FDI and Environmental Pollution Nexus in China

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Contents

Abstract

Our paper studies the foreign direct investment (FDI)-pollution nexus based on China's province level panel data from 2005 to 2014. The analysis focuses not only on a national panel (including all provinces), but also on three regional panels (provinces are divided by economic region. We applied dynamic panel data model with lagged variables based on general moment method (GMM) to capture causality. Because of the complexity of our data, the empirical results are quite complicated when it comes to different geographic regions and environment indicators. Overall, we find some evidence that FDI and environmental pollution causally interact with each other.

Key words: Foreign direct investment; environmental pollution; causality; pollution haven hypothesis; pollution halo hypothesis.

Introduction

Driven by economic globalization and trade liberalization, international trade forms, such as multinational corporations and foreign direct investment (FDI), have flourished and developed tremendously over the past several decades. The grounded fundamental reasoning behind multinational corporations and FDI is to take advantage of cost differences between developing countries and developed countries, and make use of lower production costs to promote overseas activity (Ietto-Gillies 2012). Currently, several theories explain the causes and consequences of FDI, such as the life cycle theory by Vernon (1966) and the internalization theory by Buckley and Casson (1976). According to these theories, the main determinants of FDI include trade tariffs, exchange rate, management costs and market sizes. It was not until the 1970s that people started to realize the importance of how environmental issues could have affected trade patterns, trade cost and production location (Jayadevappa and Chhatre 2000) in international trade arenas(Bailey 1993). Cross-border environmental issues began to generate public concern in terms of trade negotiation in the 1980s (Jayadevappa and Chhatre 2000). In the 1990s, the pollution haven and pollution halo hypotheses began to draw lots attention in academic debates (Neumayer 2001). As a result, the relationship between FDI and the environment is now an important topic in the global trade agenda.

Since its reform from a planned economy to an open economy in 1978, China has become more attractive for FDI inflows. The increase in FDI inflows has been relatively rapid and steady since the new millennium, compared to the fluctuations in other economies. According to OECD (2004), China has surpassed the US to become the largest destination in the world for FDI, with a total inflow of 53.5 billion US dollars (USD). In 2014, while global FDI flows declined, China maintained its developing speed and occupied 9.72% of the total world FDI, with 3797.73 billion USD (UNCTAD 2015).

Massive development often leads to derived problems, and the most concerning one in China is environmental consequences. China has been the country with the largest CO_2 emissions worldwide since 2006, according to World Development Indicators (Olivier, Janssens-Maenhout et al. 2014). The 2015 urban air quality report released by Environment Protection Agency (EPA) indicates that only 11 of the 74 main monitored cities meet Chinese air pollution standards (EPA 2016), although this is decent progress compared to the three qualified cities in 2013. When it comes to water quality, the China Social Assistance Foundation together with the China Water Security Charity Fund conducted national resident drinking water sample testing in 29 cities from November 2014 to January 2015, with 89 valid samples and 20 key indicators. Test outcomes show that 14 cities failed to meet at least one indicated standard (Outlook 2015).

The reality of similar developing trend between FDI and environment pollutions in China, and the growing amount of literature debating relationship between these two, makes us wondering if there exists any correlation based on China's case? Should FDI be responsible for environmental pollution in China? Alternatively, is it the worsening environment that makes China more appealing?

To gain a comprehensive understanding of the relationship between FDI and environmental pollution, we use both national and regional panel data[1] from 2005 to 2014. FDI and pollution problems vary among different regions in China; thus, comparisons of regional panel data will allow us to consider whether FDI status and pollution level covary within China. We analyze panel data using least squares regression and dynamic data models based on the general moment method (GMM) (Hansen, 1982). Empirical results reveal some unidirectional and bidirectional causal relationship between FDI and environmental pollution, depending on the regions and pollutants considered.

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[1] The national panel means all provinces are included; the regional panel means only provinces that belong to this economic region are included.

The paper is structured as follows: we first discuss some stylized facts in detail about FDI and environmental pollution in China, and briefly review literature on the main theoretical frameworks. We then outline the methodology and data we used to empirically test the relationship between FDI and pollution, and present the results. In the last section, we draw general conclusions and note the limitations of our results.

Stylized Facts

Since reforms in 1978, China has become the fastest developing emerging country in the world. With an average gross domestic product (GDP) annual growth rate of 9.81% from 1978-2015 (Figure 1), far greater than the world average GDP growth rate of 3.63% during this period,[2] China has ranked second in world GDP since 2010.

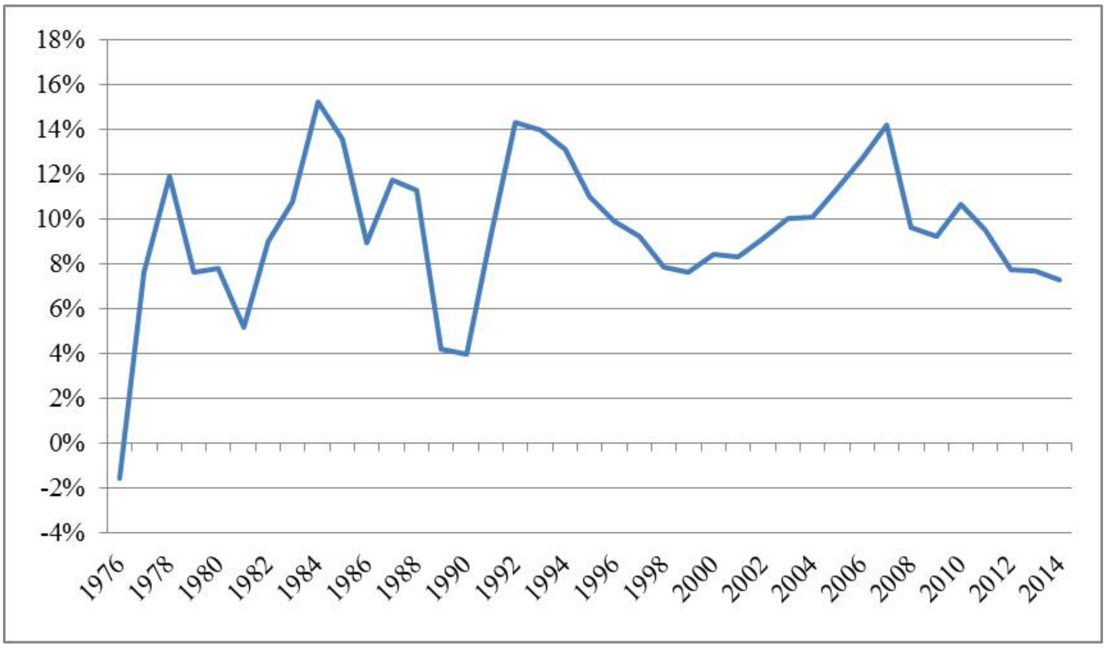

Figure 1: China annual GDP growth rate from 1976 to 2014

Source: World Bank national accounts data, and OECD National Accounts data files

The transformation from a planned economy to an open market economy has made China more attractive as a destination for FDI. The first few years after the reform, there was no significant increase of FDI into China; in fact, the total amount of FDI inflow was only 1.786 billion USD from 1979 to 1983. The growth rate has risen dramatically since the beginning of 1990s, with 1996 having 41.725 billion USD FDI inflows. Although the growth rate declined, even becoming negative due to the Asian financial crisis in the late 1990s, it has recovered from the economic downturn starting in 2000 and FDI inflow has

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[2] Calculated by author according to available data from The World Bank.

maintained a steady upward trend since then. According to the OECD, China attracted almost one third of developing world's FDI in 2002. Moreover, in 2003, China surpassed the US to become the largest recipient of FDI with total inflow of 53.5 billion USD (OECD 2004).

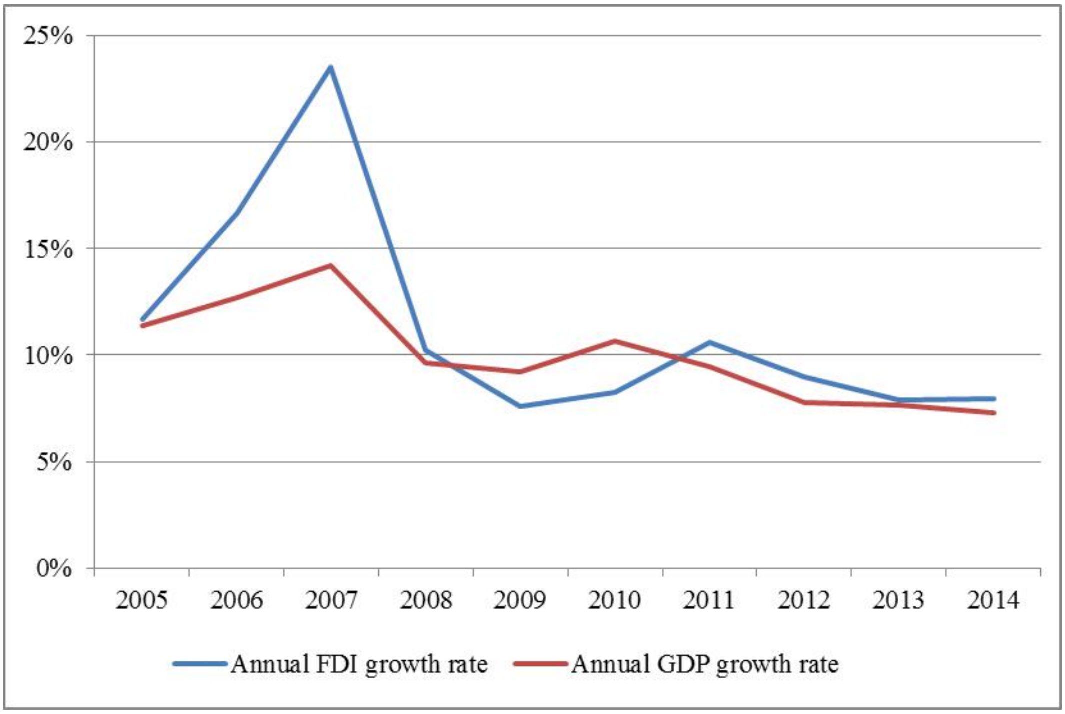

Figure 2: China annual GDP and FDI growth rate from 2005 to 2014

Source: China Statistical Yearbook

Despite a trend of declining global FDI inflow in 2014, China maintained its development speed and occupied 9.72% of world FDI inflow[3] (UNCTAD 2015). Figure 2 shows the annual FDI growth rate together with annual GDP growth rate in China during our study period; similar trends in the past decade suggest GDP and FDI complement and promote each other. Except for the noticeable achievement in FDI amount, nature of FDI inflow also has changed during these years. It was commonly assumed in the early years after reform that multinational enterprises targeted China as a destination in order to gain use of its resources and low-wage labor; however, there is an increasing tendency for large foreign companies to locate in China as part of a strategy to serve local clients or gain a

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[3] Calculated by author according to available statistic data from National Bureau of Statistics of China and United Nations Conference On Trade And Development (UNCTAD).

strategic position in China for its promising market future (OECD 2004).

Having created enormous achievements, FDI in China is notably imbalanced in terms of form, source, and distribution in regions and sectors. The main forms of FDI inflow in China include foreign contractual joint ventures, joint ventures and wholly foreign-owned enterprises; new ways to make use of FDI also include foreign-invested joint-stock company. Figure 3 reveals the composition of FDI inflow forms in 2014.

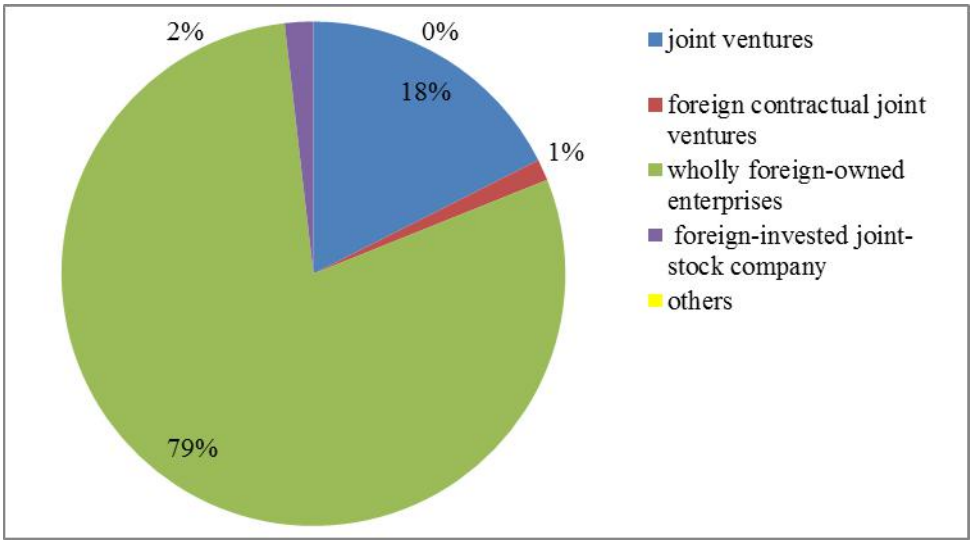

Figure 3: China FDI inflow form in 2014

Source: China National Bureau of Statistics

FDI sources in China from 1997 to 2014 were mostly Asian countries, which contributed 70% of FDI inflow to China, followed by Latin America, Europe and North America with 14%, 7% and 5%, respectively. The top three FDI inflow source countries/regions to China are Hong Kong, Singapore and Japan, all located in Asia. In figure 4 we calculate the source of actually used FDI.

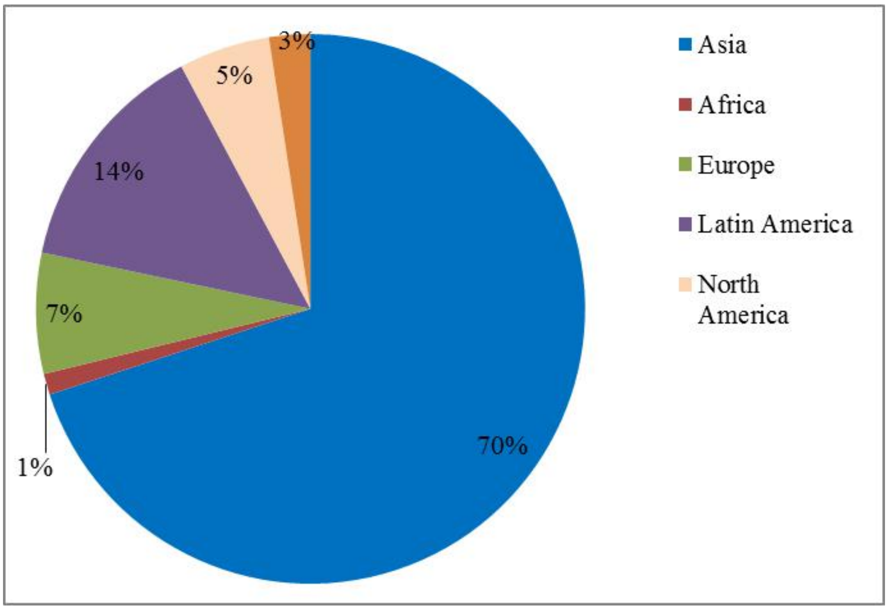

Figure 4: Source of actually used global FDI from 1997 to 2014

Source: China National Bureau of Statistics

Figure 5 and Table 1 show how China is geographically divided into three major economic zones of China, according to China's Seventh Five-Year Plan, namely, the eastern region, central region and western region, which contain 11, 10 and 10 provinces/municipalities/autonomous regions, respectively (Chongqing has become a municipality since 1997 and is classified in western region ever since). Generally speaking, development level of regions decreases from east to west. In consistent with this gradient tendency, during our research period, 2005-2014, 82.7% FDI inflow settled in the east region, while only 5.7% flowed to west inland area. By industry sector, the majority of FDI inflows occur in secondary industry[4] (especially manufacturing). We do see an increasing proportion of FDI inflow into tertiary industry[5] through these years; the share of foreign-funded enterprise total assets in tertiary industry rose from 35.22% to 41.30% between 2004 and 2013 (Xiaojuan et al. 2016).

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[4] According to National Bureau of Statistics of China, secondary industry in China mainly refers to mining, manufacturing, production and supply of electricity, gas and water, and construction.

[5] While primary industry refers to agriculture, forestry, animal husbandry and fishery, tertiary industry contains all fields of economic activities other than primary and secondary industries.

Figure 5: Geographic division of three economic regions in China

Source: China National Bureau of Statistics

Table 1: Province division of three economic regions in china

Three economic regions division in China					
Eastern Region		Central Region		Western Region	
Beijing		Shanxi		Chongqin	
Tianjin		Inner Mongolia		Sichuan	
Hebei		Jilin		Guizhou	
Liaoning		Heilongjiang		Yunnan	
Shanghai		Anhui		Tibet	
Jiangsu		Jiangxi		Shaanxi	
Zhejiang		Henan		Gansu	
Fujian		Hubei		Qinghai	
Shandong		Hunan		Ningxia	
Guangdong		Guangxi		Xinjiang	
Hainan					

Source: China National Bureau of Statistics

These significant economic achievements in China have at the same time led to some severe problems, the most concerning of which is environment pollution. According to World Development Indicators, China has surpassed the US as the world's largest CO_2

emitter since 2006. In 2013, CO_2 emission per capita in China was 6.2 metric tons, far beyond the global average of 4.9 metric tons (World Bank, 2014). Based on current statistics by the Ministry of Environmental Protection of China, less than 10% of China's cities have first-rate air quality.[6] Nationally, three commonly used major environmental pollution indicators are waste water discharge, sulfur dioxide emission and solid waste generated. Secondary industry, especially manufacturing, is main contributor of environmental pollution. In figure 6 below, we plot growth rate of these three environmental indexes, together with FDI growth as comparison.

FDI and pollution levels on a national scale reveals that the growth rates of the four indicators, in general, share similar trends and fluctuations (Figure 6). One exception occurred in 2007, where growth rate of FDI, wastewater and solid waste all showed a small peak, but growth rate of SO_2 dropped to below zero and stayed there till the end our study period (except for an tiny increase in 2011). In addition, the growth rate of solid waste increased rapidly in 2011, reaching a peak of 34%.

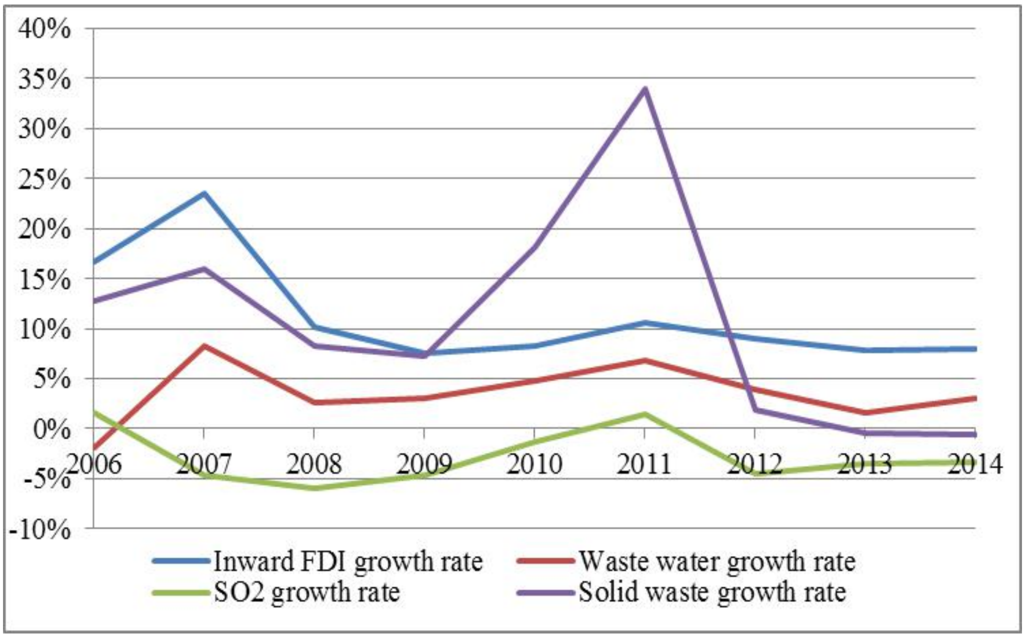

Figure 6: FDI, SO2, wastewater and solid waste growth rate from 2006 to 2014

Source: China National Bureau of Statistics

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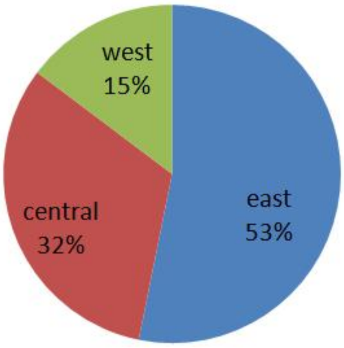
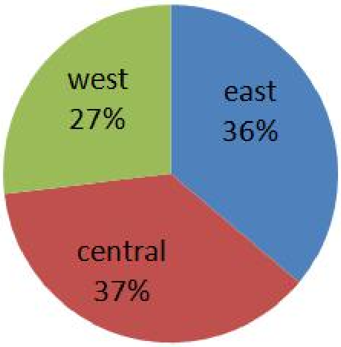
[6] Based on the standard of air quality index.

Looking at data by region from 2005 to 2014 (Figure 7), reveals that the eastern and central regions produced similar amounts of SO_2 emission and solid waste, summing up to about 75% of the national gross in each category. In contrast, for wastewater, the eastern region alone discharged more than half of wastewater, while central region discharged about 32%. We can conclude that there exist regional distribution imbalances in pollution; the eastern region yields the most environmental pollution, followed closely by the central region, while western region generates less pollution than either of the other two regions. While pollution production is unequal among regions, the pattern is to some extent consistent with patterns of the geographic distribution of FDI in the three regions as mentioned before.

Wastewater:



SO2:



Solid

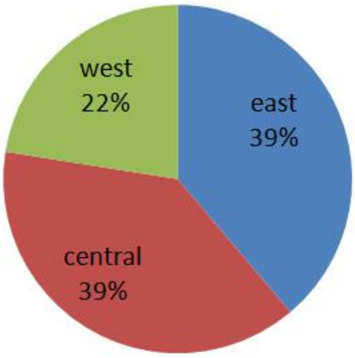


Figure 7: Regional distribution of wastewater, SO2 emission and solid waste, 2005-2014

Source: China National Bureau of Statistics

In contrast to the uneven distribution of FDI and total environmental pollution production, the growth rates of these variables seem to be more similar across regions. Figures 8 to 11 reveal the regional growth rates of FDI, SO_2, solid water and wastewater, respectively. The growth rate of FDI dropped dramatically from 2007 to 2009 in all regions, and then became relative stable after 2009 (Figure 8). The western region fluctuated the most, but its overall growth rate was the highest of the three economic regions during the whole period.

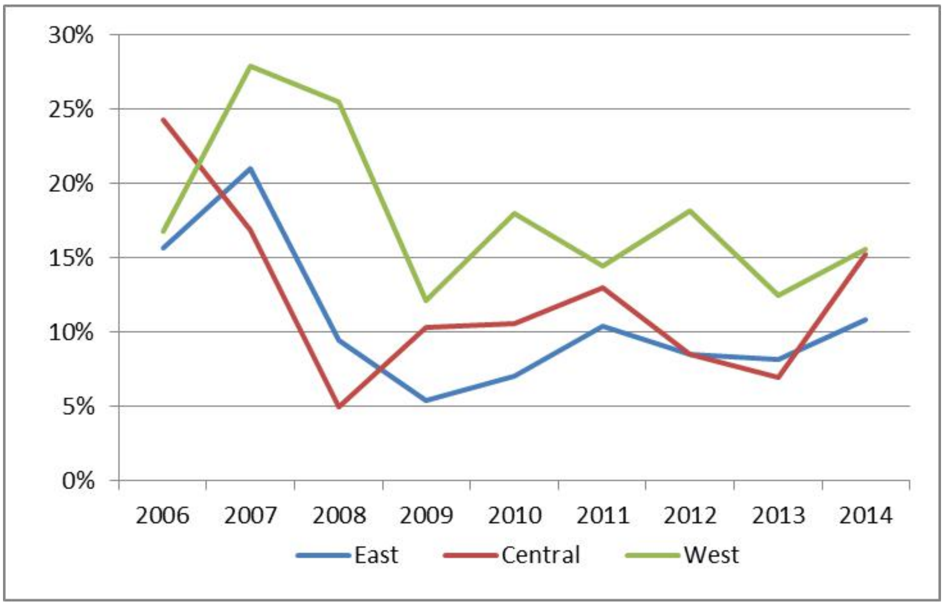


Figure 8: FDI growth rate in three regions from 2006 to 2014

Source: China National Bureau of Statistics

SO_2 emission growth rates decreased from positive to negative values from 2006 to 2008 in all regions, and then increased until 2011 (Figure 9). A sudden drop in SO_2 emissions from 2011 to 2012 made the growth rates negative again, and this negative growth rate has continued to 2014 in all regions. Growth rate trends in all three regions were similar, with the west having the highest growth rate of SO_2 emissions and the east having the lowest growth rate.

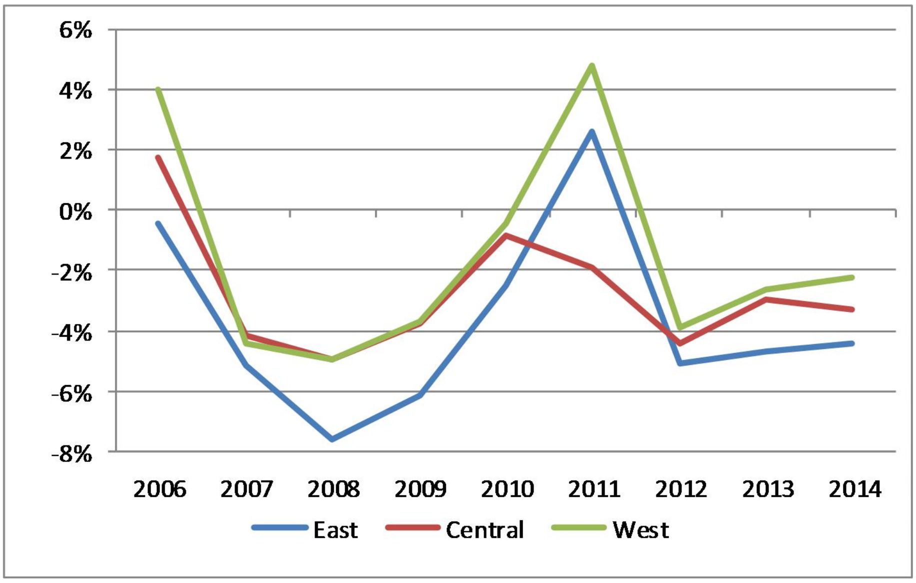


Figure 9: SO_2 emission growth rate in three regions from 2006 to 2014

Source: China National Bureau of Statistics

The growth rates of solid waste pollution were relatively stable before 2009, and then they climbed to the peak in 2011 (Figure 10). At this point, the growth rate dropped rapidly and after 2012, the growth rates of solid wastes were approximately zero. Growth rates were similar between the east and the central regions. The west region had a growth rate that rose faster in 2011, but dropped to the same level as other two regions in 2012.

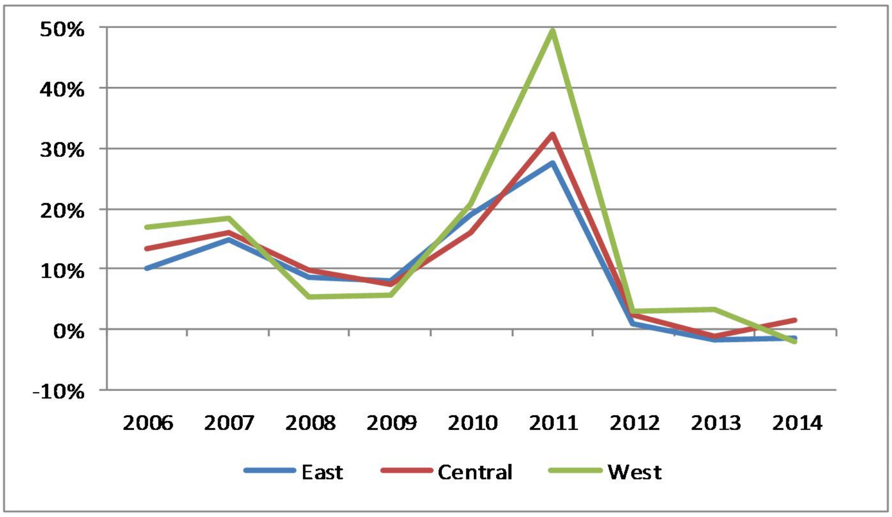


Figure 10: Solid wastes growth rate in three regions from 2006 to 2014

Source: China National Bureau of Statistics

The growth rates of water pollution varied among the three regions (Figure11). All regions experienced a rapid increase in growth rate in 2007, and then growth rates declined in 2008. After that, the growth rates remained relatively static in the east and central regions for several years, but in the west region, growth rates continued to decline until 2010 and then peaked suddenly in 2011.

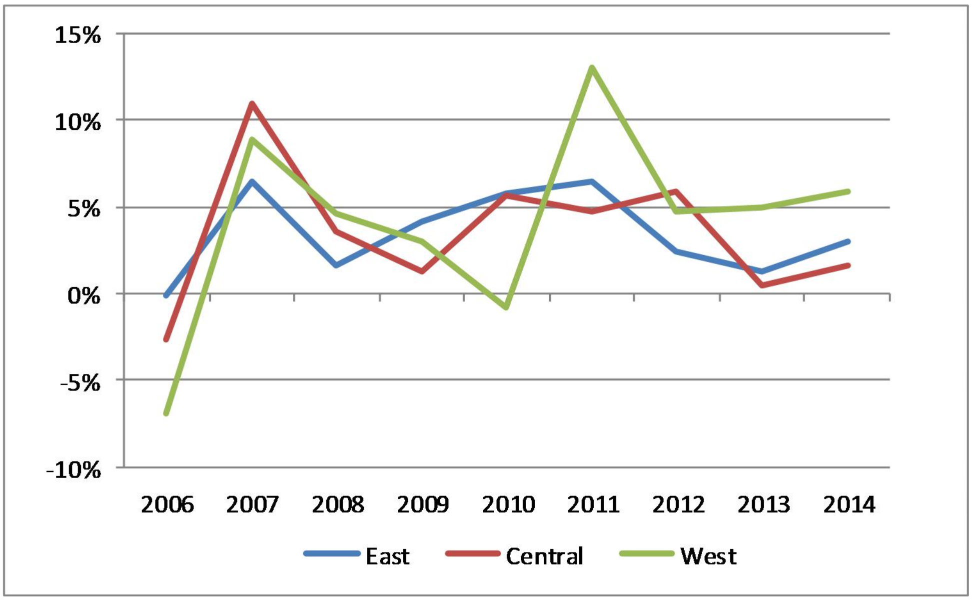


Figure 11: Waste water growth rate in three regions from 2006 to 2014

Source: China National Bureau of Statistics

In summary, the total volume of FDI inflows and environmental wastewater and solid waste pollution production increased from 2005 to 2014. The similar geographic distribution and growth trends of FDI and environmental pollution indicators suggest further study to uncover how they affect each other is worthwhile.

Early studies

Pollution haven hypothesis

As FDI increases globally, the relationship between it and the environment has become a hotly debated topic. Opponents of free trade argue that less developed countries will lower environment regulations in order to gain a competitive advantage for pollution intensive product industries in international trade competitions with developed countries (Copeland and Taylor 1994). At the same time, developed countries will require multinational corporations to relocate their high-polluting production into other areas in order to lower both environmental and financial costs (Peter 2001, Zhang and Fu 2008, Ferrara, Missios et al. 2015). Thus, pollution outputs will geographically shift to developing countries, adding to pollution production already incurred from developed countries. Further, a 'race to the bottom' will occur among developing countries with lax regulations, both environmental and other standards, to attract greater FDI inflow (Revesz 1992, He 2006, Mutafoglu and H. 2012). This is the general corollary of 'pollution haven hypothesis' and it postulates an increasing amount of environmental pollution in those countries that lack stringent environmental standards. Copeland and Taylor (1994) were one of the earliest to demonstrate the pollution haven hypothesis. In their paper, they apply a North-South static model to show that international free trade between countries leads to different pollution levels relative to an autarky world, and that if the trade pattern is driven only by pollution policy, then world pollution levels could rise as industry in rich developed countries benefit from relocating to less developed countries.

However, empirical results testing the pollution haven hypothesis have provided mixed results. List and Co(2000) explore how new plant locations of foreign multinational corporations were affected by state environment regulations in the US from 1986 to 1993 and show an inverse relationship between environmental stringency and attractiveness of a location. Keller and Levinson (2002) employ an 18-year panel dataset to show that pollution abatement costs have a moderate influence on capital and number of employees in foreign-owned manufacturers, especially in highly contaminated industries, and on the quantity of newly planned foreign-owned manufacturing facilities in US. Similar conclusions are drawn by Xing and Koldstad (2002). However, all of these studies are based on data from within the US and the sample sizes are relatively small, making the reliability of the results less certain. Eskeland and Harrison (2003) focus on four developing countries - Mexico, Venezuela, Morocco and Côte d'Ivoire. Controlling for country-specific factors, they find weak evidence that FDI inflows are concentrated in sectors with high levels of air pollution using different measures of pollution. They also suggest that FDI in these developing economies is unrelated to abatement costs in developed countries.

MacDermott (2009) investigated bilateral FDI among 26 OECD countries from 1982-1997. Using the same approach by Xing and Koldstad (2002), he takes pollution emission as a proxy for environmental stringency and shows that firms favor countries with fewer environmental regulations. In addition, using carbon dioxide as a measure of environment pollution, Tang and Tan (2015) examined data from Vietnam 1976-2009, and found FDI and CO_2 emission were correlated. These are two of the few studies to conclude a "strong" support for pollution haven hypothesis.

On the other hand, some study results clearly do not support the pollution haven hypothesis. Javorcik and Wei (2004) researched FDI inflows from multiple countries to 25 states in Eastern Europe and the former Soviet Union, but found no evidence for increased pollution in these transition countries. The mixed evidence could due to differences in assumptions, methods, measurements or study objects. For example, Chang (2012) applies a vector auto regression (VAR) model in China and suggests that the relationship between FDI and industrial pollutants could be positive or negative during 1981-2008, depending on the pollutant considered. To sum up, there is little solid empirical evidence for pollution haven hypothesis.

Pollution halo hypothesis

An alternative to the pollution haven hypothesis is the pollution halo hypothesis, which holds that FDI will decrease environmental pollution. Supporters of the pollution halo hypothesis argue that international free markets create a competitive atmosphere that compel companies to improve productive management and technique in developed economies, which are greener and more environment-friendly, and that these companies then spread these practices to developing countries, establishing a "pollution halo", through overseas multinational corporations (Zarsky 1999, Bora 2002, Blaine 2009). In a single year 1990, global market sales for pollution abatement and related services totaled $200 billion (Duchin et al. 1995) and were expected to grow by 50% in the next decade (OECD 1992). Zarsky (1999) suggested that the "halo" does exist, but the effect is "apparently pretty small." According to an overview of literature by the OECD (1997), the influence of FDI on environment, can be positive or negative depending on circumstances, but, on average, it is positive.

To challenge the pollution haven hypothesis, Birdsall and Wheeler (1993) investigated whether economic openness led to pollution-intensive industrial development in Latin American countries during 1960-1988. Their empirical evidence suggests more open countries end up with cleaner industry and higher environment standards. Although pollution intensity increased as a whole after OECD environment regulations become stricter, it was due to those protectionist economies into which dirty industries shifted. Thus, the pollution haven has nothing to do with openness but is instead a consequence of a protectionist policy (Birdsall and Wheeler 1993). The authors also note that if pollution goes up in developing countries due to free trade, then developed countries may need to pay extra costs because of globally negative externalities. This is one reason that developed countries will not just vandalize the environment for a temporary benefit.

Using a North-South market share game model, Xin and Baomin (2012) show that if market sizes are small in two countries, FDI will raise the emission standard in the host country; if both market sizes are large enough, then emission standard remains the same in the receiving country.

Using comprehensive provincial panel data from 1995-2010, Zhang and Zhou (2016) find that FDI is correlated with CO_2 emission reductions in China, and that this impact decreases from the western region to eastern region and central region. Similar results supporting the pollution halo hypothesis are found by Al-mulali and Foon Tang (2013) in Gulf Cooperation Council (GCC) countries; while they find FDI has no short-run causal relationship with CO_2 emission, over a longer time span, FDI inflow results in lower CO_2 emission. Lee and Brahmasrene (2013) apply unit root and cointegration tests with panel data from EU countries, and find that FDI has a strong significant negative effect on CO_2 emissions.

Environmental effects of FDI

Grossman and Kruger (1991) proposed three mechanisms for analyzing the impact of foreign trade and FDI on environmental pollution. The first is the scale effect, which has negative effects on the environment. The scale effect suggests FDI could result in greater manufacturer output as resources are allocated more efficiently, but that environmental pollution will simultaneously increase with greater level of FDI at the same time. The second mechanism is the composition effect, which states that FDI can affect the environment indirectly through changes in industrial structure that arise since foreign capital is mostly contributed by industries with a competitive advantage. As a result, the net effect of FDI on the environment depends on whether the inflowing industries are pollution-intensive and whether the competitive advantage comes from fewer environmental regulations. This argument is also the main theoretical support of the pollution haven hypothesis, since the less stringent environmental regulations give the host country a comparative advantage in pollution-intensive sectors. Zhang and Fu (2008) indicate that in China, increased stringency of environmental regulations have a significant negative effect on FDI. Regions with weaker environmental regulations are more attractive to FDI inflow. The last mechanism is the technique effect that suggests FDI may transfer new technologies that reduce pollution production, especially in developing countries, and could create positive spillovers to local firms. This argument is that of the pollution halo hypothesis, and suggests international trade flows assist in raising higher environment standards. In addition, FDI can stimulate local economic growth, and residents with increasing economic income may require higher living standards, leading to pressure on governments to maintain or enhance environmental standards.

In empirical studies, the overall effects of FDI are often complex and cannot be attributed clearly to one of the mechanisms. The overall effect will depend on which mechanism dominates: if the technology effect dominates, FDI will benefit the environment. In contrast, if the scale effect (pollution haven) dominates, environmental quality will deteriorate with FDI. Thus, the net effect of FDI is an empirical question (Gabriele Spilker, 2013).

Recent studies on the environmental effects of FDI have focused on developing countries since the current global FDI trend is for developed economies to invest in developing countries. Baekand Koo (2009) analyzed the cointegration of FDI and environment in China and India, using a vector error-correction model and found that over the long term, FDI has a positive effect on SO_2 emission in both countries. In the short run, the causal link is unidirectional – running from FDI to SO_2, the reverse does not hold. Using spatial econometric models, Tang et al. (2016) also find a positive effect of FDI on air pollution in China. According to their analysis, haze pollution increases by 0.0235% as FDI increase 1%. Some research on the effect of FDI suggests that results may differ depending on a country's development level. Hoffmann et al. (2005) analyzed the relationship between

FDI and pollution across 112 countries, and found that in low income countries, lower CO_2 emission standards attract more FDI inflow; however, in middle income countries, increased FDI led to more CO_2 emissions and no relationship was seen in high income countries. The overall study results suggest that, in less developed countries, FDI inflows and pollution load are more likely to be positively correlated.

Methods

One popular method to investigate the interaction of economic variables is the Granger causality test, which statistically tests whether the past value of a variable X can predict the value of another variable Y efficiently (Granger, 1969). Our analysis considers both the whole country and individual economic region, so the number of observations is quite small in each region, which limits our empirical method options. We use general moment method (GMM) to perform Granger causality test with panel data.

We use dynamic models that include lagged variables as our basic model since we are more interested in the effects of conditions at earlier time points, rather than the variation tendency in the corresponding period. In addition, in order to capture autoregressive behavior, we also include the lagged dependent variable in our models. Fixed effects are included in each model. The fixed effect model is designed to analyze the net effect of the determinants by removing the effect of time-invariant factors. The basic assumption of fixed effect model is that the error term includes two parts, one that varies across time and one that does not. The unobserved factors are fixed over time and are correlated with the independent variables. Therefore, all variables in a fixed effect model must be time-variant.

Then we use GMM to estimate the models. GMM is a widely adopted method in economic models to derive estimators. It requires only specified moments of the random variables to generate an objective function, so complete knowledge of the distribution of variables is not needed (Hansen, 1982). In addition, the fixed effect model produces biased coefficients in dynamic models, especially in panels where the time length is relatively short and the observations are large (Nerlove, 1967; Nickell, 1981). Previous studies have found that such bias can be reduced by GMM estimator. Judson and Owen (1999) and Buddelmeyer et al. (2008) indicate the outperformance of GMM estimator in their studies. Here we use the first-differenced GMM developed by Arellano and Bond (1991). Higher lagged levels of regressors are used as instruments, and by adding year dummies, we control for time fixed effects. We estimate the model with a two-step GMM.

To obtain a stationary series, we test for unit root before running the regression. Spurious regressions can occur if the variables are non-stationary. Yule (1926) first studied spurious regressions, noting that time series analysis may reveal nonsense correlations. Granger and Newbold (1974) and Phillips (1986) have developed the theory, showing that spurious regressions can result in incorrect results that do not reflect true statistical relationship among variables. Eviews provides panel unit root tests based on Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003), as well as Fisher-type tests using ADF and PP tests (Maddala and Wu, 1999; Choi, 2001; Hadri, 2000). Appendix 1 shows the results of panel unit root tests for four groups: the national panel, the east panel, the central panel and the west panel. The series of *FDI, SO2, Solid, Water, GRP* and *Road* are tested in their logarithms. Nelson and Plosser (1982) indicate that most macroeconomics series are non-stationary at level, but stationary at first difference. In our sample, unit root tests reflected this same pattern: most of the tests do not reject the null hypothesis of unit root at level, except for *ln*(*Road*), but all series become stationary after the first differencing. Since the economic meaning of the variables becomes growth rate after first differencing their logarithms, the following results and conclusions reflect changes in growth rate of variables.

Data

Our analysis is based on the annual data of each province in China for the period from 2005 to 2014. Hainan is removed due to the dramatic fluctuation of FDI inflow in that province during this period, since it unduly influences the results, especially in the regional panel. We thus have 30 provinces in the national panel and 10 provinces in each regional panel. Six variables (*FDI, SO2, Solid, Water, GRP, Road*) are included, among which *FDI*, *SO2, Solid and Water* are our core variables (see Table 2).

FDI is "total investment of foreign funded enterprises (USD million)." According to the National Bureau of Statistics of China, FDI is measured as direct investment by foreign entrepreneurs, which refers to "the investments inside China by foreign enterprises and economic organizations or individuals (including overseas Chinese, compatriots from Hong Kong and Macao, and Chinese enterprises registered abroad)" (China Statistical Year Book, 2014). At the province level, the bureau of statistics provides only data on the "total investment of foreign funded enterprises," so we use it as the measurement of FDI in this study, although the data may have some discrepancies with the actual direct investment by foreign entrepreneurs. In the national panel, the mean FDI inflow in province level during 2005 to 2014 was 84 273 million USD. To show the uneven distribution of FDI, we compare the mean FDI in each regional panel with that in the national panel: the east region had the highest mean FDI, at a value of 208 269 million USD, 147% larger than the national mean; in the central region, the mean FDI was 64% less than national level; in the west region, the mean FDI was 83% less than national level. We can directly see that most of the FDI flowed to provinces in the east coast in the past ten years, and only a small part flowed to provinces in the west: the mean FDI was over 14 times larger in the east than in the west.

Given that most FDI flow is to the industrial sector, and based on the availability of data, we employ three pollution indicators: SO_2 emission, solid waste and waste water as measurements of environmental pollution. Unlike the large variability of FDI inflow across regions, environmental pollution did not differ strongly. Regardless of which measurement index is used, the east coast is the most polluted region and the west is the least polluted.

SO2 is "total volume of sulfur dioxide emission (ton)," and reflects air quality, although it is just a part of the overall air pollution. Other pollutants, such as nitrogen oxide and smoke dust are also relevant. However, while the National Bureau of Statistics provided overall air pollution data before 2011, after that, only SO_2 emission data are provided. In China, the main sources of SO_2 are power plants and industrial sectors; residents contribute only a small amount of SO_2 emission from daily life (Lu et al., 2010). Air pollution was similar among regions, especially the east coast and central regions. The central region was the most air-polluted region in china: mean SO_2 emission was 10% larger than the national mean. In the east region, mean SO_2 emission was 8% larger than the national level. The west region experienced the least air pollution, with a mean SO_2 emission that was 19.12% less than the national level.

The environmental pollution index, *Solid*, measures "industrial solid waste (ten thousand tons)." It refers to solid wastes "produced and discharged at the places outside the special facilities or special sites for preventing against pollution" (National Bureau of Statistics of China). The distribution of solid waste was similar to the distribution of SO_2 emission: the east and the central regions generated most of the solid waste. The mean value in both regions was about 16% larger than the national level, while the mean value in the west was 40% less than in the east and central.

The final environmental pollution measurement we included is *Water*, indicating "total volume of waste water discharged (ten thousand tons)." Water pollution was decreasing from the east to the west region in China. In the east region, the mean value of wastewater was about 1.5 times larger than national level, while in the west region, the mean value was less than a half of the national level. Among all three environmental pollution indicators, water pollution was the only one that had the same distribution across regions as FDI.

Two control variables, *GRP* and *Road*, are also included in our analysis. *GRP* is "per capita gross regional product", which can reflect the economic growth, labor price and living standard of a region. Economic growth generally exerts a positive effect on FDI inflow, but FDI inflow does not promote economic growth (Carkovic and Levine, 2002, Zang, 2013). *Road* is an index we calculated to estimate the road infrastructure in different provinces, it reflects the convenience of transportation in a place. Expanding the network of roads can augment FDI inflow into a region (Castro et al. 2007). By adding the length of railway (km) and the length of road (km) together, and then dividing by the province area (km^2), we got the average road length per km^2.

Table 3 shows the contemporaneous correlations of the growth rate of the variables. The correlations between variables are small (between 0.24 to 0.06). Among our core variables, FDI are negatively correlated with SO2 and wastewater, but positively correlated with solid waste.

Table 2. Descriptive statistics

		FDI	SO2	Solid	Water	GRP	Road
National	Mean	84273	755042	7997	203101	32860	0.79
	Maximum	718131	2002000	45576	905082	105231	2.15
	Minimum	350	1660	5	2685	5052	0.04
	S.D.	128040	443971	7502	163444	20575	0.49
	Obs.	300	300	300	300	300	300
East	Mean	208269	816802	9296	322297	50865	1.15
	Maximum	718131	2002000	45576	905082	105231	2.15
	Minimum	21930	78906	1021	56928	14782	0.39
	S.D.	159963	522144	10169	198593	22205	0.40
	Obs.	100	100	100	100	100	100
Central	Mean	29988	837655	9295	196606	26335	0.75
	Maximum	77671	1624000	30520	422832	71046	1.53
	Minimum	7710	356310	2457	55102	8670	0.07
	S.D.	13159	392187	6180	90965	13053	0.41
	Obs.	100	100	100	100	100	100
West	Mean	14561	610670	5400	90399	21380	0.47
	Maximum	82752	1465000	17335	331277	47850	1.57
	Minimum	350	1660	5	2685	5052	0.04
	S.D.	18343	370227	4263	75790	10558	0.40
	Obs.	100	100	100	100	100	100

Data source: National Bureau of Statistics of China

Table 3. Contemporaneous correlations

	ΔlnFDI	ΔlnSO2	ΔlnSolid	ΔlnWater	ΔlnGRP	ΔlnRoad
ΔlnFDI	1					
ΔlnSO2	-0.02	1				
ΔlnSolid	0.14**	0.19***	1			
ΔlnWater	-0.17***	0.15**	0.05	1		
ΔlnGRP	0.14**	0.10*	0.24***	0.17***	1	
ΔlnRoad	0.15**	0.18***	0.03	-0.22***	0.06	1

Significance levels: *10%, **5%, ***1%.

Empirical results

Regression results: the impact of environmental pollution on FDI

We first consider whether past situations of environmental pollution have impacts on FDI inflow. In this model, FDI is treated as dependent variable; environmental pollution is treated as main explanatory variables that we are interested in; economic level *GRP* and road infrastructure *Road* are included as control variables. In the national panel, the model is specified as:

$$\Delta lnFDI_{it} = \beta_0 + \beta_1 \Delta lnFDI_{i,t-1} + \beta_2 \sum_{l=1}^{j} \Delta lnPollution_{i,t-l} + \beta_3 \sum_{l=1}^{j} \Delta lnGRP_{i,t-l}$$

$$+ \beta_4 \sum_{l=1}^{j} \Delta lnRoad_{i,t-l} + \eta_i + \delta_t + \varepsilon_{it} \qquad (1)$$

where the subscript $i = 1, 2,\ldots, n$ denotes province, $t = 1, 2,\ldots, m$ denotes year, $l = 1,\ldots, j$ is the time lag, we include no more than two lags in our model; β is the coefficient to estimate, η_i indicates the province-specific effect, δ_t indicates the time-specific effect, and ε_{it} is the error term. *Pollution* is the environmental pollution indicator, three variables: *SO2, Solid* and *Water* are employed as the pollution indicators. We use each pollution indicator respectively in our models[7]. It will be specified which indicator is used in the results table.

In the regional panels, *Road* is removed due to singular matrix. And the time lag of explanatory variables is 2, because including 1 lag in regional panels result in near singular matrix. The specific model is:

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[7] Near singular matrix occur in Eviews in regional panels if all pollution indicators are included in one model.

$$\Delta lnFDI_{it} = \beta_0 + \beta_1 \Delta lnFDI_{i,t-1} + \beta_2 \sum_{l=1}^{j} \Delta lnPollution_{i,t-l} + \beta_3 \sum_{l=1}^{j} \Delta lnGRP_{i,t-l} + \eta_i + \delta_t + \varepsilon_{it} \quad (2)$$

The regression results of Model 1 and 2 are showed in Table 4. Column (a), (b) and (c) indicate which variable is treated as the environmental pollution indicator in the equation. The results are presented in the national group, the east group, the central group and the west group. For each variable, the lag used is given parenthetically. Column (a) shows the impact of air pollution on FDI inflow. Significant results are observed only in the national panel. *SO2 (-2)* has a positive significant effect on *FDI*, Indicating that when SO_2 emission increase 1%, FDI inflow will increase by near 0.17% two years later. FDI inflow is also affected by economic level and road infrastructure. *GRP* and *Road* both exert negative effects on *FDI*, reflecting that FDI inflow will decrease after per capita GRP increase and road infrastructure expanding.

Column (b) reveals the influence of solid waste on FDI inflow. Significant effects of solid waste are observed not only in the national panel, but also in the central panel. In the national panel, *Solid(-1)* has a positive effect on *FDI.* A 1% increase of solid waste will lead FDI inflow rise 0.1% in the next year. However, in the central region, *FDI* is negatively affected by *Solid(-2)*, so if solid waste keep increasing, it will becomes a barrier to FDI inflow two years later. Besides solid waste, *GRP(-1)* and *Road(-2)* also have significant impacts on FDI inflow in the national panel, and the effects are negative, just same as in Column (a).

Unlike air pollution and solid waste pollution, water pollution shows no significant effect on FDI inflow in all groups (see Column (c)). Here FDI inflow is influenced by *GRP(-1)* and *Road(-2)* with negative effects.

Table 4. Regression results: Model 1 and 2

Dependent variable: FDI							
Pollution indicator		(a) SO2		(b) Solid		(c) Water	
		Coeff.	S. E.	Coeff.	S. E.	Coeff.	S. E.
Model 1.							
National							
FDI	(-1)	0.07***	0.02	0.05	0.02	0.01	0.05
Pollution	(-1)	0.01	0.09	0.10***	0.03	-0.01	0.13
	(-2)	0.17**	0.08	-0.02	0.03	0.04	0.09
GRP	(-1)	-0.36*	0.21	-0.73***	0.25	0.40	0.71
	(-2)	-0.52***	0.14	-0.31	0.20	-0.65***	0.18
Road	(-1)	-0.41	0.27	0.53	0.35	0.03	0.39
	(-2)	-0.14***	0.02	-0.14***	0.02	-0.15***	0.06
Prob. J		0.43		0.59		0.23	
Model 2.							
East							
FDI	(-1)	1.07	2.18	0.24	1.27	0.49	0.98
Pollution	(-2)	3.38	4.01	0.00	0.09	-0.01	0.27
GRP	(-2)	0.46	2.32	0.18	0.60	0.12	0.71
Prob. J		0.59		0.43		0.44	
Central							
FDI	(-1)	-0.60	0.62	-0.56***	0.10	-0.05	0.22
Pollution	(-2)	-1.00	1.67	-1.12**	0.49	0.71	1.35
GRP	(-2)	-2.45	3.75	0.54	1.46	-2.85	7.53
Prob. J		0.25		0.48		0.19	
West							
FDI	(-1)	-0.10	0.19	-0.06	0.25	-0.21	0.49
Pollution	(-2)	-1.82	2.89	0.96	1.63	0.54	0.75
GRP	(-2)	-1.34	3.25	-0.15	3.99	6.41	8.28
Prob. J		0.69		0.18		0.18	

Significance levels: *10%, **5%, ***1%

Regression results: the impact of FDI on environmental pollution

We next consider the possibility that past growth levels of FDI can influence environmental pollution. Here, the dependent variable is environmental pollution and the core explanatory variable is FDI inflow. Per capita GRP and road infrastructure are again used as control variables. As in the previous analysis, to ensure the existence of solutions, the time lag is not larger than second order. In the national panel, the model is given by:

$$\Delta lnPollution_{it} = \beta_0 + \beta_1 \Delta lnPollution_{i,t-1} + \beta_2 \sum_{l=1}^{j} \Delta lnFDI_{i,t-l} + \beta_3 \sum_{l=1}^{j} \Delta lnGRP_{i,t-l} + \beta_4 \sum_{l=1}^{j} \Delta lnRoad_{i,t-l} + \eta_i + \delta_t + \varepsilon_{it} \quad (3)$$

Again in the regional panels, *Road i*s removed and the time lag is adjusted. The model is specified as:

$$\Delta lnPollution_{it} = \beta_0 + \beta_1 \Delta lnPollution_{i,t-1} + \beta_2 \sum_{l=1}^{j} \Delta lnFDI_{i,t-l} + \beta_3 \sum_{l=1}^{j} \Delta lnGRP_{i,t-l} + \eta_i + \delta_t + \varepsilon_{it} \quad (4)$$

Table 5 shows the results of Model 3 to 4. Column (d) reveals the impact of FDI inflow on SO_2 emission. In the national panel, *FDI(-1)* positively affects *SO2*, indicating that SO_2 emission will increase by 0.07% two years later after FDI inflow increased by 1%. No significant influence of FDI inflow on environmental pollution is found in the regional panels. However, the control variable, *GRP(-2)*, negatively affects SO_2 emission in 10% significance level.

The growth rate of solid waste is affected by FDI inflow in the national and central panels. (see Column (e)). In the national panel, *FDI* exerts negative effect on *Solid* with one and two lags. The influence of *FDI(-1)* is greater with larger coefficient and lower significance level than *FDI(-2)*. According to the results, solid waste will reduce by 0.79% in the first year after FDI inflow increased by 1%, and the negative significant effect of FDI inflow will continue in the second year, when solid waste will decrease by 0.22%. In the central region, solid waste will also decrease by 0.22% two years after FDI inflow increased by 1%. Moreover, solid waste is negatively affected by per capita GRP. A faster growth rate of per capita GRP will result in the lower growth rate of solid waste after two years.

The last column (Column (f)) shows how waste water is influenced by FDI inflow. The significant effect of FDI inflow is observed in the west region, where the growth of FDI inflow increase by 1% can cause waste water decline by 0.11%. While in the national panel, what affects water pollution is *GRP(-2)*. The effect of per capita GRP is quite significant: a 1% increase in per capita GRP will lead waste water increase by 0.88% two years later.

Table 5. Regression results: Model 3 and 4

Dependent variable: Pollution							
Pollution indicator		(d) SO2		(e) Solid		(f) Water	
		Coeff.	S. E.	Coeff.	S. E.	Coeff.	S. E.
Model 3.							
National							
Pollution	(-1)	-0.31***	0.07	-0.09	0.10	-0.18	0.14
FDI	(-1)	-0.01	0.05	-0.79***	0.14	-0.04	0.07
	(-2)	0.07**	0.03	-0.22*	0.13	-0.01	0.03
GRP	(-1)	0.06	0.22	-0.49	0.77	-0.17	0.29
	(-2)	-0.23	0.17	-0.66	1.08	0.88***	0.29
Road	(-1)	-0.07	0.42	-0.55	1.71	0.14	0.42
	(-2)	0.00	0.02	-0.03	0.11	0.01	0.04
Prob. J		0.45		0.44		0.49	
Model 4.							
East							
Pollution	(-1)	0.65	0.90	-0.27	0.52	-0.33	0.28
FDI	(-2)	0.16	0.90	-0.48	1.45	0.22	0.22
GRP	(-2)	1.19	0.74	1.44	2.88	0.53	0.68
Prob. J		0.66		0.09		0.13	
Central							
Pollution	(-1)	-0.26**	0.12	0.09	0.15	-0.14***	0.05
FDI	(-2)	0.02	0.03	-0.22**	0.09	0.00	0.02
GRP	(-2)	-0.11*	0.06	-0.83***	0.21	0.12	0.22
Prob. J		0.23		0.59		0.39	
West							
Pollution	(-1)	-0.90	1.39	0.26	0.26	0.09	0.14
FDI	(-2)	-0.04	0.15	0.24	0.33	-0.11**	0.05
GRP	(-2)	1.32	2.13	-1.13	2.87	-0.19	0.78
Prob. J		0.45		0.27		0.67	

Significance levels: *10%, **5%, ***1%

Conclusions

The causal relationship between FDI inflow and environmental pollution is complicated in China, especially when we narrow the analysis down to individual economic region. Results differ among regions due to the various development levels and geographical conditions among them. Since we use stationary data and lagged variables to capture the causal relationship between the variables, the results provide unique insight from previous studies.

Table 6. Causal relationship between FDI and environmental pollutions

	FDI and SO2	FDI and Solid	FDI and Water
National	SO2 (-2) → FDI + FDI (-2) → SO2+	Solid (-1) → FDI + FDI (-1, -2) → Solid-	-
East	-	-	-
Central	-	Solid (-2) → FDI - FDI (-2) → Solid -	-
West	-	-	FDI (-2) → Water -

Causal relationship: from environmental pollution to FDI

Table 6 visually shows the causal relationship between FDI inflow and environmental pollution factors. In the national panel with all provinces included, the relationships between them are clear and significant. Our results show water pollution has no significant influence on FDI inflow. SO_2 emission and solid waste both exert positive effects on FDI inflow with one two lags. High levels of SO_2 emission and solid waste may reflect less-stringent environmental regulations. The results provide evidence supporting the pollution haven hypothesis that developing country get comparative advantages from low standard of environmental regulations, which is helpful for attracting FDI from developed countries (Peter 2001, Zhang and Fu 2008, Ferrara et al. 2015). However, we cannot conclude the overall air pollution does affect FDI inflow in the national panel, since the indexed SO_2 just accounts for a part of air pollution. If the data of overall air pollution is available, the result may be different.

In the regional panels, the impact of environmental pollution is significant only in the central region. But the effect of solid waste is opposite with that in the national panel, suggesting that FDI inflow will decrease due to worse environmental quality, so the pollution haven hypothesis is not supported in the central region.

Causal relationship: from FDI to environmental pollution

In the national panel, FDI inflow has significant influences on SO_2 emission and solid waste with one or two time lags. The difference is that the effect is positive on SO_2 emission but negative on solid waste. The effect of *FDI* on *SO2* implies that FDI inflow increases SO_2 emission. This suggests that both the scale effect and the composition effect may be mechanisms generating environmental effects of FDI (Grossman and Kruger, 1991). The composition effect of FDI may influence the environment in different ways according to the types of industries involved. If the industries with a competitive advantage are pollution-intensive, and lax environmental regulations are the main attraction for foreign investment, the increasing FDI inflow can result in worse environmental quality. The positive sign of *SO2* in our study reflects this negative composition effect. On the contrary, the negative effect of *Solid* suggests that solid waste decreases after the increasing inflow of FDI, providing possible evidence that the technique mechanism is occurring. If foreign firms bring in environmentally friendly advanced technologies, local industries and the environment will benefit. The composition mechanism is another possible explanation for this result. Unlike the possible negative composition effect *FDI* exerts on *SO2*, now FDI inflow results in better environmental quality. Moreover, the pollution halo hypothesis also explaining this positive effect since solid waste decreases after FDI inflow increased.

However, it is difficult to identify the actual environmental impacts of FDI inflow because it increases SO_2 emission while it reduces solid waste. This demonstrates the point made earlier that the relationship between FDI and environmental pollution can be opposite depending on the pollutant measured. In addition, it is challenging to analyze which mechanism's effect will dominate. Further studies can address this by differentiating the industries from which FDI comes.

In the regional panel, FDI affects solid waste in the central region and affects waste water in the west region. But it has no significant effects in the other two panels. The signs are negative in both regions, indicating that FDI may affect solid waste pollution in the central region and water pollution in the east region through mechanisms similar to those proposed for the effects on solid waste in the national panel.

If combined with the environmental impact of FDI, our results suggest that in the national panels, a bidirectional causal relationship between FDI inflow and SO_2 emission is present. The effects are positive for both directions. Beyond that, solid waste and FDI inflow are also bidirectionally related in the national panel and the central panel. However, when the influence of FDI inflow on solid waste is negative in both panels, the effects of solid waste show opposite signs in each panel. In the national panel, the growth of solid waste acts as an accelerator of FDI inflow, while in the central panel, the growth of solid waste slows down the increase of FDI inflow. The causality between FDI inflow and water pollution only exists in the west region, with an unidirectional causal effect from *FDI(-1)* to *Water*. No significant causal relationship is found between FDI inflow and environmental pollution indicators in the east region.

There are some limitations of our study. First, some robust tests are not provided in Eviews when panel data is used. Moreover, the data scope is limited since China National Bureau of Statistics changed the statistical standards during the past years, and some province level data was not presented before 2005. Further studies could be done if more specific data is available.

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Appendix 1.

Panel unit root tests: national

	Null: Unit root (assumes common unit root process)	Null: Unit root (assumes individual unit root process)		
Variables	**Levin, Lin and Chu (LLC)**	**Im, Pesaran and Shin W-stat (IPS)**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
Level				
lnFDI	-6.60575 (0.0000)***	-1.64088 (0.0504)**	104.737 (0.0003)***	194.656 (0.0000)***
lnSO2	-0.72922 (0.2329)	3.31943 (0.9995)	29.0060 (0.9998)	21.6085 (1.0000)
lnSolid	-9.31391 (0.0000)***	-0.86960 (0.1923)	66.2314 (0.2707)	128.133 (0.0000)***
lnWater	-3.67813 (0.0001) ***	2.52223 (0.9942)	43.7182 (0.9435)	32.0962 (0.9988)
lnGRP	-10.9350 (0.0000) ***	-1.65539 (0.0489) **	73.8051 (0.1085)	238.941 (0.0000)***
lnRoad	-26.3978 (0.0000) ***	-32.1895 (0.0000) ***	428.764 (0.0000)***	470.622 (0.0000)***
First difference				
ΔlnFDI	-11.5892 (0.0000) ***	-4.15401 (0.0000) ***	124.344 (0.0000)***	159.674 (0.0000)***
ΔlnSO2	-15.9308 (0.0000) ***	-6.42846 (0.0000) ***	157.385 (0.0000)***	206.456 (0.0000)***
ΔlnSolid	-12.0225 (0.0000) ***	-5.16909 (0.0000) ***	137.182 (0.0000)***	154.513 (0.0000)***
ΔlnWater	-17.5456 (0.0000) ***	-9.21624 (0.0000) ***	209.046 (0.0000)***	264.646 (0.0000)***
ΔlnGRP	-11.1399 (0.0000) ***	-2.55344 (0.0053) ***	89.2489 (0.0085)***	73.5563 (0.1122)
ΔlnRoad	-277.913 (0.0000) ***	-118.076 (0.0000) ***	421.191 (0.0000)***	539.382 (0.0000)***

Probabilities are in parentheses. Significance levels: * 10%, ** 5%, ***1%.

Panel unit root tests: east

	Null: Unit root (assumes common unit root process)	Null: Unit root (assumes individual unit root process)		
Variables	**Levin, Lin and Chu (LLC)**	**Im, Pesaran and Shin W-stat (IPS)**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
Level				
lnFDI	-3.98362 (0.0000)***	-0.03786 (0.4849)	24.0950 (0.2383)	48.2659 (0.0004)***
lnSO2	-0.23124 (0.4086)	2.69918 (0.9965)	5.53807 (0.9994)	9.09997 (0.9817)
lnSolid	-7.11620 (0.0000)***	-1.57663 (0.0574)*	31.9681 (0.0436)**	58.0907 (0.0000)***
lnWater	-2.89641 (0.0019)***	1.14113 (0.8731)	18.3616 (0.5636)	19.3364 (0.5001)
lnGRP	-7.87643 (0.0000)***	-1.80091 (0.0359)**	30.7830 (0.0581)*	102.092 (0.0000)***
lnRoad	-20.5677 (0.0000)***	-18.4285 (0.0000)***	165.736 (0.0000)***	163.565 (0.0000)***
First difference				
ΔlnFDI	-9.66781 (0.0000)***	-3.62954 (0.0001) ***	52.0387 (0.0001)***	45.3514 (0.0010)***
ΔlnSO2	-6.17950 (0.0000) ***	-2.53384 (0.0056) ***	41.1627 (0.0036)**	59.3140 (0.0000)***
ΔlnSolid	-7.19068 (0.0000) ***	-3.66435 (0.0001) ***	52.5282 (0.0001)***	69.6318 (0.0000)***
ΔlnWater	-10.1967 (0.0000) ***	-4.96416 (0.0000) ***	66.7526 (0.0000)***	78.7776 (0.0000)***
ΔlnGRP	-8.54706 (0.0000) ***	-2.01050 (0.0222) **	33.9858 (0.0262)**	26.7128 (0.1435)
ΔlnRoad	-105.072 (0.0000) ***	-55.2663 (0.0000) ***	146.908 (0.0000)***	171.474 (0.0000)***

Probabilities are in parentheses. Significance levels: * 10%, ** 5%, ***1%.

Panel unit root tests: central

	Null: Unit root (assumes common unit root process)	Null: Unit root (assumes individual unit root process)		
Variables	**Levin, Lin and Chu (LLC)**	**Im, Pesaran and Shin W-stat (IPS)**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
Level				
lnFDI	-4.20613 (0.0000) ***	-1.12410 (0.1305)	33.7688 (0.0277)**	76.3978 (0.0000)***
lnSO2	-0.62738 (0.2652)	1.40910 (0.9206)	14.0840 (0.8262)	4.80534 (0.9998)
lnSolid	-5.76809 (0.0000) ***	-0.79138 (0.2144)	23.0382 (0.2869)	52.2963 (0.0001)***
lnWater	-1.01381 (0.1553)	2.24112 (0.9875)	4.93062 (0.9998)	3.89303 (1.0000)
lnGRP	-6.99019 (0.0000) ***	-1.37937 (0.0839)*	30.7830 (0.0581)*	81.0689 (0.0000)***
lnRoad	-15.8645 (0.0000) ***	-23.9872 (0.0000)***	134.880 (0.0000)***	178.909 (0.0000)***
First difference				
ΔlnFDI	-6.07337 (0.0000) ***	-2.29238 (0.0109) **	39.8535 (0.0052)***	63.2111 (0.0000)***
ΔlnSO2	-9.92225 (0.0000) ***	-4.31454 (0.0000) ***	59.4322 (0.0000)***	78.6037 (0.0000)***
ΔlnSolid	-6.31215 (0.0000) ***	-2.30740 (0.0105) **	38.5304 (0.0076)***	33.3047 (0.0312)**
ΔlnWater	-7.32243 (0.0000) ***	-3.48528 (0.0002) ***	54.9680 (0.0000)***	84.6691 (0.0000)***
ΔlnGRP	-7.47151 (0.0000) ***	-0.58342 (0.2798)	28.7720 (0.0923)*	63.9054 (0.0000)***
ΔlnRoad	-281.785 (0.0000) ***	-107.207 (0.0000) ***	139.253 (0.0000)***	189.389 (0.0000)***

Probabilities are in parentheses. Significance levels: * 10%, ** 5%, ***1%.

Panel unit root tests: west

	Null: Unit root (assumes common unit root process)	Null: Unit root (assumes individual unit root process)		
Variables	**Levin, Lin and Chu (LLC)**	**Im, Pesaran and Shin W-stat (IPS)**	**ADF - Fisher Chi-square**	**PP - Fisher Chi-square**
Level				
lnFDI	-4.31239 (0.0000) ***	-1.63199 (0.0513)	46.8731 (0.0006)***	69.9922 (0.0000)***
lnSO2	-0.68769 (0.2458)	1.65273 (0.9508)	9.38393 (0.9780)	7.70323 (0.9937)
lnSolid	-3.14021 (0.0008) ***	0.85742 (0.8044)	11.2250 (0.9402)	17.7461 (0.6041)
lnWater	-2.32271 (0.0101)**	1.01493 (0.8449)	20.4260 (0.4316)	8.86676 (0.9844)
lnGRP	-4.31108 (0.0000) ***	0.31305 (0.6229)	15.4323 (0.7512)	55.7798 (0.0000)***
lnRoad	-13.6126 (0.0000) ***	-13.2620 (0.0000) ***	128.148 (0.0000)***	128.148 (0.0000)***
First difference				
ΔlnFDI	-4.13116 (0.0000) ***	-1.25902 (0.1040)	32.4522 (0.0387)**	51.1119 (0.0002)***
ΔlnSO2	-11.2509 (0.0000) ***	-4.31268 (0.0000) ***	56.7905 (0.0000)***	68.5379 (0.0000)***
ΔlnSolid	-7.63957 (0.0000) ***	-2.98998 (0.0014) ***	46.1234 (0.0008)***	51.5770 (0.0001)***
ΔlnWater	-7.32243 (0.0000) ***	-3.48528 (0.0002) ***	54.9680 (0.0000)***	84.6691 (0.0000)***
ΔlnGΔlnP	-7.22630 (0.0000) ***	-2.20303 (0.0138)	37.2582 (0.0109)**	30.6061 (0.0606)*
ΔlnRoad	-69.0942 (0.0000) ***	-41.9058 (0.0000) ***	135.030 (0.0000)***	178.519 (0.0000)***

Probabilities are in parentheses. Significance levels: * 10%, ** 5%, ***1%.