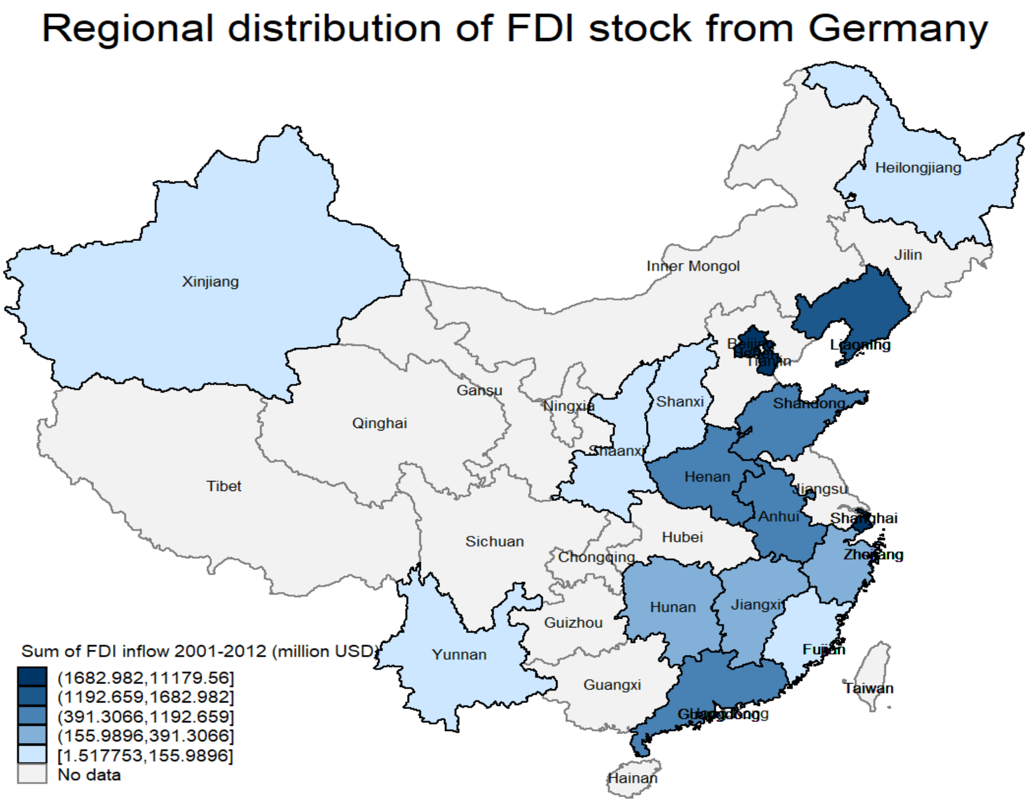
Figure 8-12 represent the regional distribution of FDI inflow from western source countries including United State, Germany, France, United Kingdom and Italy. For the enterprises from United State, Liaoning and Tianjin are the first-tier options to allocate investment, additionally Shandong Guangdong and Shanghai are also attractive regions. Germany firms prefer to invest in Beijing, Tianjin and shanghai mostly, and Liaoning is a less priority option. Both France and United Kingdom allocate a significant share of investment in Guangdong province. The enterprise from France also consider Tianjin is one of the best FDI location choice, however, the firms from United Kingdom prefer Shanghai. The FDI location pattern of the France enterprises is slightly different from the enterprises from other countries, besides Beijing and Tianjin, French firms shows a considerable interest in sending capital to Hunan province as similarly much as to Zhejiang.

Figure 8 Regional distribution of FDI stock from United State



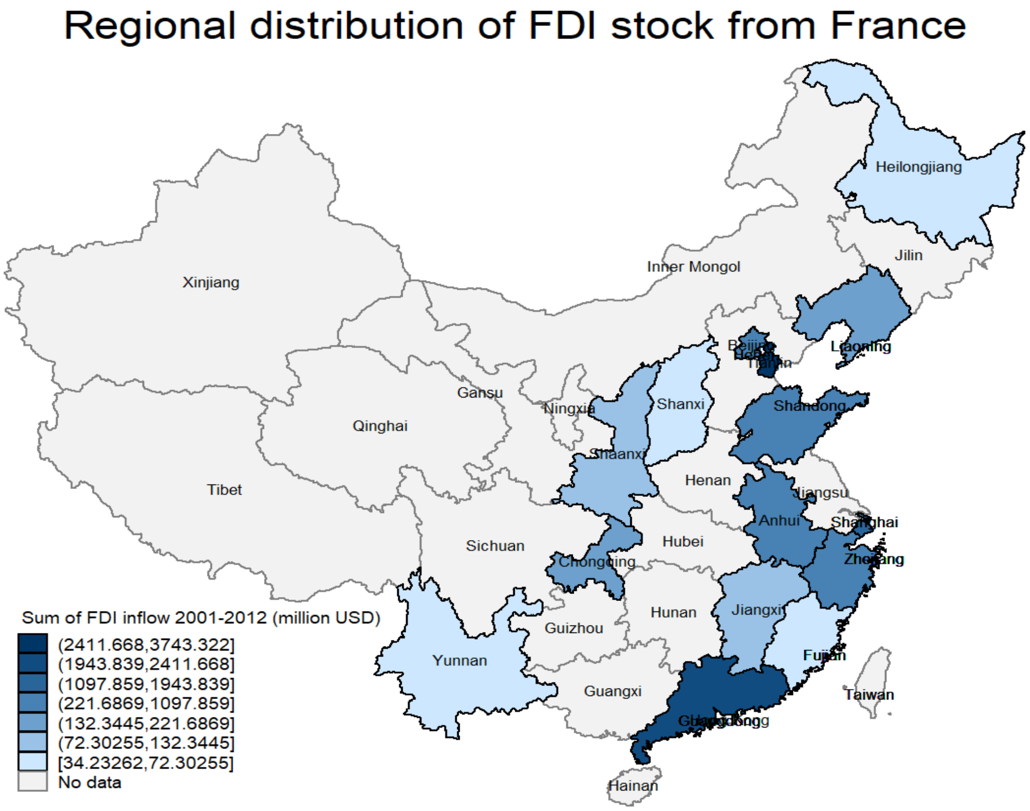
Data source: Statistical yearbooks of various provinces 2002-2013

Figure 9 Regional distribution of FDI stock from Germany



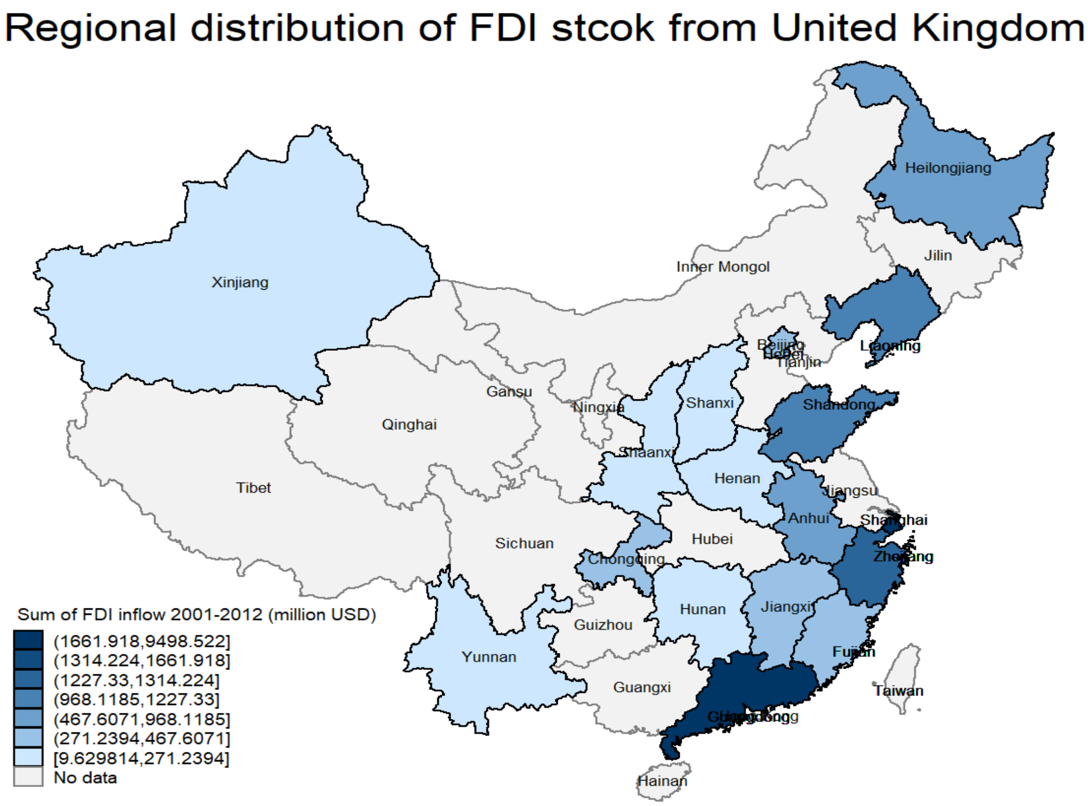
Data source: Statistical yearbooks of various provinces 2002-2013

Figure 10 Regional distribution of FDI stock from France



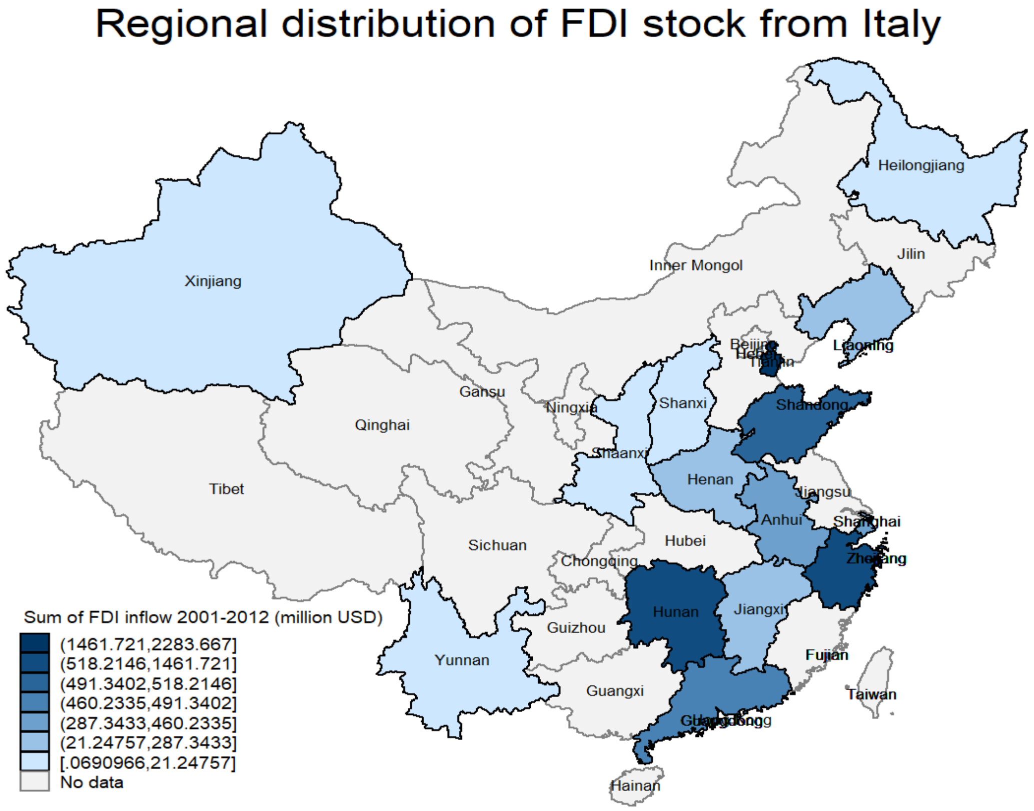
Data source: Statistical yearbooks of various provinces 2002-2013

Figure 11 Regional distribution of FDI stock from United Kingdom



Data source: Statistical yearbooks of various provinces 2002-2013

Figure 12 Regional distribution of FDI stock from Italy



Data source: Statistical yearbook of various provinces 2002-2013

To sum up, Beijing, Tianjin, Shanghai, Guangdong and Liaoning are the most popular FDI locations for the multinational enterprises. However, heterogeneity exists on FDI location pattern among different source countries. The enterprises from Asia countries generally prefer to invest in a region with short geographic distance, western firms are more likely to allocate capital to big city such as Beijing and Shanghai. That heterogeneity possibly can be explained by the effect of different concept of distance on FDI location choice. And it is examined empirically by this study in following section.

3.4 Selection of Estimates

Although the gravity model is widely used to predict bilateral flow in empirical studies and provide stable and significant evidence, there are several unsolved issues related to its empirical application. For instance, the unobserved heterogeneity and existence of zero flow in the dependent variable, which reduces the feasibility of the logarithm estimation of the gravity model. In FDI and trade data, there are some zero observations. Since zero cannot be defined in logarithms, some previous literature introduced truncating and censoring estimates to deal with zeros. However, the loss of information from zero observations leads to biased estimates. Also, sample selection bias will exist with truncated estimates, since zeros are not randomly distributed in trade (Westerlund and Wilhelmsson, 2011).

The ordinary least squares (OLS) estimate is a traditional and usual choice in gravity model studies. Some used truncated OLS, which drops all zero observations and only estimates based on non-zero flow (Linders and Groot, 2006; Westerlund and Wilhelmsson, 2009; Martin and Pham, 2008). The elimination of zero flows leads to biased coefficients and loss of information (Linders and De Groot, 2006; Westerlund and Wilhelmsson, 2011). Another method to deal with zeros is to add a particular number onto the dependent variable, such as taking a log of (flow+1), and this is widely applied in empirical study because of its success at maintaining the information from zero observations. The disadvantage is biased estimates generated by the increase in the dependent variable value.

Some researchers estimated the gravity model on panel data frameworks, aiming to investigate specific time or country effects (Matyas, 1998; Egger, 2000; Glick and Rose, 2002; Egger and Pfaffermayr, 2003; Micco et al., 2003; Andrews, 2006; Henderson and Millimet, 2008). Fixed effects and random effects are two main techniques in panel frameworks. The assumption of the fixed effects estimator is that an unobserved heterogeneous and time-invariant component has an effect on each individual country or pair of countries of the panel. The fixed effects estimate is able to control unobserved heterogeneity; however, it drops constant regressors, such as distance and border variables. The random effects model is more efficient. It assumes that the unobserved heterogeneous component is exogenous and that individual effects do not correlate to regressors.

In addition, Silva and Tenreyro (2006) proclaimed that parameters of log-linearized models estimated by OLS could be highly misleading in the presence of heteroskedasticity. Therefore, they argued that the gravity equation should be estimated in its multiplicative form and with proposed Poisson pseudo-maximum-likelihood (PPML), in which the dependent variable is introduced in level value not log value and successfully captures the information from zero observations. Although, a PPML estimate was accepted by some researchers in empirical studies (Westerlund and Wilhelmsson, 2009; Siliverstove and Schumacher, 2009; Liu, 2009), it has to be mentioned that PPML estimates may present limited dependent variable bias when a significant part of the observations is censored.

The Heckman sample selection model is another widely used model in gravity equations. It is a two-step estimation method. In the first step, a probit equation is estimated to investigate whether flow occurs between the supplier and demander, or not. And in the second step, the expected values of the flow are estimated, based on an OLS estimate. The Heckman selection model requires exclusion variables that only determine the decision process. The disadvantage of the Heckman selection model is that the occurrence of the flow is not modelled completely independently from the decision of the volume of the flow. The model allows for some positive correlation between both error terms to better reveal the real decision process.

Aiming to deal with zero observations, Tobit or censored regression is another alternative estimate for the gravity model. It is simple and covers the information of zero flow. However, compared with the Heckman sample selection estimate, the disadvantage is that it uses the same set of variables to determine the probability that an observation will be censored and the value of the dependent variable.

It is not possible to say which estimate perfectly fits the gravity equation. To obtain a robust and reliable conclusion, this study estimates the gravity equation with OLS, random effect, PPML, and the Heckman selection estimate.

4. Results and Discussion

In main result section, I only report the empirical results based on the gravity model using population as the mass variable. Results with GDP capturing mass effects are presented in Table 4.11. And for the robustness check, quantile regression results are provided in Table 4.12. Tables 4.1-4.9 report the regression results with various estimates. Table 4.1 is general OLS estimated with a log of FDI+1, Table 4.5 is OLS estimated with year dummy variables, Table 4.6 is panel-data regression results with a random effect, Table 4.7 is concerned with xttobit estimates, Table 4.8 is the Heckman selection results, and Table 4.9 reports PPML estimate results. Table 4.10 reports the regression results, including all the independent variables based on various estimates.

In summary, the existence of gravity effects was confirmed in most results. The coefficients of mass variable and POP are mostly significant and positive, except for the PPML estimates. In Tables 4.1-4.8, the dependent variable is FDI+1 in ln. Table 4.9 used a level value of FDI in flow as the dependent variable. Source and host population, distance, source and host GDP per capita, colonial tie, economic similarity, source R&D, and duty-free port dummy were introduced incrementally in order to check the stableness and significance of the effects on FDI flow. The coefficients in each regression are relatively stable and statistically significant.

4.1 Main Results

Table 4.1: Results on the OLS estimates for $Ln\ (FDI_{ijt}+1)$

	(1)	(2)	(3)	(4)	(5)	(6)
$LnPOP_{it-1}$	0.279***	0.579***	0.533***	0.428***	0.483***	0.476***
	(6.85)	(13.79)	(12.52)	(9.94)	(7.77)	(7.63)
$LnPOP_{ijt-1}$	1.313***	2.064***	2.069***	2.289***	2.383***	2.246***
	(9.20)	(15.95)	(15.88)	(17.14)	(17.56)	(15.45)
$LnDIST_{ijt}$	-1.928***	-2.448***	-2.443***	-2.892***	-3.039***	-3.057***
	(-23.16)	(-29.92)	(-30.00)	(-30.60)	(-29.23)	(-28.98)
$LnGDPpc_{it-1}$		1.593***	1.530***	1.444***	1.694***	1.681***
		(20.17)	(19.37)	(18.76)	(15.34)	(15.19)
$LnGDPpc_{jt-1}$		2.837***	2.726***	2.903***	2.846***	2.452***
		(23.07)	(22.03)	(22.75)	(21.29)	(14.37)
$COLO_{ij}$			2.833***	2.050***	1.799***	1.611***
			(11.25)	(7.75)	(6.53)	(5.83)
$SIMI_{ijt-1}$				-5.792***	-4.944***	-5.250***
				(-10.63)	(-7.53)	(-7.71)
RD_{it-1}					3.631***	3.724***
					(7.29)	(7.46)
BA_{jt-1}						0.793***
						(3.65)
Constant	11.83***	-37.27***	-35.27***	-31.76***	-35.54***	-30.35***
	(8.04)	(-19.34)	(-18.18)	(-15.82)	(-16.55)	(-11.46)
Observation	5003	4884	4884	4674	4351	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.2: Results on the OLS estimates with year dummy for *Ln* $(FDI_{ijt}+1)$

	（1）	（2）	（3）	（4）	（5）	（6）
$LnPOP_{it-1}$	0.277***	0.581***	0.540***	0.444***	0.555***	0.549***
	(6.90)	(13.70)	(12.58)	(10.12)	(8.64)	(8.52)
$LnPOP_{ijt-1}$	1.287***	2.283***	2.276***	2.456***	2.581***	2.519***
	(9.01)	(17.06)	(17.22)	(18.21)	(19.01)	(17.02)
$LnDIST_{ijt}$	-1.933***	-2.424***	-2.420***	-2.852***	-3.025***	-3.032***
	(-23.29)	(-29.32)	(-29.43)	(-29.99)	(-28.79)	(-28.64)
$LnGDPpc_{it-1}$		1.605***	1.549***	1.468***	1.798***	1.788***
		(20.13)	(19.39)	(18.70)	(15.98)	(15.84)
$LnGDPpc_{jt-1}$		3.789***	3.641***	3.728***	3.793***	3.606***
		(26.43)	(25.08)	(24.80)	(24.63)	(17.87)
$COLO_{ij}$			2.447***	1.753***	1.442***	1.387***
			(10.24)	(6.97)	(5.54)	(5.23)
$SIMI_{ijt-1}$				-5.326***	-4.001***	-4.159***
				(-9.74)	(-5.85)	(-5.91)
RD_{it-1}					3.338***	3.386***
					(6.69)	(6.77)
BA_{jt-1}						0.292
						(1.30)
Constant	11.49***	-50.70***	-48.24***	-43.67***	-50.36***	-46.22***
	(7.72)	(-22.40)	(-20.95)	(-18.18)	(-19.84)	(-14.22)
Observation	5003	4884	4884	4674	4351	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.1 shows the regression results on the OLS estimates. The dependent variable used in this regression model is Ln (FDIijt+1). From column (1) to column (6), the results are consistent and robust. The coefficients of the gravity model are statistically significant in all the models at the 0.1% level, and the signs are the same as in the gravity model hypothesis. Moreover, both GDP per capita in the source country and the host region significantly and positively relate to the dependent variable. Since the dependent variable is Ln (FDIijt+1) in the regression model, the value of the coefficient is biased and cannot be interpreted directly as how much the independent variables contribute to FDI flow. However, by comparing the coefficients of GDP per capita in the source country and host region, the effect of GDP per capita in the host region is stronger than in the source country, which implies that the pulling factors for inward FDI are stronger than the pushing factors for outward FDI. And this is also confirmed by the coefficients of population, which are much greater in the host region than in the source country.

In terms of distance indicators, the coefficients of distance variables are all statistically significant at the 0.1% level. The variable DIST negatively relates to FDI flow in all the models, which demonstrates that longer geographic distances between the source and host regions leads to less FDI flow. Referring to cultural distance, the variable COLO is confirmed to have a significant and positive impact on FDI flow in models (3), (4), (5), and (6). That implies that if the source and host regions share a colonial tie, the FDI flow between them is greater than between a pair of regions without a colonial tie. Additionally, as models (4), (5), and (6) show, the coefficient of economic distance is statistically negative, which indicates that FDI flows more to economically dissimilar regions.

The other two variables, RD and BA, are both significant and positive in relation to the dependent variable. These empirical results demonstrate that a country having a higher level of R&D conducts more outward FDI, and that a host region having a bonded area is more attractive for inward FDI.

Table 4.2 reports the regression results on the OLS estimates with a year dummy and the dependent variable $Ln\ (FDI_{ijt}+1)$, the same as in Table 4.1. The overall empirical results are consistent with those of Table 4.1, except for the variable BA. The coefficients of population in both the source and host regions are significantly positive at the 0.1% level, and the coefficients of DIST are significantly negative, which confirms the existence of a gravity factor. Additionally, $LnGDPpc_{it-1}$ and $LnGDPpc_{jt-1}$ both significantly and negatively relate to the dependent variable, and the promoting factor in the host region is greater than in the source country, which is also found in the results on the OLS estimates without a year dummy. All the coefficients of the three distance variables are statistically significant at 0.1%. The results are consistent with Table 4.1, and the signs of geographic distance and economic distance are negative but that of COLO is positive. According to the results in models (5) and (6), the R&D level in the source country has a significant and positive impact on FDI outflow; however, dissimilarly to the result in Table 4.1, the coefficient of the variable BA is statistically insignificant, which means a host region with a bonded area holds no advantage in attracting FDI over the regions that do not have a bonded area.

Table 4.3: Results on the random effect estimates

	（1）	（2）	（3）	（4）	（5）	（6）
$LnPOP_{it-1}$	0.209**	0.454***	0.412***	0.319***	0.313*	0.313*
	(2.70)	(5.65)	(5.11)	(3.92)	(2.43)	(2.43)
$LnPOP_{ijt-1}$	2.028***	1.725***	1.734***	2.072***	2.275***	2.267***
	(6.88)	(6.57)	(6.65)	(7.80)	(8.23)	(8.19)
$LnDIST_{ijt}$	-1.950***	-2.407***	-2.405***	-2.927***	-3.025***	-3.027***
	(-7.76)	(-10.71)	(-10.77)	(-11.94)	(-11.27)	(-11.26)
$LnGDPpc_{it-1}$		1.327***	1.257***	1.154***	1.337***	1.337***
		(7.71)	(7.31)	(6.75)	(5.91)	(5.91)
$LnGDPpc_{jt-1}$		1.601***	1.591***	1.995***	1.834***	1.792***
		(11.06)	(11.01)	(12.41)	(10.50)	(9.66)
$COLO_{ij}$			3.593***	2.523*	2.327*	2.282*
			(3.65)	(2.57)	(2.40)	(2.35)
$SIMI_{ijt-1}$				-7.097***	-6.608***	-6.635***
				(-7.20)	(-6.06)	(-6.08)
RD_{it-1}					4.071***	4.084***
					(3.84)	(3.84)
BA_{jt-1}						0.157
						(0.66)
Constant	6.721*	-18.66***	-17.67***	-16.39***	-19.27***	-18.84***
	(1.98)	(-5.38)	(-5.11)	(-4.64)	(-5.05)	(-4.86)
Observation	5003	4884	4884	4674	4351	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.4: Results on the xttobit estimates

	(1)	(2)	(3)	(4)	(5)	(6)
$LnPOP_{it-1}$	0.278*	0.579***	0.532***	0.409***	0.380*	0.381*
	(6.85)	(5.36)	(4.91)	(3.73)	(2.15)	(2.16)
$LnPOP_{ijt-1}$	2.711***	2.273***	2.285***	2.763***	3.084***	3.074***
	(6.77)	(6.34)	(6.43)	(7.61)	(8.05)	(8.03)
$LnDIST_{ijt}$	-2.452***	-2.970***	-2.967***	-3.686***	-3.774***	-3.776***
	(-7.27)	(-9.75)	(-9.83)	(-11.08)	(-10.26)	(-10.28)
$LnGDPpc_{it-1}$		1.684***	1.601***	1.458***	1.629***	1.631***
		(7.12)	(6.79)	(6.21)	(5.21)	(5.23)
$LnGDPpc_{jt-1}$		2.059***	2.048***	2.620***	2.425***	2.379***
		(10.31)	(10.28)	(11.76)	(9.99)	(9.25)
$COLO_{ij}$			4.182**	2.739*	2.533	2.480
			(3.16)	(2.07)	(1.92)	(1.88)
$SIMI_{ijt-1}$				-9.679***	-9.177***	-9.202***
				(-7.08)	(-6.01)	(-6.03)
RD_{it-1}					5.102***	5.116***
					(3.49)	(3.51)
BA_{jt-1}						0.180
						(0.54)
Constant	3.361	-28.84***	-27.71***	-26.32***	-30.02***	-29.56***
	(0.74)	(-6.09)	(-5.87)	(-5.45)	(-5.69)	(-5.54)
Observation	5003	4884	4884	4674	4351	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.3 presents the empirical results on the random effect estimates, which are relatively similar to those in Tables 4.1 and 4.2. The random effect results also provide evidence in favour of the gravity model although the coefficient of population in the source country is less significant than in the OLS estimate results, and is relatively statistically significant at the 5% level in models (5) and (6). Additionally, the significance level of the variable COLO is also less than in the OLS estimate results. According to models (4), (5), and (6), the coefficient of COLO is relatively significant only at the 5% level, and the sign stays positive. Similar to the results in Table 4.2, there is no empirical evidence that a bonded area has any significant impact on FDI flow based on random effect estimates. Despite these slight differences, the rest of the regression results are consistent with the OLS estimates.

Table 4.4 reports the regression results on the xttobit estimates, which are very similar to those in Table 4.3. The only difference is that the variable COLO is insignificant in columns (5) and (6), although the sign is still positive.

Table 4.5(1): Results on the Heckman selection estimates (1)

	Heckman (1)	**Select (1)**	**Heckman (2)**	**Select (2)**
$LnPOP_{it-1}$	0.201*** (6.2)	0.125*** (12)	0.100** (2.9)	0.122*** (11)
$LnPOP_{ijt-1}$	0.692*** (6.5)	0.566*** (15)	0.445*** (3.9)	0.575*** (15)
$LnDIST_{ijt}$	0.886*** (12)	0.321*** (16)	0.667*** (8.4)	0.314*** (16)
$LnGDPpc_{it-1}$	1.927*** (9.2)	0.509*** (13)	1.745*** (16)	0.513*** (13)
$LnGDPpc_{jt-1}$	-1.434*** (-15.99)	-0.518*** (-16.64)	-1.349*** (-15.38)	-0.470*** (-14.69)
$COLO_{ij}$	1.435*** (7.5)	1.083*** (5.1)	1.010*** (5.3)	1.099*** (5.1)
$SIMI_{ijt-1}$			-1.604*** (-5.98)	
RD_{it-1}				
BA_{jt-1}				
Constant	-21.51*** (-9.99)	-9.134*** (-14.17)	-14.27*** (-5.82)	-9.583*** (-14.74)
Observation	4884		4703	

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.5 (2): Results on the Heckman selection estimates (2)

	Heckman (3)	**Select (3)**	**Heckman (4)**	**Select (4)**
$LnPOP_{it-1}$	0.136**	0.193***	0.126**	0.193***
	(2.87)	(15.25)	(2.67)	(15.25)
$LnPOP_{ijt-1}$	0.444***	0.636***	0.349**	0.636***
	(3.87)	(15.49)	(3.01)	(15.49)
$LnDIST_{ijt}$	0.819***	0.465***	0.805***	0.465***
	(8.12)	(18.96)	(8.02)	(18.96)
$LnGDPpc_{it-1}$	1.728***	0.496***	1.509***	0.496***
	(17.48)	(12.43)	(13.72)	(12.43)
$LnGDPpc_{jt-1}$	-1.471***	-0.548***	-1.483***	-0.548***
	(-15.90)	(-15.18)	(-16.08)	(-15.18)
$COLO_{ij}$	0.913***	1.041***	0.791***	1.041***
	(5.07)	(4.81)	(4.37)	(4.81)
$SIMI_{ijt-1}$	-1.293***		-1.565***	
	(-4.07)		(-4.86)	
RD_{it-1}	1.694***		1.763***	
	(7.12)		(7.42)	
BA_{jt-1}			0.434***	
			(4.46)	
Constant	-15.82***	-11.50***	-12.62***	-11.50***
	(-6.14)	(-16.78)	(-4.74)	(-16.78)
Observation	4456		4456	

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.6: Results on the PPML estimates

	（1）	（2）	（3）	（4）	（5）	（6）
$LnPOP_{it-1}$	-1.275*	-0.324	-0.641	0.653	0.770*	0.658
	(-2.18)	(-0.57)	(-0.93)	(1.84)	(2.34)	(1.85)
$LnPOP_{ijt-1}$	-3.820	3.581	3.647	2.001	0.975	-4.071
	(-1.01)	(1.12)	(1.14)	(0.62)	(0.29)	(-1.28)
$LnDIST_{ijt}$	-2371.7***	-435.6***	-431.6***	-437.3***	-475***	-487.7***
	(-14.65)	(-15.65)	(-15.49)	(-13.74)	(-13.5)	(-14.47)
$LnGDPpc_{it-1}$		27.88***	26.62***	31.29***	28.75***	27.79***
		(12.66)	(11.51)	(11.16)	(10.15)	(8.95)
$LnGDPpc_{jt-1}$		28.07***	28.00***	27.28***	28.93***	16.83***
		(8.16)	(8.11)	(7.47)	(7.90)	(4.45)
$COLO_{ij}$			0.380*	0.872****	0.796***	0.47*
			(2.38)	(4.92)	(4.45)	(2.19)
$SIMI_{ijt-1}$				2.647***	2.965***	2.542***
				(4.46)	(4.81)	(3.66)
RD_{it-1}					0.332*	0.483*
					(2.08)	(2.83)
BA_{jt-1}						0.898**
						(3.24)
Constant	16.57***	14.54***	14.56***	13.69***	13.73***	14.10***
	(66.85)	(42.40)	(42.35)	(46.31)	(43.30)	(44.82)
Observation	5003	4884	4884	4674	4351	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Tables 4.5 (1) and (2) show the results on the Heckman selection estimates. The selection step includes the variables of population, GDP per capita, geographic distance, and colonial tie, and the Heckman regression contains all the variables. The coefficients of all the variables in Tables 4.5 (1) and (2) are statistically significant in all models, and the signs are the same as for the results on other estimates.

Additionally, Table 4.6 presents the empirical results on the PPML estimates. Different from the other results, there is no evidence that population in the source country or host region has a significant impact on FDI flow. Additionally, the coefficients of SIMI are significant and positive, which demonstrates that economic similarity significantly increases FDI flow. The results for other variables are similar to those for the OLS, random, xttobit, and Heckman selection estimates, although the values of coefficients are dissimilar, which is due to the fact that the dependent variable used in PPML is a level value.

4.2 Discussion

Table 4.7: Results on various estimates

	OLS	OLS (year)	Random effect	XTTOBIT	Heckman	PPML
$LnPOP_{it-1}$	0.476***	0.549***	0.313*	0.381*	0.126**	0.476***
	（7.63)	(8.52)	(2.43)	(2.16)	(7.77)	7.63()
$LnPOP_{ijt-1}$	2.246***	2.519***	2.267***	3.074***	2.383***	2.246***
	(15.45)	(17.02)	(8.19)	(8.03)	(17.56)	(15.45)
$LnDIST_{ijt}$	-3.057***	-3.032***	-3.027***	-3.776***	-3.039***	-3.057***
	(-28.98)	(-28.64)	(-11.26)	(-10.28)	(-29.23)	(-28.98)
$LnGDPpc_{it-1}$	1.681***	1.788***	1.337***	1.631***	1.694***	1.681***
	(15.19)	(15.84)	(5.91)	(5.23)	(15.34)	(15.19)
$LnGDPpc_{jt-1}$	2.452***	3.606***	1.792***	2.379***	2.846***	2.452***
	(14.37)	(17.87)	(9.66)	(9.25)	(21.29)	(14.37)
$COLO_{ij}$	1.611***	1.387***	2.282*	2.480	1.799***	1.611***
	(5.83)	(5.23)	(2.35)	(1.88)	(6.53)	(5.83)
$SIMI_{ijt-1}$	-5.250***	-4.159***	-6.635***	-9.202***	-4.944***	-5.250***
	(-7.71)	(-5.91)	(-6.08)	(-6.03)	(-7.53)	(-7.71)
RD_{it-1}	3.724***	3.386***	4.084***	5.116***	3.631***	3.724***
	(7.46)	(6.77)	(3.84)	(3.51)	(7.29)	(7.46)
BA_{jt-1}	0.793***	0.292	0.157	0.180	0.434***	0.793***
	(3.65)	(1.30)	(0.66)	(0.54)	（4.46）	(3.65)
Constant	-30.35***	-46.22***	-18.84***	-29.56***	-35.54***	-30.35***
	(-11.46)	(-14.22)	(-4.86)	(-5.54)	(-16.55)	(-11.46)
Observation	4351	4351	4351	4351	4351	4351

*t statistics in parentheses * $p < 0.05$, ** $p < 0.001$, *** $p < 0.001$*

Tables 4.7 summarise the regression results on various estimates. First, the signs of standard variables in the traditional gravity model are significant in most regressions, which is in accordance with past literature. The result shows that the mass variable, source population, and host population, have significant positive effects on FDI flow into a province. Besides population in the home country being relatively significant in columns (3) and (4) in the random effect and xttobit estimates, it is not significant in most PPML regressions. Population represents market size in this study. Thus, the positive signs of both source and host populations mean the following: (i) a source country with a greater market size has more incentive to conduct investment abroad than a country with a smaller market size and (ii) a host region in China with a greater market size will receive more foreign investment compared to a province with a smaller market size. This result is in accordance with previous empirical evidence (Aleksynska and Havrylchyk, 2013; Bailey and Li, 2015). From the perspective of the demand side, MNEs prefer to invest in an economy with a larger market and higher potential growth (Duanmu, 2012). Market size is important for a firm's short-term and long-term sales and profits (Makino et al., 2004). For market-seeking FDI, a larger market size provides more opportunities to maximise the effects of economies of scale and scope by supplying products and services to a new market (Dunning, 1980). For efficiency-seeking FDI, many business activities are scale-sensitive, for instance, production, distribution, and per-unit costs. Thus, aiming at sustainable growth and future profit, firms are more likely to choose a host region with a larger market size.

Second, geographic distance significantly reduces FDI flow. Combining the positive effects of the mass variables mentioned above, the negative effect of geographic distance confirms the existence of the gravity effect on FDI location choice in China. FDI flow grows with the market size of the source and host regions but reduces as the geographic distance increases. That may imply that vertical FDI still dominates in China. Differing from trade studies, the influence of spatial distance in FDI studies is not predictable. In terms of international business, long geographic distance represents high transportation costs for sending staff and shipping goods. Those high transportation costs seem to have opposite effects on vertical and horizontal FDI. For vertical FDI, costly shipping is a hindrance, since vertical FDI needs to export its products back to the home country and not only sell them in the host market. However, for horizontal FDI, long geographic distance gives MNEs more motivation to conduct

FDI rather than export to the foreign market, which demonstrates that FDI flow between a pair of regions separated by a longer geographic distance should be greater than with those separated by a shorter distance. Thus, the significant negative effect of geographic distant on FDI inflow in China possibly implies that vertical FDI dominates in China rather than horizontal FDI. That is also confirmed by data; in 2012, FDI in the manufacturing industry still accounted for 43.74% of the total and took the largest share in the total 19 industries.

GDP per capita in both home and host regions has significant positive effects on FDI flow. GDP per capita can present a number of economic-related factors, such as economic level, income, and infrastructure. Those empirical results suggest that regions with a more advanced economic level, higher income, and better infrastructure receive and conduct more FDI. GDP per capita in host regions is a proxy for the potential demand for foreign products (Belderbos et al., 2011). Thus, the significantly positive sign of GDP per capita implies the importance of the demanding factor for attracting inward FDI. From the perspective of an investment supplier, a firm sourcing from a mature economic environment has abundant business experience of marketing and managing. That experience makes MNEs more competitive in a foreign economy compared to local and other foreign firms.

The COLO dummy variable is strongly significant in most regressions, relatively significant in the random effect estimates in columns (4)-(6) and in the PPML estimates in columns (3) and (6), but insignificant in the xttobit estimates. The existence of colonial tie between a pair of source and host regions is a significant increasing factor, which is similar to what was shown in previous studies (Aleksynska and Havrylchyk, 2013; Choi et al., 2016). This positive coefficient implies that cultural distance significantly impacts FDI location choice in China. MNEs prefer a culturally closer host region rather than a culturally remote region. This result is consistent with Du et al.'s (2012) argument that FDI from a culturally closer country could effectively turn government intervention into help, whereas FDI from a culturally remote area is less able to do so. Since cultural distance is an important component of administrative distance, the positive sign of the COLO variable also demonstrates that an administratively similar region is a preferred location for FDI (Bailey and Li, 2015).

However, economic similarity is significant and negatively related to FDI flow in all models except for in the PPML estimates. The coefficient of the economic similarity variable is significant and negative. That implies that MNEs in China prefer to invest in a dissimilar economy. Horizontal FDI produces services for both the parent and host regions and tends to be located in similarly endowed economies. However, this occurs in dissimilar economies, since headquarter services are completely separated from production to exploit factor cost differentials. Thus, the preference for an economically dissimilar region implies that vertical FDI dominates in China, which is consistent with the result of the geographic distance variable.

The sign of the R&D in the home country variable is significantly positive in most regions and relatively significant in the PPML estimates, which means that the level of R&D in the source country is a pushing factor for outward FDI. This result is consistent with previous studies that showed that offshore R&D is an extension of MNCs' home R&D bases, and MNCs can be an intermediate vehicle of knowledge flowing from the home to host countries (Gupta and Govindarajan, 1991). And, in developing countries, MNCs tend to be more involved in home-based technology, exploiting rather than augmenting (Diez and Berger, 2005). The dummy variable BA positively and significantly relates to FDI flow in the OLS and Heckman selection estimates, relatively significantly in the PPML estimates, but insignificantly in the other estimates.

In summary, the promoting factors for FDI flow into China's various host regions are market size and GDP per capita of both home and host regions, colonial relations, the R&D level in the home region, and a bonded area in the host region. The resistance factors include geographic distance and economic similarity.

4.3 Robustness Check

Table 4.8: Results using an alternative model on various estimates

	OLS	OLS (year)	Random effect	XTTOBIT	Heckman	PPML
$LnPOP_{it-1}$	0.464***	0.502***	0.230	0.275	0.398***	0.638***
	(6.94)	(7.45)	(1.62)	(1.45)	(5.67)	(7.51)
$LnPOP_{ijt-1}$	0.615***	0.882***	0.878***	1.207***	-0.100	-0.947***
	(3.93)	(5.35)	(3.60)	(3.63)	(-0.86)	(-5.68)
$LnDIST_{ijt}$	1.189***	1.212***	0.947***	1.159***	0.987***	0.698***
	(13.56)	(13.87)	(4.46)	(4.08)	(10.82)	(11.32)
$LnGDPpc_{it-1}$	1.350***	2.007***	1.147***	1.493***	1.646***	1.520***
	(7.82)	(10.12)	(4.53)	(4.33)	(14.61)	(9.94)
$LnGDPpc_{jt-1}$	-3.125***	-3.136***	-3.037***	-3.794***	-2.021***	-0.971***
	(-30.06)	(-30.08)	(-10.24)	(-9.65)	(-12.95)	(-19.81)
$COLO_{ijt}$	1.498***	1.320***	2.481*	2.701	1.185***	0.260
	(5.89)	(5.30)	(2.32)	(1.91)	(4.69)	(1.26)
$SIMI_{ijt-1}$	-5.585***	-5.171***	-7.528***	-10.42***	-0.445	7.398***
	(-7.42)	(-6.83)	(-6.03)	(-6.02)	(-1.19)	(6.98)
RD_{it-1}	3.701***	3.560***	4.198***	5.296***	1.534***	-1.152**
	(7.21)	(6.97)	(3.68)	(3.44)	(6.00)	(-3.14)
BA_{jt-1}	1.465***	1.159***	0.129	0.199	0.669***	0.319
	(6.54)	(4.85)	(0.53)	(0.59)	(6.21)	(1.00)
Constant	-4.917*	-17.42***	-1.29	-6.276	-12.65***	2.574
	(-2.14)	(-5.98)	(-0.38)	(-1.45)	(-5.88)	(1.34)
Observation	4351	4351	4351	4351	4427	4351

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

To confirm the robustness of the empirical results, I used GDP as an alternative measure of market size. The results in Table 4.8 are consistent with my main results. GDP in the home and host countries is the economy mass variables capturing the market size in alternative gravity regression. The coefficients of GDP in the home country remain positive; however, they are not statistically different from zero in the random effect or xttobit regression estimates. GDP in the host region shows a positive effect on inward FDI in most regressions, except for the PPML and Heckman estimates. The COLO variable is also found to have significant and positive coefficients in most regressions, relatively significant ones in the random effect estimates, but insignificant ones in the xttobit and PPML estimates. The coefficient of economic similarity is significantly positive in the PPML estimates, negative but not statistically significant in the Heckman estimates, and significantly negative in the other regressions. The result of R&D in the home country based on the PPML estimates is opposite to the main result, but the same as the main results in the other estimate regressions. B&A is positive in all regressions but only significant in a few regressions. The results of other independent variables, including GDP per capita in the home and host regions separately and geographic distance, are very similar to the main results.

Table 4.9: Models of log total FDI+1 via OLS and QR

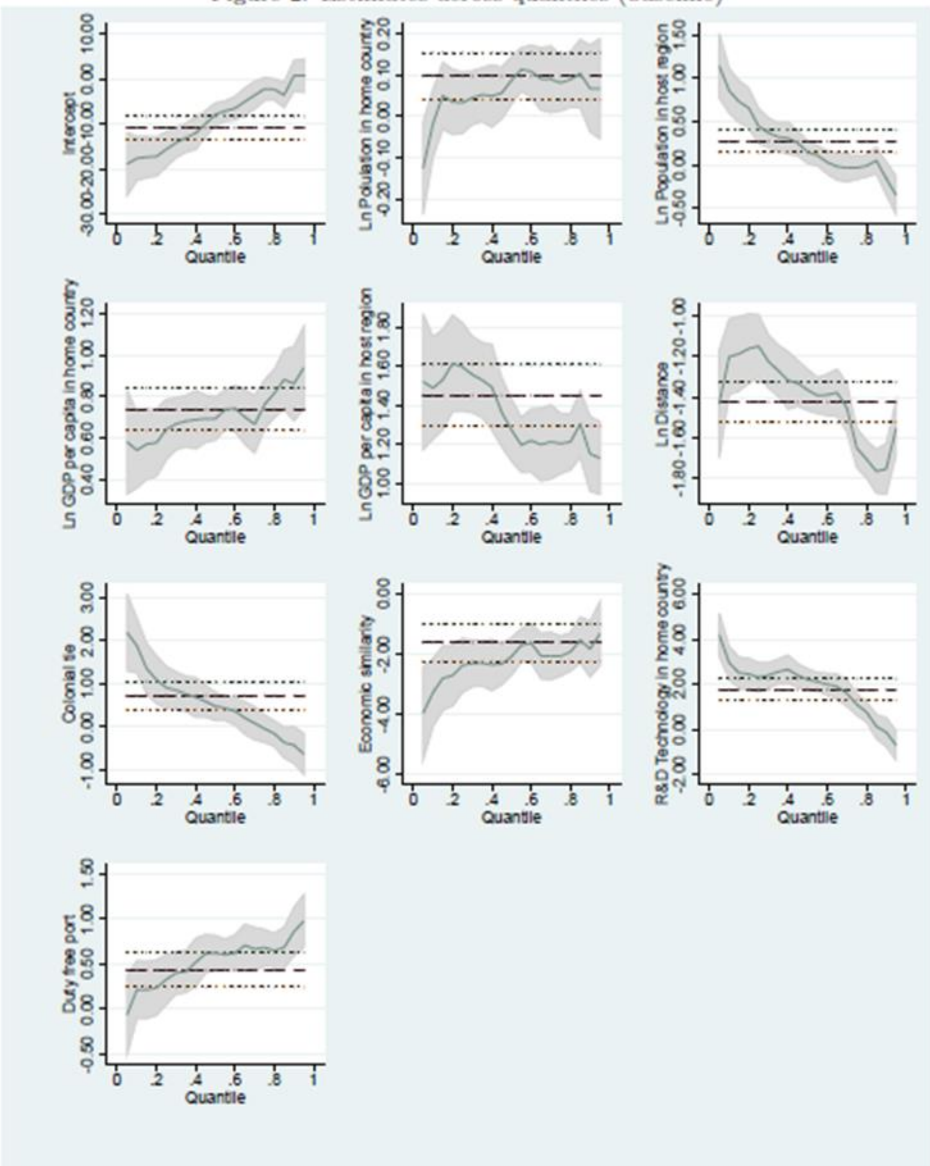
	OLS	**Q(0.10)**	**Q(0.25)**	**Q(0.50)**	**Q(0.75)**	**Q(0.90)**	**Q(0.99)**
$\boldsymbol{LnPOP_{it-1}}$	0.0976^{**}	-0.0166	0.0335	0.0877^{**}	0.0817^{*}	0.0678	0.000168
	(3.10)	(-0.26)	(0.75)	(2.72)	(2.45)	(1.65)	(0.00)
$\boldsymbol{LnPOP_{ijt-1}}$	0.276^{***}	0.861^{***}	0.448^{***}	0.148^{*}	-0.0315	-0.155	-0.323
	(3.69)	(5.86)	(4.41)	(2.01)	(-0.41)	(-1.66)	(-1.86)
$\boldsymbol{LnDIST_{ijt}}$	0.740^{***}	0.542^{***}	0.642^{***}	0.695^{***}	0.763^{***}	0.863^{***}	0.991^{***}
	(12.42)	(4.66)	(7.98)	(11.95)	(12.66)	(11.68)	(7.19)
$\boldsymbol{LnGDPpc_{it-1}}$	1.451^{***}	1.488^{***}	1.596^{***}	1.273^{***}	1.204^{***}	1.151^{***}	1.385^{***}
	(19.89)	(8.43)	(13.06)	(14.43)	(13.16)	(10.26)	(6.62)
$\boldsymbol{LnGDPpc_{jt-1}}$	-1.424^{***}	-1.200^{***}	-1.148^{***}	-1.364^{***}	-1.649^{***}	-1.752^{***}	-1.502^{***}
	(-25.97)	(-10.71)	(-14.79)	(-24.33)	(-28.40)	(-24.58)	(-11.30)
$\boldsymbol{COLO_{ijt}}$	0.735^{***}	1.890^{***}	0.913^{***}	0.483^{**}	-0.0387	-0.420	-0.546
	(6.40)	(5.18)	(3.62)	(2.65)	(-0.20)	(-1.81)	(-1.26)
$\boldsymbol{SIMI_{ijt-1}}$	-1.621^{***}	-3.280^{***}	-2.375^{***}	-2.078^{***}	-2.067^{***}	-1.834^{***}	-1.253
	(-4.59)	(-4.72)	(-4.94)	(-5.98)	(-5.74)	(-4.15)	(-1.52)
$\boldsymbol{RD_{it-1}}$	1.767^{***}	2.948^{***}	2.301^{***}	2.210^{***}	1.096^{***}	-0.134	-0.497
	(8.33)	(5.60)	(6.32)	(8.40)	(4.02)	(-0.40)	(-0.80)
$\boldsymbol{BA_{jt-1}}$	0.435^{***}	0.214	0.330^{*}	0.624^{***}	0.683^{***}	0.861^{***}	0.809^{**}
	(4.41)	(0.99)	(2.22)	(5.80)	(6.13)	(6.29)	(3.17)
Observation	3109	3109	3109	3109	3109	3109	3109

*t statistics in parentheses * p <0.05, ** p < 0.001, *** p < 0.001*

Table 4.9 reports the results of quantile regression based on OLS. OLS is the most widely used estimate in empirical gravity model studies. However, standard linear regression technique reflects the average effect of each regressor and the outcome variable based on the conditional mean function E(y|x), assuming that this function is normal and has symmetrical distribution. Paniagua et al. (2015) found that OLS provides only a partial view of FDI, since at firm level, a few firms are responsible for most of the world's FDI. Quantile regression has a capability that investigates the relationship when the data concentrate at different levels in the conditional distribution of the dependent variable concentrate most of the data. Regarding my data set, a few home countries contribute the most FDI flow to China. Thus, I applied a quantile regression to check the robustness of the main results.

Table 4.9 presents the baseline estimate results without fixed effects. Overall, the empirical results of quantile regression perform well and are consistent with the main results. Most of the variables are statistically significant with the expected signs that vary with the quantiles. The rest of the columns show the results using OLS, and the others present the results for the 10%, 25%, 50%, 75%, 90%, and 99% quantiles. Figure 2 interprets how the coefficients of each variable vary with the quantiles. The effect of population in the host region decreases with the quantile, which means that market size is less important for foreign investment compared to smaller investment. GDP per capita in the host region, geographic distance, colonial tie, and R&D in the home country follow the same trend. In addition, the coefficients of population, colonial relation, economic similarity, and R&D are not statistically significant for large quantiles, indicating that the effects of these variables are not significant for large investments. The duty-free port dummy variable shows the clearest upward trend, and it is positive and significant in all quantiles.

Figure 2: Estimates across quantiles (baseline)



5 Conclusion

Besides the importance of the location choice of FDI at a national level, MNEs make equal considerations regarding sub-national locational advantages offered by multi-level local governments when selecting a proper site for investment (Nielsen, Asmussen, and Weatherall, 2017). This is especially true for a country such as China, whose market is geographically wide and where the regional disparity is tremendous. That regional disparity includes differences in language, culture, climate, economic development, and government administration, which are determinant factors for MNEs' location choices. However, the previous literature relating to sub-national level location choices of MNEs mainly focuses on the effects of some locational specific factors in the host region but overlooks the impact of relational factors between the source and recipient regions of investment. Thus, this study has first addressed the impact of distance on sub-national level location choices of FDI in China, which is missing in the previous literature.

I made estimates using the gravity model with provincial FDI flow data from 2000 to 2012, and employed three concepts of distance. They were geographic distance, cultural distance, and economic distance. The regression results indicate that geographic distance and cultural distance have significant negative effects on FDI flow, whereas economic distance has a significant positive effect. That means that FDI prefers to locate in regions that are geographically and culturally close but economically distant from the home country, which further implies that FDI in China is dominated by vertical FDI. The results also confirm the existence of the gravity effect. FDI increases with market size in both home and host regions but decreases with distance. Other independent variables are also significant determinants of FDI. The economic standard in the home and host regions, the R&D level in the home country, and a bonded area in the host region are contributing factors to FDI flow.

The empirical findings above suggest implications for policy-makers in China. First, the provincial government should put the emphasis on attracting FDI from culturally close countries and the countries with advantages in R&D, since these countries have more motivation to invest than others. Second, the government should provide some institutional and policy support to encourage and promote horizontal FDI, which can reduce the negative effects of geographic and economic distances on FDI inflow.

Appendices

Appendix1: Variable description and source

	Variable	Description	Source
Dependent variable	*FDI*	Logarithm of annual FDI inflow from parent country to a host province (10,000 US dollar)	Statistical yearbook of various provinces,
Independent variables of parent countries	*GDPpc*	Logarithm of GDP per capita (constant 2010 US dollar)	World Bank
	POP	Logarithm of Midyear estimates of all residents including legal status and citizenship	World Bank
	RD	Medium and high-tech industry (% manufacturing value added)	United Nations Industrial Development Organization, Competitive Industrial Performance database
Independent variable of host regions	*GDPpc*	Logarithm of real GDP per capita (constant 2010 RMB Yuan)	China Statistical Yearbook
	POP	Logarithm of total population at the end of year	China Statistical Yearbook
	BA	Takes the value of 1 if the region has duty free Port and otherwise 0	Manual collections by the author
Linkage variables	*DIST*	Logarithm of direct distance between the capital cities of pair regions	Goggle map, and calculations by the author
	COLO	Take the value of 1 if the pair regions have ever had a colonial link, and 0 otherwise	Manual collections by the author
	SIMI	An index measuring the economic similarity of pair regions	Calculated by the author

Appendix 2. Observations in dataset

	Anhui	Beijing	Chongqing	Fujian	Guangdong	Hainan	Heilongjiang
Australia	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Austria	2001-2012	2001-2012	N	N	2001-2012	N	N
Barbados	2001-2012	2001-2012	N	N	N	N	2001-2012
Belgium	2001-2012	N	2001-2012	N	2001-2012	2001;2001;2005;2010-2012	2001-2012
Bermuda	N	2001-2012	N	N	2001-2012	N	2001-2012
Brazil	2001-2012	N	N	N	N	N	2001-2012
Brunei	2001-2012	N	N	N	2001-2012	N	2001-2012
Canada	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Denmark	2001-2012	N	N	N	2001-2012	N	N
Finland	N	N	N	N	2001-2012	2001;2001;2005;2010-2012	2001-2012
France	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Germany	2001-2012	2001-2012	N	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Hong Kong	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Hungary	N	N	N	N	N	N	2001-2012
India	2001-2012	N	N	N	2001-2012	N	2001-2012
Indonesia	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Ireland	2001-2012	N	N	N	2001-2012	N	2001-2012
Italy	2001-2012	N	N	N	2001-2012	2001;2001;2005;2010-2012	2001-2012
Japan	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Korea	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012
Liberia	2001-2012	N	N	N	2001-2012	N	N
Luxembourg	N	N	N	N	N	N	2001-2012
Macao	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005;2010-2012	2001-2012

Malaysia	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Mauritius	2001-2012	2001-2012	N	N	2001-2012	N	2001-2012
Netherlands	2001-2012	2001-2012	N	N	2001-2012	2001;2001;2005; 2010-2012	2001-2012
New Zealand	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Philippines	2001-2012	N	N	2001-2012	2001-2012	N	2001-2012
Russia	2001-2012	N	N	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Samoa	2001-2012	2001-2012	N	N	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Singapore	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
South Africa	N	N	N	2001-2012	N	N	2001-2012
Spain	2001-2012	N	N	N	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Sweden	2001-2012	N	2001-2012	N	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Switzerland	2001-2012	N	2001-2012	N	2001-2012	N	2001-2012
Taiwan	2001-2012	2001-2012	2001-2012	N	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Thailand	2001-2012	N	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
Turkey	2001-2012	N	N	N	N	N	2001-2012
United Kingdom	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012
United States	2001-2012	2001-2012	2001-2012	2001-2012	2001-2012	2001;2001;2005; 2010-2012	2001-2012

	Henan	Hunan	Jiangxi	Liaoning	Ningxia	Shaanxi	Shandong
Australia	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Austria	N	N	N	N	N	2001-2012	2002-2012
Barbados	N	N	N	N	N	2001-2012	N
Belgium	N	N	N	2001-2012	2009-2012	2001-2012	2002-2012
Bermuda	N	N	N	N	N	2001-2012	2002-2012
Brazil	N	N	N	N	N	N	N
Brunei	N	N	N	N	N	2001-2012	N
Canada	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Denmark	N	N	N	2001-2012	N	N	2002-2012
Finland	N	N	N	2001-2012	N	2001-2012	N
France	N	N	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Germany	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Hong Kong	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Hungary	N	N	N	N	N	2001-2012	2002-2012
India	N	N	N	N	N	2001-2012	N
Indonesia	N	N	2001-2012	2001-2012	N	N	2002-2012
Ireland	N	N	N	N	N	N	N
Italy	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Japan	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Korea	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Liberia	N	N	N	N	2009-2012	N	N

Luxembourg		2001-2008;2010-2012		N	N	2001-2012	2002-2012
Macao	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Malaysia	N	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Mauritius	N	N	N	N	N	2001-2012	2002-2012
Netherlands	N	N	2001-2012	2001-2012	N	2001-2012	2002-2012
New Zealand	N	N	2001-2012	2001-2012	N	2001-2012	2002-2012
Philippines	N	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Russia	N	N	N	N	N	N	2002-2012
Samoa	N	N	N	N	2009-2012	2001-2012	2002-2012
Singapore	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
South Africa	N	N	N	N	N	2001-2012	N
Spain	N	N	2001-2012	2001-2012	N	2001-2012	2002-2012
Sweden	N	N	N	2001-2012	N	2001-2012	2002-2012
Switzerland	N	N	N	N	N	2001-2012	2002-2012
Taiwan	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012
Thailand	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
Turkey	N	N	N	N	N	N	N
United Kingdom	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	N	2001-2012	2002-2012
United States	2001-2012	2001-2008;2010-2012	2001-2012	2001-2012	2009-2012	2001-2012	2002-2012

	Shanghai	Shanxi	Tianjin Xinjiang	Xinjian	Yunnan	Zhejiang
Australia	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Austria	N	2002-2012	N	N	N	N
Barbados	N	N	N	N	N	N
Belgium	N	2002-2012	N	N	2001-2012	N
Bermuda	N	2002-2012	N	N	N	N
Brazil	N	2002-2012	N	N	2001-2012	N
Brunei	N	N	N	N	N	N
Canada	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Denmark	N	N	2001-2012	2001-2012	2001-2012	N
Finland	N	2002-2012	N	N	2001-2012	N
France	2001-2010	2002-2012	2001-2012	N	2001-2012	2001-2012
Germany	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Hong Kong	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Hungary	N	2002-2012	N	N	N	N
India	N	2002-2012	N	N	N	N
Indonesia	N	2002-2012	N	N	N	N
Ireland	N	N	N	N	2001-2012	N
Italy	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Japan	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Korea	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Liberia	N	2002-2012	N	N	N	N
Luxembourg	N	2002-2012	N	N	N	N
Macao	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	N
Malaysia	N	2002-2012	2001-2012	2001-2012	2001-2012	N
Mauritius	N	2002-	N	N	N	N

		2012				
Netherlands	N	2002-2012	2001-2012	N	2001-2012	N
New Zealand	N	2002-2012	N	N	2001-2012	N
Philippines	N	2002-2012	N	N	2001-2012	N
Russia	N	N	N	N	2001-2012	N
Samoa	N	2002-2012	N	N	N	N
Singapore	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
South Africa	N	2002-2012	N	N	N	N
Spain	N	2002-2012	2001-2012	N	2001-2012	N
Sweden	N	2002-2012	2001-2012	N	N	N
Switzerland	N	2002-2012	N	N	2001-2012	N
Taiwan	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
Thailand	2001-2010	2002-2012	N	2001-2012	2001-2012	N
Turkey	N	2002-2012	N	2001-2012	N	N
United Kingdom	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012
United States	2001-2010	2002-2012	2001-2012	2001-2012	2001-2012	2001-2012

Appendix 3. Category of China's region

Economic areas	Provincial level regions
East area	Beijing; Tianjin; Hebei; Liaoning; Shanghai; Jiangsu; Zhejiang; Fujian; Shandong; Guangdong; Hainan
Central area	Shanxi; Jilin; Heilongjiang; Anhui; Jiangxi; Henan; Hubei; Hunan
West area	Chongqing; Sichuan; Guizhou; Yunnan; Tibet; Shaanxi; Gansu; Qinghai; Ningxia; Xinjiang; Inner Mongolia

Note: The classification is cited from Report on Foreign Investment in China.

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Chapter3: How the intensity of environmental regulation impacts employment: Evidence from China's industrial sector, 2001–2015

1. Introduction

In response to the continuous degradation of the environment, many national states around the world are making efforts towards pollution abatement through the tightening of environmental regulations. China, as a developing country, is in the initial stage of seeking a way to balance economic development with requirements to undertake the environmental issues. China is one of the most polluted countries in the world. Air pollution in China averaged 55.749 micrograms per cubic metre exposure to PM2.5 during 2000–2015, which is over 12 units higher than the global mean of 43.309 micrograms per cubic metre (World Bank, 2016). Additionally, water pollution is also a serious environmental problem. The average renewable internal freshwater resources per capita in China was 2,119 cubic metres during 2002–2014, which is only roughly one-third the global average of 6,387 cubic metres (World Bank, 2017).

Beginning in 2001, the central government began to place an emphasis on environmental protection and first introduced an environmental target, as opposed to economic development, as the main objective of the 10th Five-Year Plan. Regrettably, the objective of a 10% reduction of SO_2 emissions was not achieved by 2005. However, the central government did not abandon faith in environmental governance. The 11th and 12th Five-Year Plans increasingly emphasize environmental regulation. There is a 30% objective in the 11th Five-Year Plan relating to green development, and the 12th Five-Year Plan encompasses China's first full-fledged green development plan containing both qualitative and quantitative objectives for a wide range of ecological and environmental targets.

However, alongside the betterment of China's environmental regulatory system are concerns about the adverse impacts of environmental regulation. One such concern is that the intensity of environmental regulation will lead to a reduction in employment. This concern has prompted debate around the country's environmental policies, especially because there are 450 million rural workers who are expected to migrate to urban areas within the next two decades, which will generate challenges for the government in creating jobs and promoting rapid economic development (Liu et al., 2017).

Popular thinking is that environmental regulation will cause a reduction in labour demand in the directly regulated sectors. The economic perspective behind this claim is that higher standards for pollution abatement increases production costs, which then further raises prices and reduces demand for output, thus reducing employment. For instance, the implementation of more stringent environmental regulations may force some enterprises to acquire new equipment to reduce their discharge of pollutants, which they must do in order to avoid being shut down. This creates extra costs in production and operations, and consequently, reduces employment (Chen et al., 2018). Additionally, environmental regulation may encourage innovation and productivity as enterprises adopt more environmentally friendly production technologies and improve their production efficiency, which often reduces the demand for production workers. However, this argument is not necessarily supported by economic theories. According to a neoclassical microeconomic analysis, Berman and Bui (2001) demonstrated that environmental regulation can also be a labour-enhancing factor. To comply with new environmental regulations, plants need to hire workers to install and maintain pollution treatment equipment or modify production processes to reduce pollution, which may lead to more of a rise or decline in labour demand than the previous production process. Consequently, the impact of the intensity of environmental regulation on the employment of regulated enterprises cannot be predicted by standard neoclassical microeconomic theory. Thus, it remains inconclusive and needs to be examined empirically.

In response to the doubts about how environmental regulations will impact employment in the regulated sectors in China, this study extends the existing empirical analyses by investigating the relationship between the intensity of environmental regulation and employment using data from China's industrial sector during the period 2001 to 2015, which covers three of China's Five-Year Plans (the 10th, 11th, and 12th). The purpose of this study is to explore the relationship between environmental regulation and employment in China's industrial sector. This study aims to answer the following questions: Whether the increasing intensity of environmental regulation reduces employment or not? How the effects of environmental regulation on employment changes over different five years plans? Is the impact of environmental regulation on employment is same across enterprises with various ownership?

Only a few empirical studies have examined the impact of environmental regulation on employment in China. One utilized firm-level data in the textile printing and dyeing industry (Liu et al., 2017), and another relied on a cross-sectional data set from the World Bank's Investment Climate Survey of 18 Chinese cities in 2003 (Sheng et al., 2019). Thus, this paper is potentially the first empirical study on the effect of environmental regulation on employment in China using a longer time period from an industry-level data set. Benefited by this relatively long period covered by the data set, this study makes contributions to the existing literature on three points. First, it examines the continuous effect of environmental regulation on employment over a long period of time. Second, this study uses empirical regression for sub-samples of three different Five-Year Plan periods to investigate the differences in the impact of environmental regulation among the various periods. Third, this study also checks the heterogeneity of the relationships between environmental regulation and employment across enterprises with different ownership structures.

The empirical results lead to three conclusions. First, environmental regulations, especially water pollution control regulations, promoted employment in industrial enterprises between 2001 and 2015. In addition, water pollution regulations dominated the environmental regulation effect rather than gas pollution regulations. The effects of gas pollution regulations became apparent beginning in the 12th Five-Year Plan period. Second, the environmental regulation effect on industrial employment changed over time. It moved from being a labour-enhancing factor in the 10th Five-Year Plan to being a labour-reducing factor in the 11th and 12th Five-Year Plan periods. Additionally, the impacts of the intensity of environmental regulation on employment in industrial enterprises were heterogeneous across different ownership structures. In general, this impact is positive in state-owned industrial enterprises, negative in privately owned enterprises, and insignificant in foreign-owned enterprises.

The remainder of this paper is organized as follows. Section 2 summarizes the environmental regulations in the 10th, 11th, and 12th Five-Year Plan periods covering

2001 to 2015. Section 3 reviews the relevant empirical literature regarding the impact of environmental regulation on employment, including studies done in both China and other economies, and introduces the theoretical framework of the present study. Section 4 outlines the empirical regression model and describes the data and variables used for this study. Section 5 interprets the main empirical results. Section 6 discusses a series of robustness checks with alternative estimators or alternative environmental regulation indicators. Section 7 draws conclusions from the empirical results and provides some potential explanations for the findings. Finally, the last section concludes this study and gives some suggestions for policy and future research.

2. Background: Environmental regulations in the 10th, 11th, and 12th Five-Year Plans

China's Five-Year Plans are a series of national social and economic development initiatives containing detailed guidelines for economic and social development. The first Five-Year Plan was issued in 1953, and the 10th, 11th, and 12th Five-Year Plans covering the period researched in this study ran from 2000 to 2005, 2006 to 2010, and 2011 to 2015, respectively. The core objective of the Five-Year Plan is to promote China's economic growth and social progress. However, the Plan has experienced a transition from an economic plan to a strategic plan, and then to a comprehensive development plan over time. The first to fifth Five-Year Plans emphasized the importance of heavy industry, the steel industry, and the manufacturing sector, which set the basic tone for China's "black" industrialization (Hu, 2013). The sixth to ninth Five-Year Plans gradually shifted from an emphasis on purely economic planning to social development planning. Unlike the previous growth path, the Plans in this period set forth the importance of healthy and sustainable development by promoting production through intensive utilization of capital and resources and efficient energy use. The 10th Five-Year Plan was the first to include an environmental target as a main objective by setting a goal of 10% SO_2 emission reduction. Although the implementation of this target was not achieved by 2005, the 11th and 12th Five-Year Plans continued to increasingly emphasize environmental regulation, with a 30% objective in the 11th Five-Year Plan related to green development. Further, the 12th Five-Year Plan was China's first full-fledged green development plan, containing both qualitative and quantitative objectives for a wide range of ecological and environmental targets.

This section will summarize the details of environmental regulations in the 10th, 11th, and 12th Five-Year Plans and use national-level data to provide a glance at the achievements in environmental improvement during these three respective periods.

2.1 Tenth Five-Year Plan

The 10th was the first Five-Year Plan that included environmental regulation as a main objective. According to 10th Five-Year National Total Emissions Control Plan of the Major Pollutants, the overall objective was to reduce environmental pollution;

curb the trend of environmental deprivation; improve urban and rural environmental quality, especially in large and medium-sized cities; and build a sound legal system, policy, and management regime of environmental protection. The detailed indicators of industrial pollution control include: bringing SO_2 emissions below 14.5 million tonnes, brining soot emissions below 8.5 million tonnes, reducing dust emissions to below 9 million tonnes, reducing chemical oxygen demand (COD) to below 6.5 million tonnes, controlling emissions of ammonia nitrogen to bring it below 0.7 million tonnes, increasing the rate of repetitive use of industrial water to 60%, and increasing the rate of comprehensive utilization of industrial solids to 50% (State Council, 2001).

Although the total investment in environmental protection during the 10th Five-Year Plan doubled from the Ninth Five-Year Plan, which accounted for more than 1% of the GDP for the first time, the targets of the 10th Five-Year Plan were not achieved. In comparison to 2000, the emissions of SO_2 increased by 27.8% and the reduction of COD was only 2.1%. Table 2.1 gives details on the main environmental protection indicators, goals, and outcomes in the 10th Five-Year Plan period.

Table 2.1 Main Environmental Protection Indicators, Goals, and Outcomes in the 10th Five-Year Plan Period

Indicators	2000	Targets	2005
Volume of SO2 Emission (million tons)	19.95	18	25.49
Volume of SOOT Emission (million tons)	11.65	11	11.83
Volume of DUST Emission (million tons)	10.92	9	9.11
Volume of COD Emission (million tons)	14.45	13	14.14
Volume of Industrial Waste Solid Emission (million tons)	31.86	29	16.55
Repetitive Use rate of Industrial Water	/	60%	75%
Volume of Industrial SO2 Emission (million tons)	16.13	14.5	21.68
Volume of Industrial SOOT Emission (million tons)	9.53	8.5	9.49
Volume of Industrial COD Emission (million tons)	7.05	6.5	5.55
Comprehensively Utilize rate of Industrial Solid	51.8	50%	54%

Source: 10th Five-Year National Total Emissions Control Plan of the Major Pollutants

2.2 Eleventh Five-Year Plan

The 11th Five-Year Plan also set 10% as its SO_2 and COD reduction targets (State Council, 2006). However, in contrast to the 10th Five-Year Plan, the 11th Five-Year Plan not only clearly establishes a pollution reduction target for the entire country but also allocated a different share of the reduction burden to each province. The Ministry of Environmental Protection (MEP) and the National Development and Reform Committee of China issued the "11th Five-Year National Total Emissions Control Plan of the Major Pollutants" which clearly a specifically stated the reduction targets and apportion them to the local governments (MEP, 2006). The provincial reduction target was set after the negotiation between the central and local governments. And it was determined by various factors including GDP growth, industrial structure, current pollution strength and pollution reduction ability. The provinces with poor environment and high-speed economic development took greater reduction mandates (Wu et al., 2017).

Additionally, to ensure the realization of its goals, the 11th Five-Year National Environmental Protection Plan clearly defined detailed measures that were required to reduce COD and SO_2 discharge. For instance, it required all cities to establish waste water treatment facilities by 2010 and mandated that the rate of treated waste water should reach 70%. Regarding industrial water pollution, the industries with high levels of water pollution, such as papermaking, chemicals, textile printing and dyeing, electronics, steel, and coal, were closely regulated by the establishment of strict emissions limits for wastewater and mandates for increased repetitive use.

In 2009, the total investment in environmental treatment was RMB 452.5 billion, up 89.5% from 2005. And environmental expenditures as a percentage of the GDP increased from 2.3% in 2005 to 2.33% in 2009. Ultimately, the targets of the 11th Plan were overfulfilled. With SO_2 discharges reduced by 14.29% and a COD decline of 12.45%, both were higher than the 10% established in the Plan. Energy consumption per unit of GDP declined about 19.1% during the 11th Five-Year Plan. Table 2.2 details the main environmental protection indicators, goals, and outcomes for the 11th Five-Year Plan period.

Table 2.2 Main Environmental Protection Indicators, Goals, and Outcomes for the 11th Five-Year Plan Period

Indicators	2005	Targets	2010
Volume of Industrial COD Emission (million tons)	14.14	12.7	12.381
Volume of Industrial SO2 Emission (million tons)	25.49	22.95	21.85
Proportion of Water Quality Worse than Grade V in Surface Water Monitored Section (%)	26.1	<22	16%
Proportion of Water Quality better than Grade III in Main Water System Monitored Section (%)	41	>43	60%
Proportion of Air Quality Equal to or Above Grade II over 292 Days in Major Cities (%)	69.4	75	79.60%

Source: 11th Five-Year National Total Emissions Control Plan of the Major Pollutants

2.3 Twelfth Five-Year Plan

China's 12th Five-Year Plan was the first full-fledged green development plan; one-third of its objectives related to environmental issues and natural resources, up from 27.2% in the 11th Plan. There were six sub-components for green development, each with its own section within the entire Plan: positively responding to climate change; strengthening conservation and management of natural resources; building a "circular economy"; improving environmental protection; enhancing ecological protection and restoration; and perfecting systems for water management and disaster prevention and alleviation. Moreover, the 12th Five-Year Plan was the first time that China set a goal of reforming resource pricing and building a sound system of payment for environmental services. The new targets seemed more ambitious than the 11th Plan and by setting state goals to reduce energy intensity by another 16% before 2015. According to the 12th Five-Year National Environmental Protection Plan, the target for COD and SO_2 reduction was 8%, and another two pollutants, ammonia nitrogen and nitric oxides, were introduced into the Plan with a 10% reduction target for each (State Council, 2011).

The expenditures for environmental protection in 2014 was RMB 957.55 billion and accounted for 1.49% of the GDP. Energy consumption per unit of GDP declined about 18.4% during the 12th Five-Year Plan. The COD and emissions of SO_2, ammonia nitrogen, and nitric oxides reduced 12.9%, 18%, 13%, and 18.6%, respectively, which fulfilled the targets of the 12th Five-Year Plan. Table 2.3 gives an overview of the main environmental protection indicators, goals, and outcomes for the 12th Five-Year Plan period.

Table 2.3 Main Environmental Protection Indicators, Goals, and Outcomes for the 12th Five-Year Plan Period

Indicators	2010	Targets	2015
Volume of COD Emission (million tons)	25.517	23.476	22.235
Volume of Ammonia Nitrogen Emission (million tons)	2.644	2.38	2.3
Volume of SO2 Emission (million tons)	21.85	19.85	18.6
Volume of Nitric Oxides Emission (million tons)	22.73	20.46	18.510
Proportion of Water Quality Worse than Grade V in Surface Water Monitored Section (%)	16%	<15	8.80%
Proportion of Water Quality better than Grade III in Main Water System Monitored Section (%)	55	>60	72.10%

Note: From 2001, China's Ministry of Environmental Protection redefined statistical calibre of COD and Ammonia Nitrogen in waste water. The scope of statistic extended beyond industrial emission and household emission only to agricultural emission and motor vehicle emission.
Source: 12th Five-Year National Total Emissions Control Plan of the Major Pollutants

Generally, the environmental regulation in China is getting stricter, more specialized and using more market mechanisms rather than policy. From China's planning economy era, the Five - Year Plans sets goals for China' s development in the following 5 years, it is still the most important policy instrument and guides the main political objectives. The 10th Five – Year Plan firstly demonstrated the target to pollutant emission by 10 percentages before 2005, it was a significant signal that China's central government would tighten the environmental regulation (Cai et al., 2016). However, the targets of the pollutant reduction were not archived, the emissions of SO_2 increased by 27.8% and the reduction of COD was only 2.1%. Some previous literature imputes this failure to the poor local enforcement on environmental regulation and suggest that local enforcement is far from sufficient and effective in China due to the environmental decentralization (Lo et al., 2006; Wang et al., 2003). The local government may made concessions to local economic development and protect polluting firms through enforcement discretion (Jia and Nie, 2017; Wang et al., 2003). Additionally, a character of the pollution reduction mandate in 10th Five-Year Plan was that it only set a target but not mentioned any mechanism for coordination across regions. Environmental protection is a public mission which needs local government need to work together to archive. The central Bureau of Environmental Protection realized the shortage of coordination is one cause for the failure of pollution reduction in 10th Five-Year Plan (Chinese Academy of Environmental Planning, 2006).

In 2006, the central government modified the pollution mandate for 11th Five-Year Plan. The main pollutants including COD and SO_2 were planned to be reduced by 2 percentages each year, however these targets were not archived in 2006 when COD increased by 1.2 percent. On the National People's Congress in 2007, Premier Wen Jiabao criticized the poor performance on environmental protection of local government (Wen, 2007). Then the state council increased the share of pollution reduction for local officials who did not comply the mandate and announced that local officials would be immediately removed it they fail to meet the target by the end of 2007 (State Council, 2007). As the central governmental raised pressure on the local governments, the overall reduction mandates of the 11th Five-Year Plan were compiled by the end of 2010.

The 12th Five-Year Plan set a higher reduction mandate than the previous, which aims to reduce another 16% of energy intensity before 2015. And that ambitious objective indicated that the central government further tightened the environmental regulation in 12th Five-Year Plan. Additionally, the central government began to introduce market mechanisms such as reforming resource pricing and building a sound system of payment for environmental services.

To sum up, the environmental regulation in China since 2001 is getting stricter and the implication of environmental protection became more effective. The central government increases the stakes of reduction mandate for the provincial governments and introduced market mechanisms to enhance the environmental protection system. The increasing pressure on environmental protection may lead some side-effects in economic area such as employment. Thus, this study investigates the relationship on the environmental regulation and employment in industrial sector in China.

3. Literature review

3.1 Empirical evidence

The question of the effect of environmental regulation on employment has received a lot of attention from researchers for many years. Early mainstream empirical studies focused on developed countries such as the United States and European countries since these regions were the first movers to adopt strict environmental regulations. Both industrial- and plant-level studies in developed economies suggested relatively small effects from regulations on employment in directly involved industries. As pollution control and environmental improvement become a global issue, many governments in developing countries are tightening their pollution control regulations to prompt firms to adopt more environmentally friendly technology. The cost of strict environmental regulation in developing areas has recently received more attention from researchers. This section will briefly review a number of existing empirical studies that examine how environmental regulations impact employment, looking at them by the regions and time periods studied.

Possibly the first empirical study on the employment effects of environmental regulations was conducted by Golomvek and Raknerud (1997). Using Norwegian data, they compared the trends in labour demand between firms under strict environmental regulation and firms under loose or no environmental regulations. Their results suggested that during the period 1976 to 1991, environmental regulations had no significant effect on labour demand in the manufacture of basic industrial chemicals; however, strictly regulated firms in the manufacture of pulp, paper, and paperboard and in the manufacture of iron, steel, and ferroalloys had strong trends of increased labour demand.

Other studies focusing on Europe examined the effects of the EU emission trading system (ETS) on employment. Anger and Oberndorfer (2008) used data from 419 German firms to investigate the role of the EU ETS on firm performance and employment. Their empirical results did not show any significant impact on firm revenue or labour demand during the first phase of the EU ETS. Abrell et al. (2011) obtained similar results with a sample of 2,101 European firms. Different from Anger and Oberndorfer (2008), they used a propensity score matching approach rather than OLS regression to reduce selection bias caused by the sample data. The empirical results suggested that the EU ETS significantly reduced emissions at the beginning of the second phase but did not influence firm performance, employment, or added value during the first phase and the beginning of the second phase. Another empirical study regarding the impact of the EU ETS on material costs, employment, and revenue was conducted by Chan et al. (2013). The data set they used covered 5,873 firms in 10 European countries during the period 2001 to 2009. They applied the difference-in-differences method (DID), which allowed for a comparison of the performance of regulated and unregulated firms within the same industry. Overall, Chen et al. (2013) found that the effects of the EU ETS program were different in different industries. Their findings indicated that the EU ETS may have raised material costs in the power industry, but there were no significant differences between ETS and non-ETS firms in the cement, iron, and steel industries in terms of material costs, labour demand, or turnover.

The United States is the main focus of research in many empirical studies. Utilizing the difference-in-differences approach, Greenstone (2002) investigated the effects of county non-attainment status for the standard pollutants, including total suspended particulates, sulphur dioxide, tropospheric ozone, and carbon monoxide, on industrial activities. The environmental regulations in non-attainment areas are stricter than for attainment areas, which raises production costs and retards the economic activity of enterprises located in non-attainment areas. Greenstone merges this county attainment status information with facility-level data from the Census of Manufacturers from 1972 to 1987. The empirical results regarding employment showed that carbon monoxide and tropospheric ozone non-attainment status was associated with significant declines in employment, but the regulation effects for sulphur dioxide and total suspended particulates were such that the markers for those areas were essentially unchanged. In general, compared to attainment areas, non-attainment areas had more negative effects and lost 590,000 jobs in the 15 years after the Clean Air Act Amendments began being enforced. Similarly, Walker (2011, 2013) found statistically significant reductions in gross manufacturer labour demand in non-attainment areas, and Walker's (2011, 2013) results further suggested that the newly affected polluting industries downsized by at least 15% in the 10 years following the enforcement of regulations. In addition, in a study on how energy regulation, labour regulation, and environmental regulation influence employment distribution, Kahn and Mansur

(2013) used the border-pair methodology with a county–industry level panel data set from 1998 to 2009 and found empirical evidence that the employment growth rate in areas that adopted more stringent environmental regulations, mainly due to ozone non-attainment status, was relatively lower than areas with more lax regulations.

Additionally, there is a large number of empirical studies estimating the employment effects of environmental regulation based on the theoretical framework built by Berman and Bui (2001). Using plant-level data, Berman and Bui (2001) explored the impact of air pollution regulation on employment in the Los Angeles, California, area through three dimensions of variation, including regions, industries, and time. They combined data from the Pollution Abatement Costs and Expenditures Survey in 1979 to 1991 and the Census of Manufacturers in 1977, 1982, 1987, and 1992. Differing from the previous studies that estimated the effects of regulation by measuring abatement activity (see, for instance, Gray and Shadbegian, 1998), Berman and Bui (2001) constructed a detailed data set for environmental regulation transitions in the South Coast Air Quality Management District. This data set covers regulations' adoption dates, compliance dates, data on increasing stringency, and the stipulated pollutant for all the affected manufacturing plants. The effects of regulation were measured directly by using coded regulations as binary indicators rather than using proxies of abatement expenditures. They derived a model based on the partial static equilibrium model, which allowed some inputs to act as "quasi-fixed" factors and to be set by exogenous constraints instead of solely cost minimization (Brown and Christensen, 1981). In their study, Berman and Bui (2001) find no evidence that air quality regulations were responsible for the decline in labour demand, and further, they potentially somewhat increased employment.

Berman and Bui's (2001) model is utilized widely in empirical studies on the employment effect of environmental regulation. For instance, Morgenstern et al. (2002) examined the impact of higher abatement costs caused by regulation on labour demand in four highly polluting industries, including pulp and paper, plastic, petroleum refining, and steel. Their results suggested that increased abatement costs generally do not lead to a statistically significant change in labour demand.

Cole and Elliott (2007) adopted a similar model that was derived from Berman and Bui (2001) to examine the effects of regulation on employment using industrial-level data. Although Cole and Elliott used different proxies (measured by the ratios of pollution abatement costs over gross value-added and total capital expenditures) to capture regulation effects both exogenously and endogenously, their results, similar to Berman and Bui (2001), were that environmental regulations had no statistically significant effect on labour demand in the United Kingdom in the period 1999 to 2003.

Gray et al. (2014) used Berman and Bui's (2001) model with plant-level data from the Census of Manufacturers and Annual Survey of Manufacturers at the U.S. Census Bureau from 1997 to 2007. In addition, they used the same measurements as Cole and Elliott (2007) on environmental regulation to study whether Environmental Protection Agency regulations affected employment and found evidence from the pulp and paper industry that there was a roughly 3% to 7% reduction on employment related to the enforcement of the Cluster Rule, but the effect was sometimes insignificant. Further, these declines mainly occurred in firms that were regulated by both maximum achievable control technology air rules and best available technology water rules; the effect on employment at plants impacted by only the air rules was more often positive than negative, though it was also mostly insignificant.

Ferris et al. (2014) used a panel data set of fossil fuel fired power plants to investigate the effects on labour demand in the electric industry of Phase One of the SO_2 trading program associated with Title IV of the 1990 Clean Air Act Amendments. Based on the empirical results obtained through a Matched Pairs–Propensity Score matching with a difference-in-differences approach, there was little evidence that power plants impacted by Phase I of the SO_2 trading program had any significant decline in employment, and further, utilities tended to use the flexibility of the regulation to minimize the overall influence on labour demand.

Liu et al. (2017) investigated the impact of stringent wastewater discharge standards on employment in China's textile printing and dyeing industry. They estimated Berman and Bui's model with the difference-in-differences approach, setting the plants in Lake Tai, which is the only region covered by the first phase of new wastewater discharge standards, as the treatment group and the remaining plants in Jiangsu Province (outside the Lake Tai region) as the control group. Their empirical results suggested an approximately 7% reduction in employment caused by the new wastewater discharge standard. Furthermore, the impact of the new standard was different across various types of enterprises. For instance, the decline in labour demand among domestically owned private firms was 7.4%, but it was minimal or zero in state-owned or foreign-owned firms, respectively.

Sheng et al. (2019) included the effects of corruption in Berman and Bui's model (2001) to examine the environmental regulation effect and corruption effect on employment in the manufacturing sector in China because they believed the implementation of environmental regulations in China are highly impacted by corruption. The data set in this study was from the World Bank's Investment Climate Survey of 18 Chinese cities in 2003, which covered 2,400 enterprises from the eastern, central, and western areas of China, spanning firms of various sizes and industries. Sheng et al. (2019) found evidence that stringent environmental regulations negatively influenced employment in the manufacturing sector through both output effects and substitution effects. The effect of corruption impacted employment similarly to regulation, but weakened the impact of environmental regulations, and the effects of both regulation and corruption were heterogeneous across firms due to differences in scale, corruption tolerance, and ownership structure.

In sum, most past studies using developed country data, including European countries and the United States, suggest a relatively small or positive impact of strict environmental policies on employment. Only Greenstone (2002) and Walker (2002, 2011) found any significant reduction in labour demand associated with the implementation of environmental regulations. However, the story in developing countries in general, and China in particular, seems different. Using plant-level data, both Liu et al. (2017) and Sheng et al. (2019) found evidence that stringent environmental regulations significantly led to a decline in labour demand in the manufacturing industry, and that effect was heterogeneous across different ownership structures.

3.2 Theoretical framework

The dominant wisdom states that stringent environmental regulations must reduce employment in regulated industries because pollution abatement activities raise the costs of production, thereby reducing output. However, referring to neoclassical microeconomic analysis, Berman and Bui (2001) demonstrated that this is not necessarily true and environmental regulations can also be labour-enhancing. They deconstructed the effects of environmental regulations into two mechanisms, the output elasticity of employment, and the marginal rates of technical substitutions between abatement activity and labour. Berman and Bui (2001) adopted the approach of the partial static equilibrium model, which allows some input to act as "quasi-fixed" factors and be set by exogenous constraints rather than solely cost minimization (Brown and Christensen, 1981). Based on this framework, the costs of pollution abatement activity, including labour, materials, and services, can be treated as "quasi-fixed" factors that are caused by environmental regulations (exogenous constraints), and all other (regular) production factors, including labour, materials, and production costs, are variable factors.

Assume that in a perfectly competitive economy, a cost minimizing enterprise sets input on level V of variable factors and level Q of "quasi-fixed" factors. The variable cost function can be expressed as

$$\boldsymbol{CV = F(Y, P_1, \dots P_V, Z_1, \dots, Z_Q)} \quad \textbf{(1)}$$

where CV denotes total variable costs, Y represents the output, P_v (v = 1, .., V) is the cost of the ith variable factors, and Z_q (q = 1, …, Q) is the jth quasi-fixed factor. Then, profit maximization implies that the expression of labour demand function can be derived through the first order condition of the enterprise cost function. Thus, the variable input labour L is a function of output, costs, and "quasi-fixed" factors, which is approximated by the linear equation

$$\boldsymbol{L = \alpha + \rho_y Y + \sum_{q=1}^{Q} \beta_q Z_q + \sum_{v=1}^{v} \gamma_v P_v} \quad \textbf{(2)}$$

where L is the employment; α represents the fixed labour demand; and ρ_y, β_q, and γ_V are coefficients of employment-relevant output, the qth "quasi-fixed" input, and the vth variable input, respectively. Thus, the last three terms of Eq. (2) represent the labour demand generated by the output, all quasi-fixed factors, and all variable input, separately.

The environmental regulation is treated as an input, and the reduced form effect of regulation (R) on employment can be expressed as

$$\boldsymbol{L = \delta + \mu R} \quad (3)$$

The effects of environmental regulation on labour demand are through the mechanism

$$\frac{\mathrm{d}\boldsymbol{L}}{\mathrm{d}\boldsymbol{R}} = \boldsymbol{\rho_y} \frac{\boldsymbol{dY}}{\boldsymbol{dR}} + \sum_{\boldsymbol{q=1}}^{\boldsymbol{Q}} \boldsymbol{\beta_q} \frac{\mathrm{d}\boldsymbol{Z_q}}{\boldsymbol{dR}} + \sum_{\boldsymbol{v=1}}^{\boldsymbol{V}} \boldsymbol{\gamma_v} \frac{\mathrm{d}\boldsymbol{P_v}}{\boldsymbol{dR}} \quad (4)$$

With the assumption that the input economy is large and perfectly competitive, the enforcement of regulations will have no effect on input costs. Thus, the final term in Eq. (4) is equal to zero. The first term represents the effect of regulation on employment through its effect on output. This effect is widely assumed to be negative, since a more stringent environmental regulation may raise operating costs, which will force manufacturing plants to cut down on their production and scale or even shut down completely, which obviously reduces employment (Liu et al., 2017). However, Berman and Bui (2001) found neoclassical microeconomic theory failed to predict a reducing effect. For instance, if plants comply with regulations by increasing their investment in abatement capital that decreases marginal costs, the sign of ρ_y can be positive. The second term indicated the effect of environmental regulation on employment through its effect on the necessity of quasi-fixed pollution abatement activities, Z, and the marginal rates of technical substitution between abatement and variable factors. In that case, the demand on abatement activity caused by stringent environmental regulations $\frac{\mathrm{d}Z_q}{dR}$ should be positive.

The sign of β_q cannot be predicted. They are determined by whether abatement activity and labour demand are complements or substitutes. There are two measures to control pollution emissions. One is end-of-pipe, and the other one is changes in process. End-of-pipe means the pollution is cleaned up at the end of the production process and before it is released into the environment. In this case, enterprises demand more workers who are responsible for pollution reduction, which consequently increases employment. If enterprises choose to change their processes in response to the regulations, they need to install cleaner production equipment that creates less pollution in the production process and also improves production efficiency, which often reduces demand for production workers. Hence, the sign of the second term in Eq. (4) is unpredictable. Thus, the combination of the output effects and the substitution effects of environmental regulations on labour demand are ambiguous.

4. Methods

4.1 Model specification

According to Berman and Bui (2001), the general form of econometric model that is used to examine the influence of intensity of environmental regulation on labour demand can be expressed as Eq. (5) and Eq. (6):

$$\ln \boldsymbol{emp_{it}} = \boldsymbol{\alpha reg_{it}} + \boldsymbol{\lambda_1 ext_{it}} + \boldsymbol{\lambda_2 sca_{it}} + \boldsymbol{\lambda_3 etb_{it}} + \boldsymbol{\lambda_4 str_{it}} + \boldsymbol{\lambda_5 lp} + \boldsymbol{\lambda_6 fyp11} + \boldsymbol{\lambda_7 fyp12} + \boldsymbol{\beta_i} + \boldsymbol{\beta_t} + \boldsymbol{\epsilon} \quad \textbf{(5)}$$

$$\ln \boldsymbol{emp_{it}} = \boldsymbol{\alpha reg_{it}} + \boldsymbol{\lambda_1 ext_{it}} + \boldsymbol{\lambda_2 sca_{it}} + \boldsymbol{\lambda_3 etb_{it}} + \boldsymbol{\lambda_4 str_{it}} + \boldsymbol{\lambda_5 lp} + \boldsymbol{\beta_i} + \boldsymbol{\beta_t} + \boldsymbol{\epsilon} \quad \textbf{(6)}$$

where *i* denotes industries, and *t* denotes year; β_i is the time-invariant industries fixed effect; β_t is the time effect; *emp* is the independent variable representing labour demand of industries; *reg* is the core independent variable representing the intensity of environmental regulation; *ext*, *sca*, *etb*, *str*, *fyp11*, and *fyp12* are the control variables; α is the coefficient of environmental regulation variable; λ_l (l = 1, 2, …, 4) represents the coefficient of the *l*-th control variable; and ϵ is a random disturbance.

Eq. (5) is used to explore the effects of the intensity of environmental regulation during the time period of 2001 to 2015. It is first estimated using the full data set, which covers all enterprises in the statistical scope. Then, this study uses Eq. (6) to explore the impacts of environmental regulation on state-owned enterprises (SOE), private-sector, and foreign-owned enterprises, separately. The differences in the ownership structure of an enterprise determine the relationship with government; in particular, state-owned enterprises and government often form special relationships in China (Cull and Xu, 2003). Thus, it is rational to hypothesize that enterprises with different ownership structures take different measures to deal with stringent environmental regulations.

Eq. (6), excluding the dummy variables *fyp11* and *fyp12*, was used to examine the impacts of environmental regulation on employment in the 10th, 11th, and 12th Five-Year Plans, separately. Due to the differences in main objectives and completeness of each Five-Year Plan, the environmental regulation effect on employment can vary in these three periods. Thus, Eq. (6) was estimated for sub-samples 2001–2005, 2006–2010, and 2011–2015, separately, and further estimated for state-owned enterprises, private sector, and foreign-owned enterprises during the three respective sub-periods as well.

The dependent variable of employment was measured by Annual Average Employed Persons and is equal to the total amount of employed persons in each month divided by 12 months.

This study used few indicators to measure the intensity of environmental regulation from various perspectives. In the existing literature, the intensity of environmental regulation can be measured from the different perspectives on the levels of an industry, the plants, and the government. In terms of the industrial perspective in this study, there are two main indicators that are widely used to capture environmental regulation. One is the ratio of pollution abatement costs over total capital expenditures, which was used by Brunnermeier and Cohen (2003) and Jaffe and Palmer (1997). Regarding data availability, and following Berman and Bui (2001), Cole and Elliott (2003), Lanoie et al. (2011), and Zhao et al. (2018), this paper adjusts the ratio of pollution abatement costs over total capital expenditures to the percentages of the industrial pollution abatement and control expenditure (the sum of annual expenditures of industrial waste water treatment facilities and industrial waste gas treatment facilities for various industries) to their corresponding sales values to present the overall intensity of environmental regulation, which is identified as ER1. A greater ER1 means a greater intensity of environmental regulation for that industry. Moreover, to explore the impact of industrial waste water related environmental regulation and industrial waste gas related regulation, respectively, this study used WER1, defined as the ratio of the industrial waste water abatement and control expenditures to the corresponding sales values, and GER1 defined as the ratio of the industrial waste gas abatement and control expenditures to the corresponding sales values separately. Additionally, the intensity of environmental regulation (ER2) is adopted, which is denoted by the industrial pollution abatement and control expenditure (the sum of annual expenditures of industrial waste water treatment facilities and industrial waste gas treatment facilities in various industries) divided by the main industrial business operation costs. Meanwhile, WER2 and GER2 are denoted by the industrial water and gas pollution abatement and control expenditures of the main industrial business operation costs separately. The main analysis of this study was based on the results using ER1, WER1, and GER1; and ER2, WER2, and GER2 were used for a subsequent robustness test. The equations of each environmental regulation indicator are expressed as Equation (7) – (12):

$$\boldsymbol{ER1} = \frac{\textbf{annual expenditures of industrial waste water and gas treatment facilities}}{\textbf{sales values}} \quad (7)$$

$$\boldsymbol{WER1} = \frac{\textbf{annual expenditures of industrial waste water treatment facilities}}{\textbf{sales values}} \quad (8)$$

$$\boldsymbol{GER1} = \frac{\textbf{annual expenditures of industrial waste gas treatment facilities}}{\textbf{sales values}} \quad (9)$$

$$\boldsymbol{ER2} = \frac{\textbf{annual expenditures of industrial waste water and gas treatment facilities}}{\textbf{business cost}} \quad (10)$$

$$\boldsymbol{WER2} = \frac{\textbf{annual expenditures of industrial waste water treatment facilities}}{\textbf{business cost}} \quad (11)$$

$$\textbf{GER2} = \frac{\textbf{annual expenditures of industrial waste gas treatment facilities}}{\textbf{business cost}} \quad (12)$$

With the aim of robustness of estimations, a vector or industrial-level control variable were included. Export activity often relates to the labour demand of the manufacturing sector because an industry involved in high-volume exporting has increased levels of business activities and higher profits, which leads to greater incentive to expand scale (Calof, 1994). Additionally, exports can boost technological advancement and facilitate the employment structure (Wagner, 2002). To control the impact of exports on the labour demand of manufacturing industries, *exp* is introduced as a control variable denoted by the ratio of the value of export goods to the industrial sales value. The industry scale may have affected employment because industry may cope with environmental regulation differently on various scales, resulting in different behaviour in jobs creation and future employment (Ayyagari et al., 2011). To control for the influence of the scale of the manufacturing industry on employment, this study used the variable *sca*, denoted by the logarithm of the sale value of an industry on 2015 prices. The market structure is another potential factor in employment. The resource in an intensely competitive industry relocates more efficiently, which leads enterprises to improve production efficiency and expand the scale to increase competitiveness, thus affecting the employment behaviour of manufacturing industries (Nickell, 1996). The amount of main business competitors in the primary market of an industry is divided into five levels to measure the market structure of an industry, where the first, second, third, fourth, and fifth levels represent the number of competitors (1–99, 100–999, 1,000–4,999, 5,000–9,999, and more than 10,000, respectively). The variable *str* was included in estimations as a control variable to capture the impact of market structure on labour demand. Labour productivity, or the production value created by a single industrial worker, is another determinant of employment in manufacturing industries. The variable *lp* captured the impact of labour productivity and was represented by the sales value of an industry divided by the number of people it employs. In addition, to control for other potential impacts of the Five-Year Plan, the dummy variables *fyp11* and *fyp12* were included in Eq. (5). The definitions and data sources of all the variables are listed in Appendix 4.1.

To control the potential endogeneity of environmental regulation to employment, which is mentioned in some previous studies (eg. Cole and Elliott, 2003), this study applies the instrument estimator for Equation (5) and uses two-stage least square estimation with instrumental variables. Since it is difficult to find a proper instrumental variable for environmental regulation which does not relate to employment, this study uses 1- and 2- year lagged environmental regulation indicators as instrumental variables. Then a Hausman test is applied after the 2SLS estimator to check the existence of endogeneity of environmental regulation and a Sargan test for the validity of instrumental variables.

4.2 Data description

China applies a four-digit industrial classification standard, and the data set in this paper contains 38 two-digit level industries. In the period covered by this paper, the industry classification system was updated from GD/T4757-2002 to GD/T4757-2011.

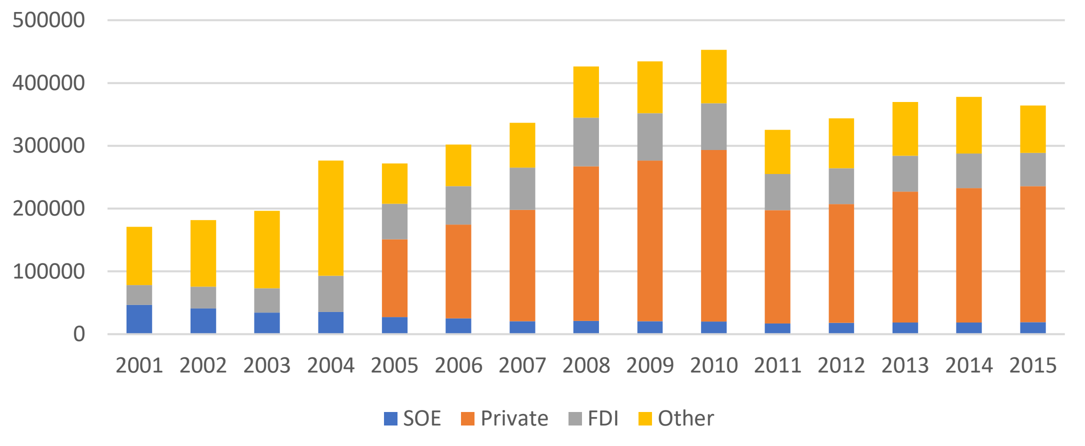
The Manufacture of Rubber and Manufacture of Plastic were defined as two separate industries before 2012 but were then merged into Manufacture of Rubber and Plastic. Therefore, the data of Manufacture of Rubber and Plastic is derived by taking the sum of Manufacture of Rubber and Manufacture of Plastic from 2001 to 2012. In addition, Manufacture of Transport Equipment was split into Manufacture of Automobiles and Manufacture of Railway, Ship, Aerospace, and Other Transport Equipment, according to the 2011 edition. Thus, the data of Industry B36 and B37 are merged into one in 2013, 2014, and 2015. The full list of the industries and their codes are provided in Appendix 4.1.

Data relating to industrial information was collected from the China Industry Economy Statistical Yearbook, and the pollution emission and abatement data came from the China Environmental Statistical Yearbook. The China Industry Economy Statistical Yearbook was not published in 2005, and the employment data was not reported in the 2013 yearbook. Therefore, the time period in this paper is 2001–2015, except for 2004 and 2012.

The statistical scope covers all state-owned industrial enterprises and non-state-owned industrial enterprises with revenue from the principal business of over RMB 5 million yuan in 1998 to 2006; all industrial enterprises with revenue from its principal business of over RMB 5 million yuan from 2007 to 2010; and all industrial enterprises with revenue from its principal business of over RMB 20 million yuan, since 2011. The data is collected from firm-level but reported as the sum of each industry and each year and for different ownership sectors. Thus, this study only can be conducted on industrial-level, there is no available data for firm-level study or regional-level study. Figure 1 presents the number of enterprises covered by the statistical scope in each year.

According to the Explanatory Notes on Main Statistical Indicators in the China's statistical yearbook, State-owned Enterprises refer to "non-corporation economic units where the entire assets are owned by the State and which have been registered in accordance with the *Regulation of the People's Republic of China on the Management of Registration of Corporate Enterprises*". And private enterprises are "profit-making economic units invested and established by natural persons, or controlled by natural persons using employed labour. Included in this category are private limited liability corporations, private share-holding corporations Ltd., private partnership enterprises and private-funded enterprises registered in accordance with the *Company Law*, *the Law on Partnership Business* and *Interim Regulations on Private Enterprises*". Foreign owned enterprises are "enterprises established in the mainland of China with exclusive investment from foreign investors in accordance with the *Law of the People's Republic of China on Wholly Foreign-owned Enterprises* and other relevant laws".

Figure 1 The numbers of enterprises covered by statistical scope in each year



Source: China's Industrial Statistical Yearbook 2002-2016

The pollution emission data and abatement expenditure data came from China's Environmental Statistical Yearbook. There is a mistake in the 2014 Yearbook where the data for the indicator Annual Expenditure for Operation of Facilities for Treatment of Waste Water is exactly the same as Capacity of Facilities for Treatment of Waste Water. According to the range of this indicator in other years, I compared the total value of all industries with the total value of all regions (although the industrial section and the regional section report data by industries and regions, respectively, the total value of the same indicator should be equal). I found the data under Total Volume of Industrial Waste Water Treated is actually the Annual Expenditure for Operation.

All the monetary values were transferred to 2015 values, according to the GDP deflator rate reported by the World Bank. Table 4.1 summarizes the description of all variables that were used in this study during the period 2001–2015 except for 2004 and 2012. Table 4.2 reports the cross-correlation among variables, excluding the dummy variables.

Table 4.1 Descriptive Summary of Variables

Data	Variable	Obs	Mean	Std. Dev.	Min	Max
Environmental Regulation Indicators	ER1	576	0.002727	0.005437	6.26E-07	0.097306
	WER1	577	0.00156	0.002674	3.86E-07	0.025429
	GER1	576	0.001192	0.004453	0	0.095334
	ER2	576	.0643726	.1115783	4.78e-06	.8776515
	WER2	577	.0330322	.0558054	3.59e-06	.6206875
	GER2	576	.0315049	.0914107	0	.859863
All data	emp	537	212.2433	186.4242	0.08	909.26
	sca	619	16831.9	19463.23	3.327731	97385.99
	ext	619	0.134716	0.161407	0	0.696465
	str	619	4.016155	0.948375	1	5
	lp	537	75.01241	70.17312	0.034132	460.5309
	fyp11	619	0.306947	0.4616	0	1
	fyp12	619	0.318255	0.466176	0	1
State-owned enterprises	emp	532	50.96433	69.50076	0	369.01
	sca	616	4416.623	8006.44	0.030628	53385.2
	ext	613	0.081245	0.091593	0	0.444818
	lp	531	73.32525	84.49945	1.647738	610.6125
	str	618	2.457929	1.016402	1	5
Private-owned enterprises	emp	426	74.52502	74.31399	0.01	316.83
	sca	466	6331.845	7416.953	0.578947	33901.29
	ext	466	0.065453	0.079357	0	0.46418
	lp	426	82.49973	98.61637	14.31435	1842.833
	str	466	3.7103	1.145248	1	5
Foreign-owned enterprises	emp	525	56.67083	90.18099	0	888.939
	sca	608	4445.108	7962.228	0	57404.2
	ext	601	0.248393	0.229103	0	1
	lp	524	130.7025	314.4494	6	5033.8
	str	618	2.933657	1.205256	1	5

Table 4.2 Correlations of Variables, Excluding Dummy Variables

	emp	ER1	WER1	GER1	ext	sca	str	lp
emp	1							
ER1	-0.2356	1						
WER1	-0.3696	\	1					
GER1	-0.0789	\	\	1				
ext	0.2561	-0.2018	-0.1903	-0.1376	1			
sca	0.8593	-0.2562	-0.4426	-0.0632	0.0345	1		
str	0.7899	-0.243	-0.3011	-0.1258	0.2387	0.6728	1	
lp	-0.0896	-0.0309	-0.1415	0.0412	-0.3494	0.3334	-0.1484	1

5. Results

5.1 Environmental regulation effects on employment in various industries from 2001 to 2015

Tables 5.1.1 to 5.1.4 display the main results when using the indicator of annual expenditures of industrial pollution treatment facilities over sales values. Table 5.1.1 is the estimate using the complete data set. Tables 5.1.2, 5.1.3, and 5.1.4 report the results estimated for, respectively, state-owned enterprises, private-sector enterprises, and foreign-owned enterprises. In each table, Models 1–3 are estimated by fixed effect, although the Hausman test suggests that the fixed effect is consistent and significant rather than a random effect in this study. The random effect results are also reported in appendices for the robustness check. Model 1 is the result with ER1, Model 2 reports the water pollution regulation effect, and Model 3 is the result with the gas pollution regulation effect.

First, I estimated Eq. (5) for all manufacturing industries, and the results are reported in Table 5.1.1. According to Table 5.1.1, the coefficients of ER1 and WER1 were significantly positive at the 1% level in Models 1 and 2, which indicates a significant positive correlation with the variable *emp*. The positive coefficient of ER1 in Table 5.1.1 suggests that the overall intensity of environmental regulation can generally promote employment in secondary industries sector. Specifically, the labour demand of secondary industries increases by 164,741 persons when the intensity of environmental regulation increases by one unit, while the other variables are fixed. According to Model 2, the intensity of industrial waste water regulation has a stronger impact on employment in secondary industries. The coefficients of WER1 with both the fixed effect and the random effect estimators are significantly positive, which indicates a stricter waste water regulation will lead a growth in labour demand, and thus employment will increase by 475,630 persons units accompanying a one unit increase in the intensity of waste water regulation. However, Model 3 suggests that the coefficient of GER1 on *emp* is not statistically significant, which demonstrate that the intensity of industrial waste gas regulation has no significant impact on employment in secondary industries.

Table 5.1.1 Main Results of Full Data Set Regressions

	(1)	(2)	(3)
ER1	7.762**		
	(2.60)		
WER1		22.41**	
		(2.96)	
GER1			5.104
			(1.51)
ext	0.859**	0.859**	0.852**
	(2.89)	(2.90)	(2.85)
sca	0.475***	0.495***	0.457***
	(9.74)	(9.91)	(9.47)
str	0.201***	0.178**	0.200***
	(3.49)	(3.11)	(3.44)
lp	-0.00172**	-0.00168**	-0.00174**
	(-3.15)	(-3.09)	(-3.17)
fyp11	-0.107	-0.115*	-0.0972
	(-1.92)	(-2.07)	(-1.75)
fyp12	-0.129	-0.149	-0.110
	(-1.50)	(-1.73)	(-1.27)
_cons	-0.189	-0.278	-0.0182
	(-0.48)	(-0.70)	(-0.05)
N	493	494	493

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

This section also examines the differences in the effects of the intensity of environmental regulation on the labour demand of industries for different ownership structures because the relationship between different industrial enterprises and government have a variable influence on the environmental regulation (Damania et al., 2004). Using the same variables in Eq. (5), the regression results of different ownership data can be used for a direct comparison.

Table 5.1.2 shows the regression result for data from state-owned industrial enterprises. The coefficients of all environmental regulation indicators, ER1, WER1, and GER1 are significant. ER1 and WER1 are significantly positive at the 0.1% level, and GER1 is relatively significant at the 5% level. According to Model 1, the significant and positive coefficient suggests that the overall intensity of environmental regulation can increase labour demand in the industrial sector, and employment will increase by 44,203 persons when the intensity of overall environmental regulation increases by one unit, while other variables are constant. As Model 2 shows, the impact of waste water regulation is stronger, which is similar to the results shown in Table 5.1.1. The coefficient of WER1 in Model 2 is significant and positive, which demonstrates that strict controls on water pollution increased labour demand in the industrial sector during the period 2001 to 2015. Similarly, employment increased by 122,661 persons when the intensity of water pollution regulation increased one unit. Different from the results of regression using the full data set, shown in Table 5.1.1, with gas pollution regulation, GER1, there is a relatively significant and positive relationship to employment such that one unit of growth in the intensity of gas pollution regulation would lead 33,521 persons more in the overall labour demand for state-owned industrial enterprises.

Table 5.1.2 Main Results for Data on State-Owned Industrial Enterprises

	(1)	(2)	(3)
ER1	8.674***		
	(3.73)		
WER1		24.07***	
		(3.78)	
GER1			6.578*
			(2.56)
ext	1.068***	1.055***	1.063***
	(4.64)	(4.59)	(4.58)
sca	0.668***	0.666***	0.663***
	(24.88)	(24.90)	(24.55)
str	0.181***	0.178***	0.180***
	(6.05)	(5.96)	(5.98)
lp	-0.00249***	-0.00244***	-0.00248***
	(-7.90)	(-7.77)	(-7.83)
fyp11	-0.414***	-0.411***	-0.421***
	(-12.02)	(-11.93)	(-12.18)
fyp12	-0.500***	-0.498***	-0.507***
	(-10.21)	(-10.18)	(-10.28)
_cons	-1.720***	-1.710***	-1.661***
	(-9.02)	(-9.00)	(-8.70)
N	490	491	490

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.1.3 gives the results of regressions using the data on privately owned industrial enterprises. Different from the results displayed in Tables 5.1.1 and 5.1.2, the indicator of environmental regulation in privately owned enterprises showed a relatively negative impact. The coefficients of ER1 and WER1 in Models 1 and 2 are negative and relatively significant at the 5% level, which indicates a relatively significant negative correlation with the dependent variable *emp*. Model 1 suggests that, overall, environmental regulation reduced employment in the privately owned industrial sector, and one unit growth in the intensity of environmental regulation would reduce 39,294 persons in labour demand. In terms of water pollution regulation, the coefficient of WER1 was −7.013, which demonstrates that employment would decline by 52,261 persons when the intensity of water pollution regulation increased one unit. Additionally, GER1 had a relatively statistically significant relationship to employment with the random effect estimation (reported in Appendix 5.1.3), and the coefficient was −11.35, also indicating a negative effect. However, with the fixed effect estimate, it was not statistically significant.

The results of regressions using foreign-owned industrial enterprise data are reported in Table 5.1.4. The coefficients of ER1, WER2, and GER2 were statistically insignificant in all the models, which demonstrates that environmental regulation had no impact on employment in foreign-owned industrial enterprises.

Table 5.1.3 Results of Regressions of Data on Privately Owned Industrial Enterprises

	(1)	(2)	(3)
ER1	-5.273* (-2.32)		
WER1		-7.013* (-2.35)	
GER1			-8.955 (-1.72)
ext	1.225*** (6.13)	1.173*** (5.94)	1.252*** (6.09)
sca	0.753*** (45.51)	0.753*** (45.44)	0.758*** (46.36)
str	0.0671** (3.12)	0.0649** (3.03)	0.0685** (3.16)
lp	-0.00232*** (-37.05)	-0.00232*** (-37.11)	-0.00232*** (-36.92)
fyp11	-0.0582* (-2.43)	-0.0599* (-2.52)	-0.0608* (-2.54)
fyp12	-0.241*** (-7.30)	-0.246*** (-7.52)	-0.245*** (-7.38)
_cons	-2.420*** (-21.90)	-2.406*** (-21.67)	-2.465*** (-22.58)
N	384	385	384

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.1.4 Results of Regressions of Data on Foreign-Owned Industrial Enterprises

	(1)	(2)	(3)
ER1	-4.520 (-1.70)		
WER1		3.480 (0.44)	
GER1			-5.400 (-1.90)
ext	0.995*** (5.37)	0.988*** (5.28)	0.981*** (5.30)
sca	0.766*** (27.69)	0.777*** (27.70)	0.769*** (28.11)
str	0.144*** (3.36)	0.150*** (3.52)	0.145*** (3.39)
lp	-0.000840*** (-12.51)	-0.000843*** (-12.53)	-0.000839*** (-12.51)
fyp11	-0.00984 (-0.26)	-0.0141 (-0.37)	-0.0109 (-0.29)
fyp12	-0.116* (-2.53)	-0.121** (-2.64)	-0.118* (-2.57)
_cons	-3.228*** (-16.55)	-3.340*** (-16.97)	-3.253*** (-17.01)
N	479	480	479

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

5.2 Environmental regulation effects on employment in industries in the 10th, 11th, and 12th Five-Year Plan periods

This section reports the regression results estimated with Eq. (6) for sub-samples during the 10th, 11th, and 12th Five-Year Plan periods. Tables 5.2.1, 5.2.2, and 5.2.3 are the results for data sets containing all industrial enterprises above a designated size with, respectively, ER1, WER1, and GER1 separately. Tables 5.2.4, 5.2.5, and 5.2.6 represent the regression results for state-owned industrial enterprise with three environmental regulation indicators. Tables 5.2.7, 5.2.8, and 5.2.9 are results for privately owned industrial enterprises. And Tables 5.2.10, 5.2.11, and 5.2.12 report results for foreign-owned industrial enterprises. In each table, the first column shows the effect of the intensity of environmental regulation in the 10th Five-Year Plan, while the second column is for the 11th Five-Year Plan, and the third column represents the 12th Five-Year Plan.

Table 5.2.1 displays the regression results with ER1 for the full data set during the three Five-Year Plan periods separately. The coefficients of ER1 in the second column are statistically significant at the 0.1% level and relatively significant in the third column at the 1% level. That demonstrates that overall environmental regulation significantly reduced employment in the industrial sector in China during the 11th and 12th Five-Year Plan periods. One unit of growth in the intensity of overall environmental regulation reduced 590,462 persons of in employment in the 11th Five-Year Plan period, and 83,710 persons in the 12th Five-Year Plan period. The coefficient in the first column is positive and statistically insignificant, which suggests that overall environmental regulation had no impact on labour demand during the 10th Five-Year Plan period.

Table 5.2.2 shows the empirical results for the effect of water pollution regulations on employment in the industrial sector in China. The coefficients of WER1 are strongly significant, shown in columns 1 and 2, at the 0.1% level, and relatively significant in column 3, at the 5% level. Similar to the empirical findings on overall environmental regulation, as reported in Table 5.2.1, the signs of the core variable WER1 transferred from positive in column 1 to negative in columns 2 and 3, and the value of the coefficient in column 2 is greater than column 3. This implies that growth in the intensity of water pollution regulation promoted labour demand in the industrial sector in the 10th Five-Year Plan period but reduced employment in the 11th and 12th Five-Year Plan periods, and the reduction effect in the 11th Five-Year Plan was greater than the 12th. According to column 1, when the intensity of water pollution regulation increased one unit, employment in the industrial sector grew by 1,227,599 persons, which dominates the promotional effect of environmental regulation in the 10th Five-Year Plan period. Moreover, the empirical findings shown in columns 2 and 3 suggest that one unit of growth in the intensity of water pollution regulation caused 792,198 persons of decline in employment during the 11th Five-Year Plan period and 85,769 persons of decline during the 12th Five-Year Plan period.

The regression results shown in Table 5.2.3 are estimated for the gas pollution regulation indicator with the full industrial enterprises data set in the three periods separately. Similar to the empirical findings estimated with ER1 and WER1, the sign of the environmental regulation variable is positive in column 1 and changed to negative in column 2 and 3. However, the coefficient is only statically significant in column 3, at the 1% level, which implies a significant negative relationship with gas pollution regulation and employment in the 12th Five-Year Plan period. Additionally, when the intensity of gas pollution regulation increased by one unit, employment reduced by 261,260 persons. There was no empirical evidence that gas pollution control regulations had any impact on labour demand in the industrial sector during the 10th and 11th Five-Year Plan periods.

Table 5.2.1 Main Results for Full Data Set Regressions with ER1 in Three Five-Year Plan Periods

	10th FYP	**11th FYP**	**12th FYP**
ER1	3.588	-26.43***	-3.454**
	(0.82)	(-5.20)	(-3.03)
ext	8.207***	0.354	1.300***
	(6.20)	(1.73)	(6.87)
sca	0.0485	0.563***	0.712***
	(0.35)	(12.03)	(27.31)
str	0.183	0.152***	0.0748*
	(1.31)	(3.90)	(2.28)
lp	-0.00151	-0.00267***	-0.00315***
	(-0.37)	(-4.57)	(-9.68)
_cons	2.112*	-0.684	-1.935***
	(2.11)	(-1.75)	(-7.50)
N	148	190	155

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.2 Main Results for Full Data Set Regressions with WER1 in Three Five-Year Plan Periods

	10th FYP	11th FYP	12th FYP
WER1	77.84***	-35.46***	-3.539*
	(3.73)	(-6.19)	(-2.40)
ext	6.997***	0.315	1.283***
	(5.42)	(1.59)	(6.72)
sca	0.166	0.541***	0.719***
	(1.24)	(11.89)	(27.46)
str	0.197	0.160***	0.0744*
	(1.49)	(4.24)	(2.24)
lp	-0.00113	-0.00258***	-0.00315***
	(-0.30)	(-4.60)	(-9.59)
_cons	1.144	-0.529	-1.992***
	(1.17)	(-1.40)	(-7.71)
N	148	190	156

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.3 Main Results for Full Data Set Regressions with GER1 in Three Five-Year Plan Periods

	10th FYP	**11th FYP**	**12th FYP**
GER1	0.609	-0.713	-10.78**
	(0.14)	(-0.06)	(-3.38)
ext	8.297***	0.600**	1.318***
	(6.26)	(2.76)	(7.02)
sca	0.0370	0.698***	0.716***
	(0.27)	(16.20)	(28.19)
str	0.183	0.111**	0.0726*
	(1.31)	(2.67)	(2.23)
lp	-0.00155	-0.00380***	-0.00317***
	(-0.38)	(-6.35)	(-9.86)
_cons	2.200*	-1.753***	-1.954***
	(2.21)	(-4.77)	(-7.73)
N	148	190	155

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.4, Table 5.2.5, and Table 5.2.6 report the empirical results for the impacts of environmental regulation on state-owned enterprises with ER1, WER1, and GER1, respectively. Only column 1 in Table 5.2.5 shows a statistically significant and positive coefficient of WER1 on the dependent variable, at the 1% level, which indicates that water pollution regulation significantly promoted employment in state-owned industrial enterprises during the 10th Five-Year Plan, and there would be 225,254 persons of growth in labour demand accompanying a one unit increase in the intensity of water pollution regulation. However, in the 11th and 12th Five-Year Plan periods, water pollution regulation had no influence. Additionally, there was no empirical evidence that overall environmental regulation and gas pollution regulation significantly impacted employment in state-owned enterprises in any of the three Five-Year Plan periods.

Table 5.2.4 Main Results for Data on State-Owned Enterprises with ER1 in Three Five-Year Plan Periods

	10th FYP	11th FYP	12th FYP
ER1	3.049	4.105	-0.582
	(1.13)	(0.56)	(-0.17)
ext	1.445*	0.676*	1.971***
	(2.02)	(2.43)	(3.88)
sca	0.704***	0.860***	0.780***
	(8.61)	(19.96)	(13.94)
str	0.318***	0.106*	0.0183
	(5.61)	(2.30)	(0.31)
lp	-0.0115***	-0.00702***	-0.00363***
	(-7.30)	(-14.26)	(-9.04)
_cons	-2.128***	-2.983***	-2.595***
	(-3.77)	(-9.46)	(-6.15)
N	148	190	152

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.5 Main Results of Data on State-Owned Enterprises with WER1 in Three Five-Year Plan Periods

	10th FYP	11th FYP	12th FYP
WER1	41.73**	1.124	0.997
	(3.08)	(0.13)	(0.26)
ext	1.171	0.683*	2.001***
	(1.68)	(2.45)	(4.00)
sca	0.698***	0.858***	0.784***
	(8.88)	(19.87)	(14.22)
str	0.293***	0.106*	0.0178
	(5.29)	(2.30)	(0.31)
lp	-0.0108***	-0.00703***	-0.00362***
	(-6.97)	(-14.24)	(-9.08)
_cons	-2.080***	-2.958***	-2.622***
	(-3.83)	(-9.39)	(-6.34)
N	148	190	153

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.6 Main Results for Data on State-Owned Enterprises with GER1 in Three Five-Year Plan Periods

	10th FYP	**11th FYP**	**12th FYP**
GER1	1.569	21.37	-11.91
	(0.56)	(1.14)	(-1.25)
ext	1.474*	0.677*	1.859***
	(2.05)	(2.44)	(3.67)
sca	0.702***	0.859***	0.770***
	(8.54)	(20.19)	(13.90)
str	0.320***	0.106*	0.0210
	(5.62)	(2.29)	(0.36)
lp	-0.0116***	-0.00706***	-0.00371***
	(-7.32)	(-14.36)	(-9.19)
_cons	-2.111***	-2.980***	-2.498***
	(-3.72)	(-9.62)	(-5.97)
N	148	190	152

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.7, Table 5.2.8, and Table 5.2.9 represent the empirical results for privately owned industrial enterprises. Due to the data limitations, there is only one year of data for the private sector during the 10th Five-Year Plan period; thus, there is not regression results for 10th Five-Year Plan.

Table 5.2.7 shows the regression results with ER1 for privately owned enterprises in two sub-samples. Similar to the results for all industrial enterprises represented in Table 5.2.1, the sign of the variable ER1 is negative in the 11th and 12th Five-Year Plan periods. However, only 2 shows statistical significance for ER1, which demonstrates that the relationship between the intensity of overall environmental regulation and employment in privately owned industrial enterprises was significant and negative in the 12th Five-Year Plan period, and in the 11th Five-Year Plan period, there was no significant relationship. Also, one unit of growth in the stringency of environmental regulations reduced employment by 4.004 units during the 12th Five-Year Plan period.

In terms of the effect of water pollution regulation on labour demand in privately owned enterprises, Table 5.2.8 provides the regression results with WER1. The coefficient of WER1 is statistically insignificant.

According to Table 5.2.9, the effect of gas pollution regulation on employment in privately owned industrial enterprises is similar as Table 5.2.7, and Table 5.2.8, which is negative in the 11th and 12th Five-Year Plan periods. However, columns 1 demonstrates that gas pollution regulation had no impact on employment in private-sector industrial enterprises during the 11th Five-Year Plan periods. However, in the 12th Five-Year Plan period, there was a significant and negative relationship between gas pollution regulation and labour demand in the privately-owned sector. If the intensity of gas pollution regulation increased by one unit, the total employment of private industrial enterprises will reduce by 104,478 persons.

Table 5.2.7 Main Results for Data on Privately Owned Enterprises with ER1 in Two Five-Year Plan Periods

	11th FYP	**12th FYP**
ER1	-4.028	-4.004**
	(-1.02)	(-2.68)
ext	1.524***	0.555
	(6.18)	(1.97)
sca	0.913***	0.883***
	(38.81)	(39.42)
str	0.0382*	-0.00128
	(2.00)	(-0.05)
lp	-0.00863***	-0.00654***
	(-13.10)	(-20.10)
_cons	-3.238***	-2.975***
	(-22.23)	(-17.89)
N	190	156

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.8 Main Results for Data on Privately Owned Enterprises with WER1 in Two Five-Year Plan Periods

	11th FYP	**12th FYP**
WER1	-3.923	-3.531
	(-0.86)	(-1.94)
ext	1.527***	0.389
	(6.17)	(1.44)
sca	0.914***	0.892***
	(38.65)	(40.40)
str	0.0363	-0.00297
	(1.93)	(-0.12)
lp	-0.00862***	-0.00662***
	(-13.07)	(-20.30)
_cons	-3.239***	-3.030***
	(-22.04)	(-18.38)
N	190	157

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.9 Main Results for Data on Privately Owned Enterprises with GER1 in Two Five-Year Plan Periods

	11th FYP	**12th FYP**
GER1	-6.425	-13.40**
	(-0.66)	(-3.22)
ext	1.552***	0.638*
	(6.32)	(2.28)
sca	0.918***	0.884***
	(39.81)	(40.97)
str	0.0364	0.000491
	(1.91)	(0.02)
lp	-0.00862***	-0.00654***
	(-13.05)	(-20.47)
_cons	-3.271***	-2.989***
	(-23.01)	(-18.58)
N	190	156

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

The results of regressions for foreign-owned industrial enterprises are reported in Table 5.2.10, Table 5.2.11, and Table 5.2.12. The coefficients of ER1, WER2, and GER2 were statistically insignificant in all the models, demonstrating that environmental regulation had no impact on employment in foreign-owned industrial enterprises during the 10th, 11th, and 12th Five-Year Plan periods.

Table 5.2.10 Main Results for Data on Foreign-Owned Enterprises with ER1 in Three Five-Year Plan Periods

	10th FYP	11th FYP	12th FYP
ER1	-2.102	-1.236	10.92
	(-1.21)	(-0.13)	(1.13)
ext	-0.0109	0.700**	0.492
	(-0.03)	(2.66)	(0.44)
sca	0.759***	0.662***	1.041***
	(22.71)	(15.30)	(8.00)
str	0.0755	0.199**	0.0278
	(1.49)	(2.78)	(0.26)
lp	-0.000351***	-0.00101***	-0.00442***
	(-7.25)	(-6.08)	(-13.90)
_cons	-2.732***	-2.546***	-4.554***
	(-10.90)	(-6.49)	(-4.66)
N	141	188	150

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.11 Main Results for Data on Foreign-Owned Enterprises with WER1 in Three Five-Year Plan Periods

	10th FYP	**11th FYP**	**12th FYP**
WER1	3.724	0.121	13.30
	(0.37)	(0.01)	(1.24)
ext	-0.0262	0.695**	0.540
	(-0.06)	(2.64)	(0.49)
sca	0.762***	0.662***	1.044***
	(22.39)	(15.32)	(8.06)
str	0.0822	0.198**	0.0228
	(1.61)	(2.75)	(0.22)
lp	-0.000351***	-0.00101***	-0.00443***
	(-7.21)	(-6.08)	(-13.99)
_cons	-2.784***	-2.549***	-4.561***
	(-10.85)	(-6.51)	(-4.71)
N	141	188	151

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

Table 5.2.12 Main Results for Data on Foreign-Owned Enterprises with GER1 in Three Five-Year Plan Periods

	10th FYP	**11th FYP**	**12th FYP**
GER1	-2.282	-5.239	4.436
	(-1.30)	(-0.28)	(0.17)
ext	-0.0185	0.697**	0.543
	(-0.05)	(2.67)	(0.49)
sca	0.760***	0.662***	1.017***
	(22.78)	(15.38)	(7.87)
str	0.0758	0.198**	0.0193
	(1.50)	(2.79)	(0.18)
lp	-0.000351***	-0.00101***	-0.00444***
	(-7.26)	(-6.07)	(-13.86)
_cons	-2.742***	-2.542***	-4.331***
	(-10.99)	(-6.48)	(-4.49)
N	141	188	150

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

5.3 Robustness check

With considering potential endogeneity of environmental regulation, this study applies 2SLS for the whole sample using 1-, 2- and 3- year lagged environmental regulation proxy as instruments respectively. The regression results suggest that the environmental regulation have no significant effects on the employment. And, Hausman test suggests environmental regulation is exogenous. The Appendix 6.1.1 reports the IV estimator results with 1- year lagged of ER1, WER1 and GER1 and Appendix 6.1.2 presents the Hausman results.

To check the robustness of the empirical results, this study first estimated random effects with ER1, WER1, and GER1. Then, the alternative environmental regulation indicators ER2, WER2, and GER2 were introduced. All the regression results based on random effects are reported in Appendix 5.1.1 -5.2.12.

First, when the regression results using both fixed effects and random effects of the appropriate environmental regulation indicator are compared with their corresponding sales values, the empirical findings are stable and robust. As discussed previously, the environmental regulation indicators are the percentages of the industrial pollution abatement and control expenditures (i.e., the sum of annual expenditures of waste water treatment facilities and industrial waste gas treatment facilities for various industries; the annual expenditures of industrial waste water treatment facilities; and the annual expenditures of industrial waste gas treatment facilities).

The results in most of the regressions have a similar sign and statistical significance as the regulation variable coefficients, but two differences should be noted. First, regarding the results for privately owned industrial enterprises, the sines of the coefficients were the same for the fixed effect and random effect estimators. However, the variables ER1 and WER1 were relatively significant at the 5% level in the fixed effect results, but they were not statistically significant in the random effect results. Moreover, the coefficient of GER1 was insignificant with the fixed effect estimation but is relatively significant in the random effect results. Second, the empirical findings suggest a significant and negative relationship between both overall environmental regulations and water pollution regulations and employment in all industrial enterprises using the fixed effect estimator, but this relationship is negative, though insignificant, based on random effects. The empirical findings in the other regression models were relatively the same between the fixed effect and random effect results.

This study also introduced alternative indicators to represent environmental regulation effects using the ratio of the industrial pollution abatement and control expenditures divided by the main industrial business operation costs, which is represented by ER2 for the sum of annual expenditures of industrial waste water treatment facilities and industrial waste gas treatment facilities in various industries, WER2 for the sum of annual expenditures of industrial waste water treatment facilities, GER2 for the sum of annual expenditures of industrial waste gas treatment facilities.

According to the fixed effect results shown in Appendix 5.3.1, Appendix 5.3.2, Appendix 5.3.3, and Appendix 5.3.4, which report the environmental regulation effect on employment during the period 2001 to 2015, the coefficients of ER2, WER2, and GER2 were not statistically significant in most of the models. However, for Model 1 and Model 2 in Appendix 5.3.3, ER2 and WER2 have a relatively significant relationship to employment at a 5% level, which demonstrates significant and negative relationships between employment in privately owned industrial enterprises with overall environmental regulations and water pollution regulations. These empirical results are consistent with the main results for ER1 and WER1 reported in Table 5.1.3.

In terms of how environmental regulations impacted employment in the 10th, 11th, and 12th Five-Year Plan periods separately, the regression results estimated with alternative indicators yielded results that were similar to the main results. First, comparing Appendix 5.4.1 to Appendix 5.4.3, with Table 5.2.1 to Table 5.2.3, the empirical results with ER2 are the same as for ER1, which implies that overall environmental regulation has no impact on employment in the industrial sector in the 10th Five-Year Plan period but resulted in significantly reduced employment in the 11th and 12th Five-Year Plan periods. The coefficients of WER2 were significant and negative in Models 2 and 3, suggesting the same conclusion as the WER1 result in Table 5.2.2 that water pollution regulation reduced employment in the 11th and 12th Five-Year Plan periods. Empirical results with GER2, shown in Appendix 5.4.3, also confirm the main regression findings in Table 5.2.3 that gas pollution regulation had no influence on industrial employment in the 10th and 11th Five-Year Plan periods, but relatively significantly reduced labour demand in the 12th Five-Year Plan period. The coefficients of alternative environmental regulations indicators in other regression models had the same signs as the main results; however, there was no empirical evidence for significant relationships between environmental regulations and employment in any of the sub-samples.

6. Discussion

Table 6.1 summarizes the coefficients of environmental regulation indicators in various models. The first horizontal section represents the coefficients of overall environmental regulation proxy ER1; the second horizontal section contains the empirical results of water pollution control regulation indicator WER1, and the third horizontal section reports the regression results of gas pollution controlling regulation variable GER1. The results for the entire sample period and for each of the three Five-Year Plan periods are shown in the first, second, third, and fourth columns in each horizontal section. The column labelled *ALL* is the result for data from all the industrial enterprises, while the column S*tate-Owned* reports the results for state-owned industrial enterprises, and the last two columns represents the empirical results for privately owned and foreign-owned industrial enterprises.

The coefficients of environmental regulation proxies in Table 6.1 imply three findings. First, environmental regulations, especially water pollution control regulation, promoted employment in industrial enterprises during the period 2001 to 2015, and water pollution regulation, rather than gas pollution regulation, dominated the environmental regulation effect. The function of gas pollution regulation began to emerge during the 12th Five-Year Plan period.

Second, the environmental regulation effect on industrial employment changed over time. It moved from being a positive effect in the 10th Five-Year Plan period to being a negative one in the 11th and 12th Five-Year Plan periods. Additionally, the impacts of the intensity of environmental regulation on the employment of industrial enterprises are heterogeneous across different ownership structure. In general, the intensity of environmental regulation promotes employment in state-owned industrial enterprises, reduces employment in privately owned enterprises, and has no impact on foreign-owned enterprises.

Table 6.1 Summary of Coefficients for Environmental Regulation Indicators

Indicators	Periods	ALL	Sate-owned	Private-owned	Foreign-owned
ER1	2001-2015	7.762**	8.674***	-5.273*	-4.52
	10th FYP	3.588	3.049	55.96*	-2.102
	11th FYP	-26.43***	4.105	-4.028	-1.236
	12th FYP	-3.454**	-0.582	-4.004**	10.92
WER1	2001-2015	22.41**	24.07***	-7.013*	3.48
	10th FYP	77.84***	41.73**	66.86*	3.724
	11th FYP	-35.46***	1.124	-3.923	0.121
	12th FYP	-3.539*	0.997	-3.531	13.3
GER1	2001-2015	5.104	6.578*	-8.955	-5.4
	10th FYP	0.609	1.569	28.18	-2.282
	11th FYP	-0.713	21.37	-6.425	-5.239
	12th FYP	-10.78**	-11.91	-13.40**	4.436

*t statistics in parentheses * p<0.05, p<0.01, p<0.001*

According to the positive coefficients of environmental regulation proxies in the column *ALL* and the first row in each horizontal section, for the entire period of 2001 to 2015, the intensity of environmental regulation had a positive impact on employment in industrial enterprises. That implies that the labour demand in industrial enterprises increased during the period 2001 to 2015 in association with the tightening of environmental regulations. This finding is consistent with Gray et al.'s (2014) empirical study on the impact of air quality rules on employment in the United States from 1997 to 2007. In this study, the positive effect is mainly due to water regulation, especially in the 10th Five-Year Plan period. Additionally, water pollution related regulation and gas pollution related regulation have different impacts on employment in the industrial sector in China. According to the second and third horizontal sections in Table 6.1, the coefficients of WER1 were significant in 8 of 16 models, but GER1 was only significant in 3 of the 16 models. Water pollution related regulation, rather than gas pollution regulation, dominated the environmental regulation effect on employment. The effect of gas pollution regulation become significant in the 12th Five-Year Plan period but was insignificant in the first two Five-Year Plan periods. Referring to the theoretical framework built by Berman and Bui (2001), a potential explanation for the existence of a positive relationship between environmental regulation and employment is that most industrial plants comply with environmental regulation by cleaning the pollution at the end of the production process and before production waste is to be released into the environment. As a result, enterprises demand more workers who are responsible for pollution reduction, which consequently increases employment.

Second, the effects of environmental regulations on employment varies in a time-dependent manner. As the second, third, and fourth rows in each horizontal section show, (a) the coefficients of ER1 in the 10th Five-Year Plan period were positive but insignificant, then change to positive and significant in the following two periods; (b) the coefficients of WER1 were significantly positive in the first period and then changed to significantly negative in the 11th and 12th Five-Year Plan periods; (c) the signs of GER1 also changed from positive in the 11th Five-Year Plan period to negative in the 12th Five-Year Plan period but only related significantly to employment in the last period.

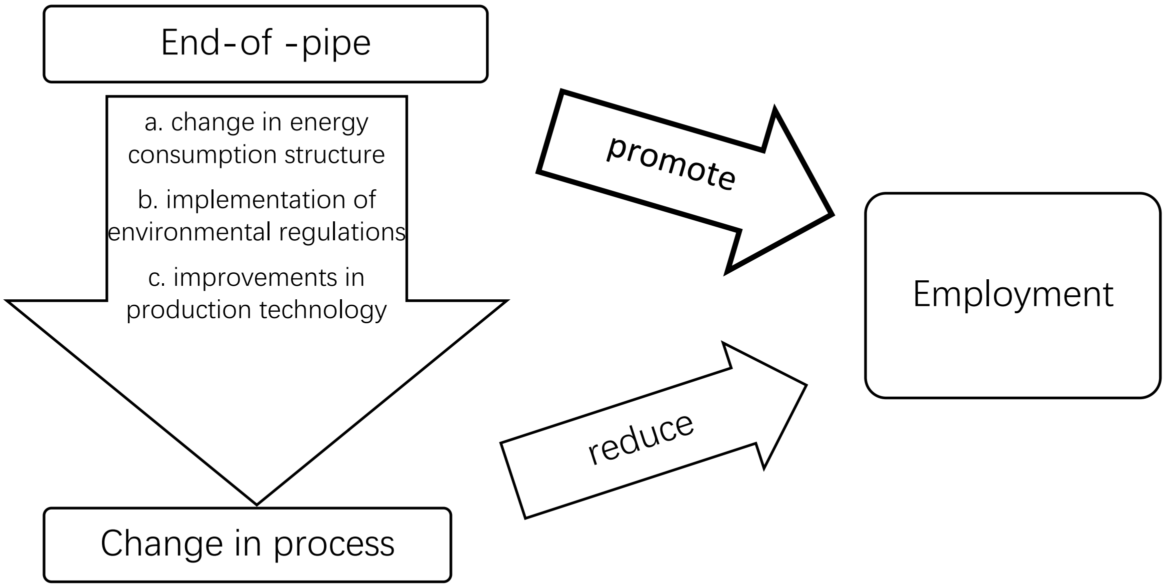
To sum up, generally, the relationship between environmental regulation and industrial employment was positive in the 10th Five-Year Plan period but negative in the 11th and 12th Five-Year Plan periods. This implies that environmental regulation contributed to employment in the industrial sector in the 10th Five-Year Plan period but then reduced industrial labour demand in the 11th and 12th Five-Year Plan periods.

To understand this time-varying effect of environmental regulation on employment through a theoretical framework, it should be noted that industrial enterprises employ more workers to clean up pollution at the end of the production process and before emission into the environment, which would have occurred in the 10th Five-Year Plan period, leading to a growth in employment. However, in the 11th and 12th Five-Year Plan periods, industrial plants installed cleaner production equipment, which create less pollution during the production process and improves production efficiency, which often reduces employment. This demonstrates that pollution control in China upgraded from an end-of-pipe solution to a change in process solution after the 11th Five-Year Plan period. This transformation was possibly caused by another three factors: a change in energy consumption structure, a strengthening of environmental regulations, or developments in production technology. In 2001, China’s consumption of non-clean energy, including coal and oil, accounted for 90.1% of the country’s total energy consumption. But this declined to 87% in 2010, while clean energy consumption increased to 13%. By 2015, at the end of the 12th Five-Year Plan period, non-clean energy consumption reduced to 82.1%, and clean energy consumption rose to 17.9%. Thus, China's energy consumption structure optimizing towards becoming cleaner since the 11th Five-Year Plan period led to the pollution treatment transformation from an end-of-pipe process to a change in process and further reduced labour demand in industrial enterprises subject to environmental regulations in China. Additionally, the strengthening of environmental regulation was another driving factor for pollution treatment changes. Although the state made efforts to construct an environmental legal system before the 11th Five-Year Plan, the environmental rules and policies implemented before 2005 fail to indicate specific actions or objectives of pollution treatment. In August 2006, China's state environmental protection administration signed a responsibility of major pollutants emission reduction goal with people's governments of provinces, autonomous regions, municipalities, and cities at the sub-provincial level. These goals clearly identify the reduction targets for COD and SO_2 by region, and that responsibility forced local governments to place emphasis on pollution abatement.

Moreover, in 2006, China's central government issued a series of environmental laws relating to the energy utilization structure, clean processes, and sustainable economic development, which included the Law on Energy Saving, the Law on Renewable Energy, The Clear Production Promoting Law, the Circulation Economy Promotion Law, and the plan for renewable energy development included in the 11th Five-Year Plan. The last potential factor is the upgrading of production technology. According to the Porter hypothesis, an appropriate environmental regulatory system will stimulate innovation in enterprise and increase the productivity and competitiveness of enterprises (Porter, 1995). The environmental regulations stemming from the 11th Five-Year Plan promoted industrial enterprises improving production technologies and utilizing more clean energy. For instance, during the 11th Five-Year Plan, the central enterprises spent RMB 358.6 billion on energy saving and pollution abatement, of which a main task was improving energy conservation and environmental technologies. To sum up, the three factors of changes in the energy consumption structure, implementation of environmental regulation, and improvement in production technologies from the 11th Five-Year Plan led the measure for pollution abatement transitions from end-of-pipe to change in process.

Then the effect of the intensity of environmental regulation on employment in industrial enterprises changed from positive to negative after the 11th Five-Year Plan period. The impacting process is described in Figure 6.1.

Figure 6.1 The impacting process



Last but not least, the impacts of the intensity of environmental regulation on the employment of industrial enterprises were heterogeneous across different ownership structures. Generally, the intensity of environmental regulation promoted employment in state-owned enterprises, especially in the 10th Five-Year Plan period, but it reduced labour demand in privately owned industrial enterprises and had no impact on foreign plants. According to the column labelled *state-owned*, environmental regulation indicators were significantly positive in four regression models and insignificant in others. The intensity of overall environmental regulation and water and gas pollution related regulations promoted employment in state-owned industrial enterprises in the whole period, and water pollution regulation made significant contributions to industrial labour demand in the 10th Five-Year Plan period; however, in the 11th and 12th Five-Year Plan periods, employment in state-owned industrial enterprises was not influenced by environmental regulations. Then, as the column labelled *privately owned* shows, in the 10th Five-Year Plan period, while overall environmental regulation and water pollution control regulations positively related to employment, the overall effect of ER1 and WER1 across the three periods were significantly negative, which implies that the intensity of environmental regulation and water pollution regulation reduced employment in privately owned industrial enterprises during the period 2001 to 2015. Additionally, in the 12th Five-Year Plan period, environmental regulation and gas pollution related regulations caused a significant decline in employment in privately owned industries. In terms of foreign-owned industries, the coefficients in the column labelled *foreign-owned* demonstrates that there was no empirical evidence that environmental regulations impacted employment. These empirical findings are consistent with Liu et al. (2017) and Sheng et al. (2019), who also found that higher pollutants discharge standards reduced employment in privately owned enterprises by 7.4% but had no influence on state-owned or foreign-owned enterprises in the textile printing and dyeing industry.

The heterogeneity of the environmental regulation effect among various ownerships potentially has two reasons. One is that enterprises with different ownership structures have different bargaining power with the local government. Adherence to related environmental regulations is often negotiable, especially if the local government has other priorities, such as economic development (Child and Tsai, 2005). Therefore, how much bargaining power an enterprise has can determine the enforcement of environmental regulations such as pollutant emissions charges and discharge standards, and these can also determinate the methods of dealing with environmental regulations (Wang and Wheeler, 2003). State-owned enterprises share a special link with local government and have stronger bargaining power than private enterprises, which makes it easier for state-owned enterprises to circumvent and any minimize negative impacts from environmental regulations (Wang et al, 2003). However, while private enterprises have less bargaining power than state-owned enterprises, they have more initiative to adopt changes in processes as a measure to control pollution. As a result, they more frequently choose innovation to alleviate the adverse influence of stringent environmental regulations (De Marchi, 2012). Thus, it is reasonable that the intensity of environmental regulations has either no impact or, at a minimum, no negative impact, on employment in state-owned enterprises, but sometimes leads declines in labour demand for privately owned plants. Foreign firms may have the least bargaining power of the three enterprise ownership types compared to domestic firms, including both state-owned and privately owned (Lin et al., 2014). Due to lack of familiarity with the local political context and weak links to local government, foreign enterprises are often targeted for regulatory enforcement. Through the perspective of bargaining power, foreign firms seem to be the most negatively impacted by the intensity of environmental regulations. However, the empirical results suggest there is no relationship between environmental regulations and employment in foreign industrial enterprises. Some previous studies found that multinational enterprises (MNEs) tend to have cleaner technology than domestic firms, most likely because developed countries usually have stricter environmental standards, which may have produced innovations and advancements of environmentally friendly technologies (Lanjouw and Mody, 1996). Moreover, MNEs often need to deal with higher institutional urging in terms of pollution controlling, and the pressure on an MNE's environmental self-regulation originates from assorted legitimating systems that exert supranational institutional pressure (Kostova and Zaheer, 1999). These two driving factors make foreign-owned enterprises more often utilize advances and cleaner production technology even when they are located in a region with relatively weak environmental standards. The ultimate result is that increasing intensity of environmental regulations has no impact on employment in foreign industrial enterprises.

7. Conclusion

The impact of the intensity of environmental regulations on employment in industries in China is an essential political and economic issue in the country and is increasingly attracting attention (Li et al., 2018). However, this impact cannot be predicted by neoclassic economic theory, and there is also a lack of empirical studies. In response to doubt about these impacts, this study investigated the role the intensity of environmental regulations plays in employment, using data from China's industrial sector during the period 2001 to 2015, which covers three of China's Five-Year Plans (the 10th, 11th, and 12th).

This study contributes to the literature through three components: First, it examined the continuous effect of environmental regulations on employment over a longer period than had been previously studied. Second, this study used empirical regression for sub-samples of three different Five-Year Plan periods to investigate the differences in the impact of environmental regulations between the various periods. Third, this study went on to check the heterogeneity of the relationship between environmental regulations and employment across enterprises with different ownership structures.

The empirical findings demonstrate three conclusions. First, overall environmental regulation, especially water pollution control regulation, promoted employment in industrial enterprises during the period 2001 to 2015. In addition, water pollution regulation had a stronger impact than gas pollution regulation, which implies that between 2001 and 2015, most industrial plants complied with environmental regulations by cleaning up the pollution at the end of their production process, before it was to be released into the environment. To do so, enterprises demanded more workers who were made responsible for pollution reduction, which consequently increased employment. Second, the role of the intensity of the environmental regulation effect on industrial employment varies over time, changing from being a labour-enhancing factor in the 10th Five-Year Plan period to becoming a labour-reducing factor in the 11th and 12th Five-Year Plan periods. This seems to indicate that pollution abatement in China upgraded from an end-of-pipe process to a change in process after the 11th Five-Year Plan period. This upgrading was possibly caused by changes in the energy consumption structure, environmental regulation strengthening, and developments in production technology. Additionally, the relationship between the intensity of environmental regulations and the employment in industrial enterprises were heterogeneous across different ownership structures. In general, this relationship is positive in state-owned industrial enterprises, negative in privately owned enterprises, and insignificant in foreign-owned enterprises. This is because the different ownerships have various levels of bargaining power with local governments, and foreign firms are usually environmentally self-regulated, with higher standards, no matter whether local environmental regulations are stringent or not.

The above empirical findings have several implications for environmental regulation policies in China. First, the government needs to consider the labour-reducing effect of environmental regulation in the industrial sectors. Although, the overall effect during the period 2001 to 2015 was positive, the role of environmental regulation changes over time, and it played a reducing role after the 11th Five-Year Plan period. Thus, government can provide institutional and financial support to enterprises to stimulate the application of environmentally friendly technology, thereby minimizing the negative influence generated by environmental regulations on employment. Second, due to the heterogeneity of the impacts of environmental regulations on employment across different ownership structures, environmental policies should be designed according to the actual situation of the different types of enterprises rather than formulated as a unified approach.

Last but not least, there are three limitations of this study that should be fulfilled by future research. First, this study fails to confirm the effectiveness of environmental regulations in China. The insignificance of the environmental regulation variable, especially for state-owned enterprises, is explained in this study by strong bargaining power that can reduce the adverse impacts of stringent regulations. It is worth doubting the impact of that bargaining power on the effectiveness of environmental regulation.

In addition, as that bargaining power helps enterprises overcome the negative effects on employment, does it also simultaneously result in the failure of the regulations to force enterprises to reduce their emissions of pollutants? Second, consideration of the impact of the intensity of environmental regulation on employment should be through a comprehensive perspective rather than solely a specific industry or sector. The growth or decline of labour demand in a particular sector is not representative of the whole labour market in China. In other words, after the labour force withdraws from an environmentally regulated industry, they may join another industry such as the service industry rather than becoming an unemployed population. Thus, if environmental regulations prompt a labour force migration from pollution-intensive industry to environmentally friendly industry, then another question to be answered by future research is if the country should promote the upgrading of its industrial infrastructures.

Last but not the least, this study fails to investigate the heterogeneous effects of environmental regulation on employment across regions or firm-level. Due to the framework of China's environmental regulation decentralization, and the different provincial reduction mandates, the regulatory intensity varies across different regions. It is reasonable to believe the relationship between environmental regulation and employment is heterogeneous across regions. Additionally, as firms contribute different volume to local economic growth and tax revenue, the local government may apply political discretion and treat firm differently. That will cause the heterogeneity on firm level. Due to the limited data availability, this study fails to explore the heterogeneity of environmental regulation-employment nexus across regions and firms, which is expected to be answer by future research.

Appendix

Appendix 4.1 List of Industry Classifications

CODE	Industries
B06	Mining and Washing of Coal
B07	Extraction of Petroleum and Natural Gas
B08	Mining and Processing of Ferrous Metal Ores
B09	Mining and Processing of Non-ferrous Metal Ores
B10	Mining and Processing of Non-metal Ores
B11	Ancillary mining activities
B12	Mining of other Ores
B13	Processing of Food from Agricultural Products
B14	Manufacture of Foods
B15	Manufacture of Beverages
B16	Manufacture of Tobacco
B17	Manufacture of Textile
B18	Manufacture of Textile Wearing Apparel, Footwear, and Caps
B19	Manufacture of Leather, Fur, Feather and Related Products
B20	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
B21	Manufacture of Furniture
B22	Manufacture of Paper and Paper Products
B23	Printing, Reproduction of Recording Media
B24	Manufacture of Articles for Culture, Education and Sport Activity
B25	Processing of Petroleum, Coking, Processing of Nuclear Fuel
B26	Manufacture of Raw Chemical Materials and Chemical Products
B27	Manufacture of Medicines
B28	Manufacture of Chemical Fibers

B29	Manufacture of Rubber and Plastics (Including Manufacture of Rubber and Manufacture of Plastics)
B30	Manufacture of Non-metallic Mineral Products
B31	Smelting and Pressing of Ferrous Metals
B32	Smelting and Pressing of Non-ferrous Metals
B33	Manufacture of Metal Products
B34	Manufacture of General-Purpose Machinery
B35	Manufacture of Special Purpose Machinery
B36，B37	Manufacture of Transport Equipment （Including Manufacture of Automobile and Manufacture of Railway, Ship, Aerospace and Other Transport Equipment)
B38	Manufacture of Electrical Machinery and Equipment
B39	Manufacture of Communication Equipment, Computers and Other Electronic Equipment
B40	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
B41	Manufacture of Artwork and Other Manufacturing
B42	Recycling and disposal of waste
B43	Repair Service of Metal Products, Machinery and Equipment
D44	Production and Distribution of Electric Power and Heat Power
D45	Production and Distribution of Gas
D46	Production and Distribution of Water

Appendix 5.2 Defination and source of variables

	Variable Name	Definition	Data Source
Dependent Variable	*emp*	Annual Average Employed Persons (total amount of employed person in each month divided by twelve months)	China Industry Economy Statistical Yearbook
Core Variables	ER1	(annual expenditures of industrial waste water treatment facilities + industrial waste gas treatment facilities) / sales values	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook
	WER1	annual expenditures of industrial waste water treatment facilities / sales values	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook
	GER1	industrial waste gas treatment facilities / sales values	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook
	ER2	(annual expenditures of industrial waste water treatment facilities + industrial waste gas treatment facilities) / business cost	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook
	WER2	annual expenditures of industrial waste water treatment facilities / business cost	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook
	GER2	industrial waste gas treatment facilities / business cost	China Industry Economy Statistical Yearbook & China Environmental Statistical Yearbook

Control Variables	*ext*	the value of export goods / the industrial sales value	China Industry Economy Statistical Yearbook
	sca	log of sale value (at 2015 price)	China Industry Economy Statistical Yearbook
	str	five levels of the number of enterprise (1-99. 100-999, 1000-9999, and more than 10000)	China Industry Economy Statistical Yearbook
	lp	the sales value of an industry / the number of its employed person	China Industry Economy Statistical Yearbook
	fyp11	dummy variable (take the value of 1 if year is during 2006-2012, and otherwise 0)	/
	fyp12	Dummy variable (take the value of 1 if year is during 2011-2015, and otherwise 0)	/

Appendix 5.1.1 Results for full-dataset regressions with Random effect estimator

	(1)	(2)	(3)
ER1	8.320** (2.63)		
WER1		21.51** (2.77)	
GER1			5.986 (1.65)
ext	0.968*** (5.05)	0.984*** (5.11)	0.941*** (4.89)
sca	0.704*** (24.47)	0.717*** (24.11)	0.695*** (24.17)
str	0.251*** (5.81)	0.237*** (5.46)	0.253*** (5.81)
lp	-0.00428*** (-9.21)	-0.00425*** (-9.15)	-0.00429*** (-9.19)
fyp11	-0.257*** (-5.75)	-0.262*** (-5.88)	-0.259*** (-5.76)
fyp12	-0.262*** (-4.25)	-0.274*** (-4.45)	-0.261*** (-4.22)
_cons	-2.150*** (-12.14)	-2.223*** (-11.95)	-2.063*** (-11.89)
N	494	495	494

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.1.2 Results for State-owned industrial enterprises data with Random effect estimator

	(1)	(2)	(3)
ER1	8.677***		
	(3.47)		
WER1		21.85**	
		(3.24)	
GER1			6.887*
			(2.48)
ext	0.922***	0.916***	0.902***
	(3.99)	(3.96)	(3.87)
sca	0.747***	0.751***	0.745***
	(37.77)	(37.87)	(37.68)
str	0.202***	0.201***	0.202***
	(7.06)	(7.00)	(7.02)
lp	-0.00337***	-0.00335***	-0.00339***
	(-11.04)	(-11.00)	(-11.04)
fyp11	-0.411***	-0.410***	-0.419***
	(-11.56)	(-11.48)	(-11.73)
fyp12	-0.477***	-0.476***	-0.484***
	(-9.77)	(-9.74)	(-9.88)
_cons	-2.237***	-2.266***	-2.199***
	(-16.08)	(-16.15)	(-15.95)
N	490	491	490

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.1.3 Results for Private-owned industrial enterprises data with Random effect estimator

	(1)	(2)	(3)
ER1	-4.300 (-1.73)		
WER1		-4.478 (-1.35)	
GER1			-11.35* (-2.08)
ext	1.674*** (8.32)	1.663*** (8.30)	1.718*** (8.44)
sca	0.828*** (53.71)	0.833*** (54.01)	0.830*** (54.45)
str	0.111*** (4.82)	0.111*** (4.78)	0.113*** (4.90)
lp	--0.00237*** (-33.91)	-0.00238*** (-33.63)	-0.00237*** (-33.91)
fyp11	-0.124*** (-5.00)	-0.130*** (-5.18)	-0.123*** (-4.94)
fyp12	-0.353*** (-10.82)	-0.364*** (-11.21)	-0.349*** (-10.63)
_cons	-3.103*** (-33.89)	-3.133*** (-34.59)	-3.124*** (-34.70)
N	384	385	384

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.1.4 Results for Foreign-owned industrial enterprises data with Random effect estimator

	(1)	(2)	(3)
ER1	-3.853		
	(-1.40)		
WER1		2.864	
		(0.36)	
GER1			-4.732
			(-1.60)
ext	1.241***	1.230***	1.231***
	(8.34)	(8.14)	(8.25)
sca	0.785***	0.791***	0.787***
	(35.61)	(34.91)	(35.90)
str	0.276***	0.273***	0.275***
	(7.17)	(7.08)	(7.14)
lp	-0.00100***	-0.000995***	-0.00100***
	(-15.25)	(-15.13)	(-15.23)
fyp11	-0.0547	-0.0533	-0.0551
	(-1.57)	(-1.52)	(-1.58)
fyp12	-0.134**	-0.134**	-0.135**
	(-3.20)	(-3.21)	(-3.23)
_cons	-3.802***	-3.853***	-3.817***
	(-29.39)	(-28.29)	(-29.97)
N	479	480	479

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.1 Results for full-dataset regressions with ER1 in three Five-Year Plan Periods using Random effect

	10th FYP	11th FYP	12th FYP
ER1	6.077	-13.90**	-2.441
	(1.29)	(-2.79)	(-1.95)
ext	0.670	0.883***	1.329***
	(1.76)	(5.39)	(7.54)
sca	0.640***	0.795***	0.821***
	(9.59)	(26.41)	(39.67)
str	0.160	0.166***	0.116***
	(1.68)	(4.36)	(3.89)
lp	-0.0166***	-0.00553***	-0.00422***
	(-5.92)	(-11.40)	(-14.83)
_cons	-0.873*	-2.755***	-3.003***
	(-2.39)	(-12.56)	(-18.04)
N	148	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.2 Results for full-dataset regressions with WER1 in three Five-Year Plan Periods using Random effect

	10th FYP	**11th FYP**	**12th FYP**
WER1	80.05***	-21.23***	-2.282
	(4.47)	(-3.61)	(-1.41)
ext	0.964*	0.875***	1.323***
	(2.52)	(5.39)	(7.50)
sca	0.679***	0.777***	0.820***
	(10.21)	(25.35)	(39.55)
str	0.160	0.174***	0.115***
	(1.73)	(4.61)	(3.85)
lp	-0.0150***	-0.00542***	-0.00418***
	(-5.55)	(-11.33)	(-14.64)
_cons	-1.438***	-2.634***	-3.004***
	(-3.70)	(-11.81)	(-17.81)
N	148	190	157

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.3 Results for full-dataset regressions with GER1 in three Five-Year Plan Periods using Random effect

	10th FYP	11th FYP	12th FYP
GER1	1.290	3.203	-8.552*
	(0.26)	(0.28)	(-2.51)
ext	0.611	0.923***	1.342***
	(1.62)	(5.60)	(7.68)
sca	0.638***	0.834***	0.819***
	(9.60)	(30.18)	(40.39)
str	0.154	0.147***	0.115***
	(1.61)	(3.85)	(3.89)
lp	-0.0170***	-0.00592***	-0.00419***
	(-6.06)	(-12.13)	(-14.84)
_cons	-0.793*	-3.046***	-2.981***
	(-2.22)	(-15.34)	(-18.02)
N	148	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.4 Results for State-owned industrial enterprises data with ER1 in three Five-Year Plan Periods using Random effect

	10th FYP	11th FYP	12th FYP
ER1	3.569	3.906	-0.0650
	(1.32)	(0.58)	(-0.02)
ext	0.554	0.646*	1.867***
	(1.12)	(2.54)	(4.78)
sca	0.781***	0.869***	0.854***
	(19.37)	(37.50)	(25.97)
str	0.259***	0.109**	0.0619
	(5.27)	(2.89)	(1.32)
lp	-0.0131***	-0.00711***	-0.00426***
	(-9.11)	(-16.44)	(-13.04)
_cons	-2.335***	-3.045***	-3.157***
	(-8.77)	(-19.03)	(-14.62)
N	148	190	152

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.5 Results for State-owned industrial enterprises data with WER1 in three Five-Year Plan Periods using Random effect

	10th FYP	**11th FYP**	**12th FYP**
WER1	38.85**	2.055	2.291
	(3.16)	(0.26)	(0.59)
ext	0.586	0.645*	1.860***
	(1.21)	(2.54)	(4.79)
sca	0.780***	0.869***	0.857***
	(19.62)	(37.23)	(26.42)
str	0.255***	0.109**	0.0620
	(5.33)	(2.91)	(1.34)
lp	-0.0124***	-0.00710***	-0.00427***
	(-8.82)	(-16.41)	(-13.23)
_cons	-2.406***	-3.038***	-3.179***
	(-9.09)	(-18.83)	(-15.03)
N	148	190	153

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.6 Results for State-owned industrial enterprises data with GER1 in three Five-Year Plan Periods using Random effect

	10th FYP	**11th FYP**	**12th FYP**
GER1	1.922	13.82	-9.805
	(0.69)	(0.86)	(-1.14)
ext	0.541	0.649*	1.838***
	(1.09)	(2.56)	(4.73)
sca	0.781***	0.867***	0.855***
	(19.31)	(37.46)	(26.13)
str	0.259***	0.107**	0.0667
	(5.23)	(2.86)	(1.43)
lp	-0.0132***	-0.00713***	-0.00432***
	(-9.15)	(-16.49)	(-13.17)
_cons	-2.318***	-3.024***	-3.154***
	(-8.70)	(-19.18)	(-14.72)
N	148	190	152

t statistics in parentheses * $p<0.05$, $p<0.01$, $p<0.001$

Appendix 5.2.7 Results for Private-owned industrial enterprises data with ER1 in three Five-Year Plan Periods using Random effect

	11th FYP	**12th FYP**
ER1	-3.340	-2.842*
	(-0.95)	(-2.16)
ext	1.179***	0.838***
	(7.49)	(4.40)
sca	0.976***	0.979***
	(79.43)	(78.29)
str	0.0315	0.00615
	(1.60)	(0.30)
lp	-0.0117***	-0.00758***
	(-28.10)	(-33.94)
_cons	-3.490***	-3.689***
	(-65.84)	(-73.86)
N	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.8 Results for Private-owned industrial enterprises data with WER1 in three Five-Year Plan Periods using Random effect

	11th FYP	**12th FYP**
WER1	-4.239	-2.653
	(-0.98)	(-1.52)
ext	1.184***	0.788***
	(7.63)	(4.17)
sca	0.977***	0.982***
	(79.66)	(78.92)
str	0.0304	0.00308
	(1.55)	(0.15)
lp	-0.0118***	-0.00762***
	(-28.07)	(-34.20)
_cons	-3.488***	-3.698***
	(-65.38)	(-74.16)
N	190	157

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.9 Results for Private-owned industrial enterprises data with GER1 in three Five-Year Plan Periods using Random effect

	11th FYP	**12th FYP**
GER1	-1.939	-7.633*
	(-0.29)	(-2.50)
ext	1.203***	0.808***
	(7.77)	(4.37)
sca	0.979***	0.979***
	(81.05)	(79.56)
str	0.0291	0.00603
	(1.48)	(0.29)
lp	-0.0117***	-0.00756***
	(-28.19)	(-33.87)
_cons	-3.507***	-3.686***
	(-71.80)	(-73.59)
N	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.10 Results for Foreign-owned industrial enterprises data with ER1 in three Five-Year Plan Periods using Random effect

	10th FYP	**11th FYP**	**12th FYP**
ER1	-1.708	-12.51	4.412
	(-0.75)	(-1.44)	(0.54)
ext	1.350***	1.207***	0.905***
	(4.82)	(6.62)	(3.90)
sca	0.754***	0.739***	0.871***
	(20.60)	(26.11)	(23.22)
str	0.266***	0.343***	0.145*
	(4.48)	(6.28)	(2.43)
lp	-0.000468***	-0.00141***	-0.00360***
	(-7.75)	(-10.33)	(-16.04)
_cons	-3.644***	-3.619***	-3.763***
	(-18.58)	(-19.99)	(-20.10)
N	141	188	150

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.11 Results for Foreign-owned industrial enterprises data with WER1 in three Five-Year Plan Periods using Random effect

	10th FYP	**11th FYP**	**12th FYP**
WER1	2.226	0.131	17.13
	(0.18)	(-1.23)	(1.65)
ext	1.354***	1.211***	0.893***
	(4.83)	(6.62)	(3.97)
sca	0.754***	0.738***	0.872***
	(20.35)	(25.65)	(23.82)
str	0.274***	0.345***	0.152**
	(4.59)	(6.29)	(2.59)
lp	-0.000471***	-0.00141***	-0.00356***
	(-7.75)	(-10.31)	(-16.11)
_cons	-3.676***	-3.630***	-3.807***
	(-17.94)	(-20.01)	(-20.69)
N	141	188	151

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.2.12 Results for Foreign-owned industrial enterprises data with GER1 in three Five-Year Plan Periods using Random effect

	10th FYP	11th FYP	12th FYP
GER1	-1.845	-13.15	-16.35
	(-0.79)	(-0.79)	(-1.17)
ext	1.351***	1.184***	0.842***
	(4.83)	(6.40)	(3.67)
sca	0.755***	0.747***	0.873***
	(20.59)	(26.54)	(23.69)
str	0.268***	0.336***	0.147*
	(4.50)	(6.09)	(2.50)
lp	-0.000469***	-0.00139***	-0.00357***
	(-7.76)	(-10.15)	(-16.13)
_cons	-3.653***	-3.666***	-3.752***
	(-18.75)	(-20.32)	(-20.74)
N	141	188	150

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.3.1 Results for full-dataset regressions with ER2. WER2, and GER2

	Fixed Effect			Random Effect		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ER2	-0.0902 (-0.47)			-0.0201 (0.11)		
WER2		-0.671 (-1.71)			-0.639 (-1.63)	
GER2			0.0951 (0.40)			0.244 (1.05)
ext	0.860** (2.87)	0.815** (2.73)	0.849** (2.83)	0.929*** (4.81)	0.889*** (4.62)	0.936*** (4.85)
sca	0.447*** (9.10)	0.431*** (8.69)	0.452*** (9.35)	0.696*** (24.09)	0.687*** (23.38)	0.694*** (24.03)
str	0.189** (3.25)	0.197*** (3.42)	0.192** (3.31)	0.248*** (5.68)	0.252*** (5.81)	0.251*** (5.74)
lp	-0.00174** (-3.15)	-0.00174** (-3.18)	-0.00178** (-3.22)	-0.00432*** (-9.18)	-0.00430*** (-9.24)	-0.00435*** (-9.26)
fyp11	-0.0878 (-1.56)	-0.0789 (-1.41)	-0.0936 (-1.67)	-0.262*** (-5.83)	-0.259*** (-5.77)	-0.260*** (-5.79)
fyp12	-0.0916 (-1.06)	-0.0840 (-0.98)	-0.101 (-1.17)	-0.263*** (-4.23)	-0.264*** (-4.29)	-0.261*** (-4.19)
_cons	0.125 (0.32)	0.247 (0.62)	0.0573 (0.15)	-2.037*** (-11.58)	-1.946*** (-10.74)	-2.035*** (-11.75)
N	493	494	493	494	495	494

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.3.2 Results for State-owned industrial enterprises data with ER2. WER2, and GER2

	Fixed Effect			Random Effect		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ER2	0.220 (1.46)			0.164 (1.04)		
WER2		0.0360 (0.11)			-0.141 (-0.42)	
GER2			0.300 (1.68)			0.280 (1.49)
ext	1.044*** (4.47)	1.056*** (4.52)	1.038*** (4.45)	0.886*** (3.79)	0.880*** (3.76)	0.878*** (3.76)
sca	0.660*** (24.35)	0.657*** (24.15)	0.658*** (24.36)	0.745*** (37.43)	0.743*** (37.00)	0.743*** (37.42)
str	0.175*** (5.79)	0.177*** (5.83)	0.176*** (5.81)	0.199*** (6.87)	0.200*** (6.92)	0.199*** (6.86)
lp	-0.00249*** (-7.81)	-0.00246*** (-7.73)	-0.00251*** (-7.85)	-0.00341*** (-11.02)	-0.00339*** (-11.01)	-0.00342*** (-11.08)
fyp11	-0.428*** (-12.33)	-0.427*** (-12.29)	-0.428*** (-12.34)	-0.425*** (-11.87)	-0.425*** (-11.87)	-0.425*** (-11.90)
fyp12	-0.514*** (-10.37)	-0.511*** (-10.32)	-0.515*** (-10.40)	-0.490*** (-9.97)	-0.490*** (-9.97)	-0.492*** (-10.01)
_cons	-1.628*** (-8.51)	-1.602*** (-8.30)	-1.610*** (-8.46)	-2.186*** (-15.74)	-2.160*** (-15.23)	-2.168*** (-15.70)
N	490	491	490	490	491	490

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.3.3 Results for Private-owned industrial enterprises data with ER2. WER2, and GER2

	Fixed Effect			Random Effect		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ER2	-0.199* (-2.23)			-0.183 (-1.91)		
WER2		-0.345* (-2.37)			-0.204 (-1.28)	
GER2			-0.155 (-1.21)			-0.227 (-1.69)
ext	1.192*** (6.01)	1.124*** (5.69)	1.197*** (5.94)	1.649*** (8.26)	1.621*** (8.10)	1.670*** (8.32)
sca	0.755*** (45.85)	0.752*** (45.37)	0.760*** (46.50)	0.829*** (54.08)	0.831*** (54.03)	0.831*** (54.68)
str	0.0681** (3.16)	0.0638** (2.98)	0.0676** (3.11)	0.112*** (4.85)	0.109*** (4.71)	0.112*** (4.85)
lp	-0.00232*** (-37.08)	-0.00233*** (-37.18)	-0.00232*** (-36.88)	-0.00237*** (-33.97)	-0.00238*** (-33.86)	-0.00237*** (-33.87)
fyp11	-0.0585* (-2.44)	-0.0588* (-2.46)	-0.0637** (-2.67)	-0.124*** (-4.96)	-0.127*** (-5.11)	-0.126*** (-5.05)
fyp12	-0.243*** (-7.37)	-0.248*** (-7.61)	-0.251*** (-7.63)	-0.353*** (-10.84)	-0.362*** (-11.25)	-0.354*** (-10.87)
_cons	-2.431*** (-22.12)	-2.394*** (-21.36)	-2.470*** (-22.57)	-3.106*** (-34.15)	-3.110*** (-33.79)	-3.132*** (-34.77)
N	384	385	384	384	385	384

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.3.4 Results for Foreign-owned industrial enterprises data with ER2. WER2, and GER2

	Fixed Effect			**Random Effect**		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
ER2	-0.340 (-1.94)			-0.418* (-2.43)		
WER2		-0.205 (-0.50)			-0.375 (-0.95)	
GER2			-0.378 (-1.91)			-0.448* (-2.26)
ext	1.031*** (5.54)	1.021*** (5.34)	0.994*** (5.37)	1.260*** (8.56)	1.272*** (8.40)	1.223*** (8.21)
sca	0.763*** (27.37)	0.771*** (27.70)	0.766*** (27.86)	0.777*** (35.24)	0.783*** (34.82)	0.784*** (35.71)
str	0.154*** (3.60)	0.149*** (3.48)	0.156*** (3.65)	0.288*** (7.52)	0.281*** (7.30)	0.284*** (7.37)
lp	-0.000835*** (-12.44)	-0.000843*** (-12.53)	-0.000835*** (-12.43)	-0.00100*** (-15.25)	-0.00101*** (-15.28)	-0.000993*** (-15.13)
fyp11	-0.00151 (-0.04)	-0.0103 (-0.27)	-0.00563 (-0.15)	-0.0446 (-1.27)	-0.0491 (-1.39)	-0.0488 (-1.40)
fyp12	-0.100* (-2.14)	-0.115* (-2.48)	-0.105* (-2.26)	-0.116** (-2.75)	-0.126** (-3.00)	-0.122** (-2.90)
_cons	-3.241*** (-16.87)	-3.294*** (-16.99)	-3.274*** (-17.26)	-3.781*** (-29.87)	-3.807*** (-28.94)	-3.815*** (-30.15)
N	479	480	479	479	480	479

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.1 Results for full-dataset regressions with ER2 in three Five-Year Plan Periods

	Fixed Effect			**Random Effect**		
	emp	emp	emp	emp	emp	emp
ER2	0.355	-0.996***	-0.178**	0.655	-0.655***	-0.108
	(0.77)	(-6.94)	(-2.69)	(1.38)	(-4.48)	(-1.57)
ext	8.211***	0.361	1.268***	0.705	0.885***	1.313***
	(6.19)	(1.89)	(6.66)	(1.83)	(5.55)	(7.44)
sca	0.0507	0.555***	0.713***	0.639***	0.781***	0.821***
	(0.37)	(13.16)	(26.94)	(9.52)	(27.08)	(39.67)
str	0.184	0.150***	0.0745*	0.159	0.169***	0.116***
	(1.32)	(4.11)	(2.25)	(1.66)	(4.61)	(3.85)
lp	-0.00171	-0.00247***	-0.00315***	-0.0168***	-0.00527***	-0.00420***
	(-0.42)	(-4.53)	(-9.62)	(-6.00)	(-11.16)	(-14.69)
_cons	2.084*	-0.610	-1.934***	-0.880*	-2.645***	-3.008***
	(2.07)	(-1.72)	(-7.37)	(-2.39)	(-12.47)	(-17.91)
N	148	190	155	148	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.2 Results for full-dataset regressions with WER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
WER2	2.664	-1.398***	-0.224*	2.714*	-1.008***	-0.119
	(1.87)	(-8.47)	(-2.26)	(2.42)	(-5.67)	(-1.11)
ext	7.876***	0.294	1.267***	0.789*	0.869***	1.314***
	(5.96)	(1.62)	(6.62)	(2.04)	(5.57)	(7.44)
sca	0.103	0.525***	0.716***	0.655***	0.755***	0.822***
	(0.73)	(13.03)	(26.81)	(9.70)	(25.97)	(39.24)
str	0.187	0.161***	0.0742*	0.150	0.181***	0.115***
	(1.35)	(4.66)	(2.23)	(1.58)	(5.03)	(3.83)
lp	-0.00213	-0.00239***	-0.00313***	-0.0168***	-0.00515***	-0.00419***
	(-0.53)	(-4.68)	(-9.49)	(-6.05)	(-11.24)	(-14.62)
_cons	1.641	-0.398	-1.964***	-1.055**	-2.474***	-3.016***
	(1.60)	(-1.18)	(-7.47)	(-2.77)	(-11.54)	(-17.80)
N	148	190	156	148	190	157

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.3 Results for full-dataset regressions with GER2 in three Five-Year Plan Periods

	Fixed Effect			**Random Effect**		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
GER2	0.0913	-0.207	-0.291*	0.225	-0.100	-0.196
	(0.19)	(-0.63)	(-2.26)	(0.42)	(-0.33)	(-1.56)
ext	8.294***	0.596**	1.266***	0.631	0.919***	1.305***
	(6.26)	(2.75)	(6.59)	(1.66)	(5.59)	(7.40)
sca	0.0374	0.694***	0.725***	0.635***	0.834***	0.826***
	(0.27)	(16.23)	(28.03)	(9.50)	(30.19)	(40.74)
str	0.184	0.111**	0.0727*	0.155	0.148***	0.113***
	(1.31)	(2.69)	(2.18)	(1.62)	(3.87)	(3.78)
lp	-0.00157	-0.00374***	-0.00320***	-0.0169***	-0.00589***	-0.00421***
	(-0.39)	(-6.25)	(-9.68)	(-6.03)	(-12.04)	(-14.72)
_cons	2.196*	-1.720***	-2.028***	-0.788*	-3.039***	-3.035***
	(2.20)	(-4.72)	(-7.86)	(-2.19)	(-15.33)	(-18.38)
N	148	190	155	148	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.4 Results for State-owned enterprises data with ER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
ER2	0.219	-0.118	-0.175	0.256	-0.131	-0.129
	(0.76)	(-0.52)	(-1.08)	(0.90)	(-0.62)	(-0.87)
ext	1.460*	0.691*	1.860***	0.547	0.646*	1.840***
	(2.03)	(2.49)	(3.64)	(1.11)	(2.55)	(4.72)
sca	0.704***	0.855***	0.767***	0.781***	0.867***	0.853***
	(8.57)	(19.99)	(13.64)	(19.38)	(37.61)	(26.00)
str	0.319***	0.107*	0.0230	0.259***	0.110**	0.0664
	(5.60)	(2.31)	(0.39)	(5.23)	(2.94)	(1.41)
lp	-0.0116***	-0.00703***	-0.00366***	-0.0133***	-0.00710***	-0.00429***
	(-7.35)	(-14.27)	(-9.16)	(-9.18)	(-16.44)	(-13.15)
_cons	-2.128***	-2.932***	-2.490***	-2.332***	-3.017***	-3.144***
	(-3.75)	(-9.40)	(-5.87)	(-8.76)	(-19.05)	(-14.61)
N	148	190	152	148	190	152

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.5 Results for State-owned enterprises data with WER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
WER2	1.011	-0.261	-0.0335	0.872	-0.257	0.0366
	(1.11)	(-0.95)	(-0.14)	(1.09)	(-0.98)	(0.16)
ext	1.410	0.694*	1.977***	0.551	0.647*	1.870***
	(1.96)	(2.50)	(3.94)	(1.12)	(2.55)	(4.81)
sca	0.704***	0.853***	0.780***	0.782***	0.865***	0.855***
	(8.61)	(19.96)	(14.07)	(19.37)	(37.27)	(26.01)
str	0.311***	0.106*	0.0183	0.257***	0.109**	0.0617
	(5.44)	(2.30)	(0.31)	(5.20)	(2.92)	(1.32)
lp	-0.0115***	-0.00705***	-0.00362***	-0.0132***	-0.00712***	-0.00426***
	(-7.32)	(-14.33)	(-9.09)	(-9.17)	(-16.50)	(-13.16)
_cons	-2.129***	-2.914***	-2.595***	-2.351***	-3.000***	-3.162***
	(-3.77)	(-9.35)	(-6.24)	(-8.76)	(-18.70)	(-14.66)
N	148	190	153	148	190	153

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.6 Results for State-owned enterprises data with GER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
GER2	0.131	0.315	-0.520	0.169	0.144	-0.345
	(0.43)	(0.61)	(-1.80)	(0.55)	(0.33)	(-1.49)
ext	1.478*	0.680*	1.761***	0.539	0.646*	1.830***
	(2.05)	(2.44)	(3.46)	(1.09)	(2.55)	(4.72)
sca	0.701***	0.857***	0.761***	0.780***	0.867***	0.855***
	(8.53)	(20.10)	(13.75)	(19.32)	(37.43)	(26.15)
str	0.320***	0.106*	0.0280	0.259***	0.109**	0.0713
	(5.62)	(2.29)	(0.48)	(5.23)	(2.90)	(1.52)
lp	-0.0116***	-0.00705***	-0.00376***	-0.0133***	-0.00712***	-0.00433***
	(-7.34)	(-14.27)	(-9.35)	(-9.18)	(-16.41)	(-13.25)
_cons	-2.108***	-2.957***	-2.426***	-2.316***	-3.026***	-3.160***
	(-3.71)	(-9.54)	(-5.80)	(-8.71)	(-19.17)	(-14.74)
N	148	190	152	148	190	152

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.7 Results for Private-owned enterprises data with ER2 in two Five-Year Plan Periods

	Fixed effect		**Random effect**	
	emp	**emp**	**emp**	**emp**
ER2	-0.261*	-0.149	-0.234*	-0.0710
	(-2.15)	(-1.85)	(-2.26)	(-1.18)
ext	1.497***	0.366	1.156***	0.736***
	(6.15)	(1.37)	(7.50)	(4.01)
sca	0.909***	0.891***	0.973***	0.984***
	(39.33)	(39.76)	(80.39)	(79.43)
str	0.0426*	-0.00310	0.0354	0.00150
	(2.27)	(-0.13)	(1.82)	(0.07)
lp	-0.00868***	-0.00662***	-0.0117***	-0.00762***
	(-13.33)	(-20.14)	(-28.42)	(-33.97)
_cons	-3.213***	-3.017***	-3.475***	-3.701***
	(-22.49)	(-17.88)	(-68.26)	(-73.79)
N	190	156	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.8 Results for Private-owned enterprises data with WER2 in two Five-Year Plan Periods

	Fixed effect		Random effect	
	emp	**emp**	**emp**	**emp**
WER2	-0.255	-0.146	-0.315*	-0.0690
	(-1.74)	(-1.22)	(-2.28)	(-0.61)
ext	1.495***	0.288	1.167***	0.733***
	(6.08)	(1.08)	(7.67)	(3.91)
sca	0.910***	0.895***	0.974***	0.985***
	(38.90)	(39.59)	(81.03)	(79.00)
str	0.0372*	-0.00379	0.0317	0.000288
	(2.00)	(-0.16)	(1.65)	(0.01)
lp	-0.00864***	-0.00665***	-0.0118***	-0.00764***
	(-13.20)	(-20.13)	(-28.57)	(-34.13)
_cons	-3.206***	-3.046***	-3.470***	-3.708***
	(-21.96)	(-17.96)	(-67.75)	(-74.49)
N	190	157	190	157

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.9 Results for Private-owned enterprises data with GER2 in two Five-Year Plan Periods

	Fixed effect		**Random effect**	
	emp	**emp**	**emp**	**emp**
GER2	-0.407	-0.286	-0.167	-0.102
	(-1.52)	(-1.94)	(-0.93)	(-1.22)
ext	1.560***	0.318	1.193***	0.705***
	(6.40)	(1.23)	(7.75)	(3.89)
sca	0.918***	0.898***	0.978***	0.985***
	(40.09)	(41.81)	(80.81)	(80.64)
str	0.0419*	-0.00263	0.0315	-0.0809
	(2.17)	(-0.11)	(1.59)	(-0.00)
lp	-0.00867***	-0.00667***	-0.0117***	-0.00763***
	(-13.19)	(-20.60)	(-28.07)	(-34.17)
_cons	-3.285***	-3.062***	-3.506***	-3.704***
	(-23.21)	(-18.82)	(-71.86)	(-74.39)
N	190	156	190	156

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.10 Results for Foreign-owned enterprises data with ER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
ER2	-0.255	-0.430	0.393	-0.255	-0.755**	-0.131
	(-1.38)	(-1.42)	(0.89)	(-1.06)	(-2.76)	(-0.51)
ext	0.00537	0.751**	0.530	1.347***	1.247***	0.872***
	(0.01)	(2.86)	(0.48)	(4.81)	(6.95)	(3.75)
sca	0.760***	0.662***	1.030***	0.755***	0.740***	0.872***
	(22.79)	(15.51)	(7.95)	(20.65)	(27.12)	(23.38)
str	0.0747	0.202**	0.0274	0.265***	0.334***	0.144*
	(1.48)	(2.86)	(0.26)	(4.46)	(6.21)	(2.43)
lp	-0.000350***	-0.00101***	-0.00443***	-0.000469***	-0.00141***	-0.00359***
	(-7.26)	(-6.12)	(-13.87)	(-7.77)	(-10.50)	(-16.09)
_cons	-2.732***	-2.548***	-4.475***	-3.633***	-3.591***	-3.747***
	(-10.93)	(-6.55)	(-4.60)	(-18.53)	(-20.77)	(-20.39)
N	141	188	150	141	188	150

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.11 Results for Foreign-owned enterprises data with WER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
WER2	-0.0114	-0.511	1.044	-0.291	-0.994**	1.095
	(-0.02)	(-1.31)	(1.59)	(-0.40)	(-2.67)	(1.77)
ext	-0.0125	0.751**	0.569	1.352***	1.272***	0.908***
	(-0.03)	(2.85)	(0.52)	(4.82)	(7.07)	(3.97)
sca	0.760***	0.663***	1.057***	0.753***	0.735***	0.871***
	(22.43)	(15.50)	(8.16)	(20.42)	(26.72)	(23.56)
str	0.0810	0.202**	0.0274	0.271***	0.342***	0.151*
	(1.59)	(2.86)	(0.26)	(4.56)	(6.36)	(2.55)
lp	-0.000351***	-0.00102***	-0.00443***	-0.000469***	-0.00141***	-0.00358***
	(-7.20)	(-6.15)	(-14.06)	(-7.74)	(-10.58)	(-16.08)
_cons	-2.763***	-2.560***	-4.690***	-3.643***	-3.593***	-3.804***
	(-10.86)	(-6.57)	(-4.82)	(-18.07)	(-20.97)	(-20.47)
N	141	188	151	141	188	151

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 5.4.12 Results for Foreign-owned enterprises data with GER2 in three Five-Year Plan Periods

	Fixed Effect			Random Effect		
	emp	**emp**	**emp**	**emp**	**emp**	**emp**
GER2	-0.279	-0.334	-0.189	-0.250	-0.563	-0.420
	(-1.44)	(-0.67)	(-0.25)	(-0.98)	(-1.25)	(-1.43)
ext	-0.0133	0.702**	0.576	1.347***	1.186***	0.828***
	(-0.03)	(2.69)	(0.52)	(4.81)	(6.44)	(3.61)
sca	0.761***	0.662***	1.017***	0.756***	0.748***	0.874***
	(22.86)	(15.42)	(7.88)	(20.64)	(26.67)	(23.75)
str	0.0750	0.198**	0.0137	0.266***	0.333***	0.146*
	(1.49)	(2.79)	(0.13)	(4.47)	(6.05)	(2.50)
lp	-0.000351***	-0.00101***	-0.00444***	-0.000469***	-0.00139***	-0.00357***
	(-7.27)	(-6.06)	(-13.88)	(-7.77)	(-10.18)	(-16.14)
_cons	-2.748***	-2.541***	-4.308***	-3.652***	-3.666***	-3.757***
	(-11.04)	(-6.49)	(-4.48)	(-18.77)	(-20.50)	(-20.77)
N	141	188	150	141	188	150

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 6.1.1 2SLS estimation results for full-dataset regressions with ER1, WER1, and GER1 using 1-year lag value as instrumental variable

	ER1 emp	WER1 emp	GER1 emp
ER1	-107.3 (-1.06)		
WER1		683.0 (0.63)	
GER1			-53.60 (-0.97)
ext	0.873 (1.28)	1.596 (0.96)	1.017* (2.43)
sca	0.0106 (0.03)	1.952 (0.82)	0.344** (2.75)
str	-0.0498 (-0.20)	-0.178 (-0.29)	0.0324 (0.20)
lp	-0.00220 (-1.61)	-0.000540 (-0.18)	-0.00190* (-2.29)
N	455	457	455

t statistics in parentheses * p<0.05, p<0.01, p<0.001

Appendix 6.1.2 Hausman test results for 2SLS estimation using 1-year lagged as instrumental variable

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	IVER1	ER1	Difference	S.E.
ER1	-116.122	7.205898	-123.328	116.6463
ext	0.185165	0.939962	-0.7548	1.041922
sca	0.110302	0.418192	-0.30789	0.309124
str	-0.08123	0.194503	-0.27573	0.278537
lp	-0.00047	-0.00185	0.001378	0.001574

b = consistent under Ho and Ha; obtained from xtivreg2
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 1.19
Prob>chi = 0.8804

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	IVWER1	WER1	Difference	S.E.
WER1	754.9548	20.35496	734.5998	1329.59
ext	3.659259	0.960398	2.698861	4.860848
sca	1.547795	0.430313	1.117483	2.028715
str	-0.20448	0.174569	-0.37905	0.717367
lp	-0.00538	-0.00186	-0.00352	0.007059

b = consistent under Ho and Ha; obtained from xtivreg2
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 0.32
Prob>chi2 = 0.9886

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	IVGER1	GER1	Difference	S.E.
GER1	-56.8205	4.773492	-61.594	60.41262
ext	0.825424	0.911082	-0.08566	0.36072
sca	0.349165	0.406902	-0.05774	0.074359
str	0.014053	0.193608	-0.17956	0.171337
lp	-0.00135	-0.00182	0.000463	0.000589

b = consistent under Ho and Ha; obtained from xtivreg2
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 1.36
Prob>chi2 = 0.8511

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