Proceedings of the 2nd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/15/20230953

The Impact of Foreign Direct Investment and Urban Economic Efficiency on Environmental Pollution: Evidence from China

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Abstract: Foreign direct investment may increase industrial pollution intensity in the host country, which will deteriorate the host country's environmental conditions; however, foreign direct investment may also enhance the economic efficiency of the host country through competitive effects, imitation effects, talent flows, and the related effects and in other ways. An improvement in economic efficiency indirectly affects the host country's environment. This article first analyzes the relationships among foreign direct investment, urban economic efficiency and environmental pollution while expanding on the relevant theories. In addition, the study constructs a comprehensive environmental pollution index for 271 Chinese cities by using the entropy method with the cities' panel data. The study also provides empirical testing of the connections among foreign direct investment, urban economic efficiency and pollution problems. The study finds that foreign direct investment has improved the economic efficiency of Chinese cities, the improvement in China's urban economic efficiency is accompanied by the discharge of pollutants, which has aggravated environmental pollution. Also, there are significant regional differences in how the foreign direct investment has shaped China's environment.

Keywords: foreign direct investment, urban economic efficiency, pollution effect, Spatial Durbin Model

1. Introduction

Since the economic reform and more open foreign policy were adopted 40 years ago, China has attracted steadily increasing foreign direct investment (FDI). According to data released by the United Nations Trade and Development Organization, FDI flowing into China in 2017 reached $144 billion. FDI has not only brought the capital needed for economic development in China but also has helped to improve the technological level of China through technological spillover effects, which has led to the upgrading of domestic industries. However, as a developing country, China's environmental supervision mechanism is still not perfect, which may cause other countries to transfer their polluting industries to China when they invest in China, which will bring about environmental degradation.

According to the data published in the 2017 China Ecological Environment Bulletin, among 338 cities that are prefecture-level and above, 239 (70.7%) have exceeded the standard air quality requirements. However, environmental protection usually entails sacrificing the economic growth rate.

Therefore, finding a way to preserve the environment while maintaining current levels of economic development is an important issue that China is facing.

Many studies are conducted on the environmental effects of FDI and how FDI has altered economic efficiency of host countries. According to most studies, host countries may become "pollution sanctuaries" for multinational companies, or they may benefit from clean production methods that are used due to FDI. In most time, environmental regulation could lead to a decline in the amount of FDI, while FDI inflows may result in a worse domestic environment [1,2,3]. FDI also promotes economic and productive efficiency of the host city [4,5,6]. Nevertheless, research rarely includes FDI, urban economic efficiency, and environmental pollution in the same analytical framework. Moreover, in the research process, most scholars operate on the assumption that regional variables are mutually independent, while ignoring trans-regional environmental pollution and the interactions of variables across different regions.

Based on the research results discussed above, this paper first constructs a theoretical framework to analyze how FDI is relevant to the urban environment. This study not only analyzes the direct impact of FDI on the environment but also proposes hypotheses and analyzes what FDI can indirectly bring to the host country environment by changing the economic efficiency of cities. Then, the interactions among FDI, urban economic efficiency, and environmental quality are studied by using a spatial panel data model. This analysis is an important contribution to the existing literature.

The paper is organized as the followings. Section 2 discusses key propositions of the study, together with the empirical models. Section 3 shows the results of models. Section 4 is the conclusion of this paper.

2. Methodology

2.1. Key Propositions

FDI is a combination of external capital, advanced technology, and management experience. When accomplishing the goals of the urbanization, upgrading domestic industrial structure, and increasing economic efficiency of the host country, FDI is a beneficial source of funds to the host country [7,8]. More importantly, it is a great channel for technological spillovers [9]. FDI has alleviated the lack of domestic capital accumulation in China and has had a positive impact by boosting employment and expanding exports. However, it should be noted that FDI may have a threshold effect on economic efficiency. The technology spillover effect of FDI is only effective when the host country has sufficient absorptive capacity [10]. If the host country lacks capacity, then domestic enterprises will be locked in a low-end value chain status, which will reduce the economic efficiency of the host country and enhance the country's dependence on foreign-funded enterprises [10]. This article draws on prior studies and proposes the following propositions.

Proposition 1: FDI indirectly affects environmental quality by affecting urban economic efficiency. When a host country has adequate absorptive capacity, FDI improves the economic efficiency of that country through economies of scale, industrial structure effects and technology spillover effects.

Scholars hold various view on how the FDI may affect environmental pollution. That some countries, especially developed ones, sacrifice competitiveness for meeting strict environmental regulations, while some other countries must reduce their environmental regulations to maintain their competitive position in trade and to obtain foreign investment. Many studies have confirmed such "pollution haven effect" [11,12]. Zeng and Eastin analyzed Chinese provincial panel data to confirm that the inflow of foreign capital can improve the environment through technological advancement, so that there exhibits a positive spillover effect on the environment [12]. Based on the above theoretical analysis and the results of prior studies, this paper proposes the next proposition.

Proposition 2: In the process of international capital transfer, the simultaneous movement of polluting industries may bring about a decline in the quality of environment in the host country; however, meanwhile, foreign-funded enterprises may also increase the environmental standards of the production methods, which improve the quality of environment in the host country. The impact of FDI on environmental pollution may be ambiguous, which could either be positive or negative.

New technologies can increase productivity, but they also cause potential harm to society. In the initial stage of the use of new technologies, the externalities of pollution caused by these new technologies have not yet been discovered. From this point of view, if an increase in economic efficiency is accompanied by an excessive discharge of pollutants, then the faster economic efficiency is improved, the more obvious the decline in environmental quality is. Due to these viewpoints, this paper proposes the third proposition.

Proposition 3: Economic efficiency has an uncertain effect on environmental quality. Economic efficiency has both a pollution increasing effect and a pollution reducing effect. If the pollution increasing effect is greater than the pollution reducing effect, then economic efficiency will increase pollution emissions. Conversely, economic efficiency will reduce pollution emissions. The following sections of this paper describe the empirical tests conducted on the above three propositions.

2.2. Empirical Models

Spatial Panel Measurement Model

To fully consider cross-regional environmental pollution, a spatial panel measurement model is conducted for this study. There are three types of commonly used spatial measurement models. They are the Spatial Lag Model (SLM), the Spatial Error Model (SEM) and the Spatial Durbin Model (SDM), which are closely connected with each other [13]. The SLM tests if there presents a spillover effect spatially on each variable included in the model; the SEM measures how the random error terms of the observations in neighboring regions influence on the observed values of a region; and the SDM considers the spatial autocorrelation of the dependent variable, as well as the spatial autocorrelation of the independent variables. In addition to considering the three situations mentioned above, this paper constructs the spatial model for FDI and the impact of urban economic efficiency on environmental pollution as:

$$\begin{cases} Y_{it}=\rho w_i^{'}Y_t+X_{it}^{'}\beta+w_i^{'}X_t\delta+u_{it} \\ \text{where} \quad u_{it}=\lambda w_i^{'}u_t+\varepsilon_{it} \end{cases} \tag{1}$$

In equation 1, i and j are different cities, Y_t is the dependent variable of the model, $w_i^{'}$ is the i-th row of the N-by-N matrix of the spatial weights, $X_{it}^{'}$ is a vector of explanatory variables, ρ, δ, and λ are the corresponding coefficients of the variables of interest.

When $\rho \neq 0$ and $\lambda = \delta = 0$, (1) is becomes a spatial autoregressive model (SAR)

$$Y_{it}=\rho w_i^{'}Y_t+X_{it}^{'}\beta+u_{it} \tag{2}$$

When $\lambda \neq 0$ and $\rho = \delta = 0$, (1) is transformed into an SEM:

$$Y_{it}=X_{it}^{'}\beta+u_{it} \tag{3}$$

and u_{it} stays the same as that in equation (1).

When $\rho \neq 0$, $\delta \neq 0$, and $\lambda = 0$, equation (1) is transformed into an SDM:

DOI: 10.54254/2754-1169/15/20230953

$$Y_{it}=\rho w_i' Y_t+X_{it}'\beta+w_i' X_t\delta+\varepsilon_{it} \tag{4}$$

A likelihood ratio (LR) test and a Wald test are conducted to judge the effectiveness of the model. Following Elhorst's study, this study conducts both the Lagrange Multiplier test (LM test) and the robust LM test on the dependent variable and residuals without considering any spatial correlation [14]. The SDM is chosen as the optimal model.

For the spatial model, spatial autocorrelation of the variables is tested. If the spatial autocorrelation does not exhibit, the standard measurement method can be implemented. This paper assumes that the spatial effect is dependent on the geographical distance between cities. Therefore, a weight matrix based on such assumption is created as follows:

$$w_{ij}=\begin{cases}0, & when\ d_{ij}\leq d\\ 1, & when\ d_{ij}>d\end{cases} \tag{5}$$

where d_{ij} is the geographical distance between two cities i and j, and d represents the critical value. A spatial weight matrix is constructed using 200 km, 300 km and 500 km as the critical values, and the regression results are compared to ensure the robustness and reliability of the results. In addition, some cities are excluded from the analysis for which the indicators are missing, and those that are considered to be "islands". That is, the distance to any city is higher than the critical value, which makes it impossible to standardize the spatial weight matrix and unable to implement the spatial measurement models. Therefore, this paper assumes the following: the value of an "island" city and its nearest city is 1, which means that the distance is beyond the critical value.

2.2.1. Environmental Pollution Index (EPI)

The data on environmental pollution retrieved from the China Urban Statistical Yearbook and the China Statistical Yearbook between 2008 and 2015. Environmental pollution index (EPI) is constructed using the entropy weight method, which can maximize Chinese cities' extant environment pollution situation generally. Since only three indicators are available in the China Urban Statistical Yearbook, this paper only constructs the comprehensive evaluation index using them.

The comprehensive assessment index of EPI is computed using the entropy method. Fir the raw data for each j^{th} environmental pollution indicator in city i is standardized using its maximum and minimum value. Then, normalized the data and calculate the proportion of the j^{th} environmental pollution indicator for each city. Next, the entropy for each indicator is computed. Finally, the comprehensive EPI is computed as the weighted average of these pollution indicators.

2.2.2. Production Function

Production function is implemented for calculating the urban economic efficiency (UEE), which refers to a city's use of production factors to achieve economic growth. The urban economic production function is as shown in (6):

$$GDP_{it}=UEE_{it}K_{it}^{\alpha}L_{it}^{\beta} \tag{6}$$

GDP_{it} is China's GDP for year t and city i. Then, the GDP index based on 2008 is deflated; L_{it} represents the number of workers by the end of the year in each city. K_{it} is the capital stock of each city. The measurement method adopts the perpetual inventory method and then adjusts the fixed asset investment price index based on 2008 values.

By taking the natural logarithm of (6), the production function is shown as

$$ln\ GDP_{it} = ln\ UEE_{it} + \alpha\ ln\ K_{it} + \beta\ ln\ L_{it} \tag{7}$$

where the coefficients α and β are obtained by the regression of the above equation. Then, the economic efficiency of the city is obtained through (8):

$$ln\ UEE_{it} = lnGDP_{it} - \alpha\ ln\ K_{it} - \beta\ ln\ L_{it} \tag{8}$$

This paper measures FDI by the amount of foreign capital actually used by cities in China. FDI affects the economic efficiency of the host country through competitive effects, imitation effects, talent flows, and the related effects. However, there is also a possibility that FDI causes polluting enterprises to move to the host country; whether or not this occurs depends on the absorptive capacity and environmental regulation measures of the host country.

To support the empirical analysis, population density (PD, which is the number of people living within a square kilometer), GDP per capita (PCG), industrial structure (IS which is the proportion of tertiary industry to total GDP), and R&D investment (RDI) are used as key control variables.

3. Results

3.1. Test of Spatial Autocorrelation

Moran's I is used as the criterion for testing spatial autocorrelation. It is the correlation between an observed value and its spatial lag, which is ranged between -1 and 1.

Table 1: Spatial autocorrelation between 2008 and 2015.

Moran's I	2008	2009	2010	2011
	0.163^{***}	0.166^{***}	0.207^{***}	0.166
	(5.792)	(5.945)	(7.365)	(1.160)
EPI	**2012**	**2013**	**2014**	**2015**
	0.019^{***}	0.052^{***}	0.196^{***}	0.060^{***}
	(3.014)	(4.633)	(6.951)	(2.722)
	2008	**2009**	**2010**	**2011**
	0.292***	0.276^{***}	0.263^{***}	0.234^{***}
	(10.057)	(9.533)	(9.067)	(8.104)
UEE	**2012**	**2013**	**2014**	**2015**
	0.236^{***}	0.227^{***}	0.256^{***}	0.283^{***}
	(8.169)	(7.845)	(8.831)	(9.759)

Notes: The parentheses below the Moran's I are z values; *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

The results in Table 1 shows that Moran's I is positive for each year. Apart from that of EPI in 2011, all the rest of the coefficients are statistically significant at 1% level, which indicates that there is a significant positive correlation between the environmental pollution index of cities in China and the economic efficiency of these cities.

3.2. Impact of FDI on Urban Economic Efficiency

Using panel data of 271 cities in China from 2008 to 2015, the results of the impact of FDI on UEE are shown in Table 2. Results from the general panel data fixed effects model (Model 1), the SAR model (Model 2) and the SEM model (Model 3) are reported for testing the robustness of the SDM model and the corresponding explanatory variables.

DOI: 10.54254/2754-1169/15/20230953

Table 2: Impact of FDI on urban economic efficiency.

TFP	Model 1 (General Panel)	Model 2 (SAR)	Model (3) (SEM)	Model (4) (SDM)
FDI	0.004***	0.005***	0.004***	0.004***
	(7.08)	(7.43)	(6.88)	(6.83)
RDI	0.020***	0.020***	0.020***	0.020***
	(22.63)	(22.62)	(22.60)	(21.92)
PCG	0.026***	0.026***	0.026***	0.028***
	(14.73)	(14.74)	(14.73)	(14.69)
IS	0.010***	0.009***	0.010***	0.011***
	(3.44)	(3.23)	(3.45)	(3.77)
WFDI		-0.005***		
		(-3.18)		
ρ		0.151**	0.012	
		(2.42)	(0.26)	
λ				0.374***
				(5.99)
Log-likelihood		4270.947	4265.9479	4281.8563
F-Statistics	84.55			
Obs	2168	2168	2168	2168

Notes: significance level are shown as * 0.1, **0.05, and ***0.01, respectively. t-statistics are reported in parentheses.

Table 2 shows that regardless of whether the general panel data fixed effects model or the spatial measurement model is used, FDI has a positive economic efficiency coefficient for the cities, and the range of the variations is not large. The results show that FDI is an important part of China's urban economic development. In addition, the empirical results are very stable. For the control variables for R&D investment, per capita GDP, and industrial structure, the coefficients are all floating and are approximately 0.020, 14.74, and 0.010, respectively, with a small range of variations. As shown in the results that the coefficients on R&D investment, per capita GDP, and the industrial structure are all positive and statistically significant at the 1% level, implying that these factors positively influence the urban economic efficiency in the region.

The SDM also contains the spatial lag term of the FDI (WFDI). The change in the explanatory variable of a certain city not only affects the interpreted variable of the region but also affects the interpreted variable of other regions.

3.3. The Impact of FDI and Urban Economic Efficiency on Environmental Pollution

To verify Propositions 2 and 3, the global index of pollution of the environment serves as a dependent variable; FDI and urban economic efficiency are the independent variables; and PD, PCG and IS are included as additional control variables. Lagged terms are also considered in the models. LM tests shows the necessity of containing elements of spatial interaction in the model. In addition, the model passed the LR test and the Wald test, which indicates that the SDM cannot be transformed into either SLM or SEM; therefore, the SDM is the optimal model for this analysis.

Table 3: Impact of FDI and urban economic efficiency on environmental pollution.

TFP	Model 5 (General Panel)	Model 6 (SDM)	Model 7 (SDM)	Model 8 (SDM)
FDI	0.054***	0.077***	0.081***	0.052***
	(4.09)	(6.06)	(6.62)	(4.04)
UEE	9.602***	10.999***	9.264***	9.827***
	(20.83)	(25.03)	(21.62)	(22.32)
PD	-0.143***	-0.046**	-0.046**	-0.089***
	(-6.53)	(-1.90)	(-1.89)	(-3.64)
PCG	-0.149***	-0.320***	-0.199***	-0.261***
	(-3.59)	(-7.62)	(-4.96)	(-6.21)
IS	-0.456***	-0.637***	-0.529***	-0.608***
	(-7.35)	(-10.73)	(-9.24)	(-9.74)
WFDI		-0.030	-0.071**	0.008
		(-1.33)	(-2.45)	(0.20)
WUEE		-9.319***	-5.371***	-4.021*
		(-10.82)	(-4.95)	(-1.86)
WPD		-0.047	-0.084*	-0.102*
		(-1.34)	(-1.91)	(-1.65)
WPCG		0.415***	0.023	0.133
		(5.07)	(0.24)	(0.89)
WIS		0.685***	0.307**	0.933***
		(5.73)	(2.20)	(3.87)
ρ		0.436***	0.668***	0.674***
		(15.86)	(25.22)	(15.45)
Log-likelihood		-2242.803	-2184.237	-2316.322
Obs	2168	2168	2168	2168

Notes: significance level are shown as * 0.1, **0.05, and ***0.01, respectively. t-statistics are reported in parentheses.

This study assumes that the spatial influence depends on the geographical distance between different cities; to test the robustness of the SDM model, this study uses 200 km (Model 6), 300 km (Model 7) and 500 km (Model 8) as the critical values to establish the spatial weight matrix, perform the spatial measurement analysis, and compare the coefficients of the general panel data model (Model 5). The regression results are presented in Table 3. According to both the normal panel data model and the SDM model, the regression coefficients of FDI and urban environment pollution as a product of the economic efficiency have a significantly positive relationship. This indicates that FDI has made the urban environmental pollution index with an observable increase, which confirms that the hypothesis of a polluting heaven exists in China. This result may have occurred because the improvement in China's economic efficiency is accompanied by production of pollutant in a large number into the environment, which is related to the development mode of China's high input, high consumption and rapid expansion in recent years.

In contrast, PD, PCG and IS have negative impacts on pollution, which is not in line with the expectations. This result may have occurred because in regions with high population density, urban economic development is also high. Consequently, the development of tertiary industry is relatively complete, and the demographic dividend would be high, which all have significant impacts on improving the environment. Overall, as the spatial weight matrix's critical value increases from 200 km to 300 km and then to 500 km, the signs of the coefficients do not change; the only differences are in the numerical values. The results of this thesis are robust and reliable.

DOI: 10.54254/2754-1169/15/20230953

3.4. Regional Differences in the Impact of FDI on Environmental Pollution

To further study the impact of FDI on environmental pollution in the different regions of China, this study divides Chinese cities into three regions, Eastern, Central and Western. For this analysis, Eastern region includes 101 cities, Central region has 100 cities, and Western region has 70 cities. The regression output is reported in Table 4.

As presented in the table, there is a significant positive impact of FDI on EPI in the Eastern and Western cities, while the impact in the Central region is significantly negative, indicating imbalanced impact of FDI onto the environmental pollution in various regions in China. This result may have occurred because the central cities have not only acquired capital, technology and management experience but also obtained production methods which conform to international environmental standards. by attracting foreign capital, which has improved the quality of its own environment. The economic efficiency coefficients for all three regions have a significantly positive relationship, and this illustrates the enhanced economic efficiency results in more environmental pollution. The reason for this result is that China's overall economic development environment has been dominated by resource consumption in recent years. These economic activities have increased the amount of wastewater, waste gas and other by-products that cause environmental degradation, which also paved the way for China's environmental regulation measures. The signs for the coefficients of PD, PCG and IS are all significantly negative, indicating that these have led to a decline in environmental pollution.

Table 4: SDM regression results for various regions in China.

TFP	Model 9 (Eastern)	Model 10 (Central)	Model 11 (Western)
FDI	0.119^{***}	-0.049^{**}	0.102^{***}
	(5.150)	(-2.260)	(4.480)
UEE	11.605^{***}	7.899^{***}	11.700^{***}
	(18.370)	(11.450)	(10.890)
PD	-0.340^{***}	-0.068	-0.041
	(-7.060)	(-1.380)	(-1.050)
PCG	-0.485^{***}	0.058	-0.285^{***}
	(-7.620)	(0.970)	(-3.060)
IS	-0.393^{***}	-0.429^{***}	-0.532^{***}
	(-4.990)	(-5.010)	(-3.120)
WFDI	-0.112^{**}	-0.156^{***}	-0.135^{***}
	(-2.550)	(-3.740)	(-3.440)
WUEE	-1.703	-8.343^{***}	-0.140
	(-1.200)	(-7.660)	(-0.070)
WPD	-0.078	0.285^{***}	-0.195^{***}
	(-0.830)	(4.030)	(-3.900)
WPCG	0.213	0.536^{***}	0.110
	(1.380)	(4.790)	(0.750)
WIS	0.338^{**}	0.574^{***}	0.435^{**}
	(2.200)	(2.980)	(1.970)
ρ	0.712^{***}	0.404^{***}	0.151^{***}
	(24.060)	(9.280)	(3.140)
Log-likelihood	-720.781	-716.800	-597.262
Obs	808	800	560

Notes: significance level are shown as * 0.1, **0.05, and ***0.01, respectively. t-statistics are reported in parentheses.

4. Conclusions

This article uses panel data of 271 cities in China from 2008 to 2015 and the SDM to investigate the relationships among FDI, urban economic efficiency and environmental pollution. The findings show that, first, FDI increases urban economic efficiency. Second, the impact of FDI on China's urban environment is dominated by the "pollution haven effect". While FDI in the central region has led to a reduction in environmental pollution, FDI in the other regions has increased the pollution levels of Chinese cities. Third, to a certain extent, urban economic efficiency in China has improved at the expense of environmental degradation, leading to an increase in environmental pollution. The above conclusions have the following policy implications.

China needs to implement a positive environmental control policy to change the direction of technological progress and embark on the path of green development. On one hand, China should learn from the experience of other developed countries and strengthen restrictions on polluting economic activities, stimulate enterprises to carry out pollution control and production technology innovation, and achieve the dual goals of pollution control and increased production efficiency. On the other hand, the implementation of environmental control measures should be based on the actual situation in China; the government should develop flexible and diverse environmental regulation policies and appropriate environmental regulation intensity that address the regional heterogeneity of pollution in China. The government can make use of sewage charges, tradable pollution permits, environmental taxes and other means to provide enterprises with a certain flexible space.

China needs to actively promote the facilitation of FDI. FDI not only alleviates the capital shortage, which affects Chinese economic development, but also introduces technology spillovers, which can improve Chinese technological innovation capability. Therefore, we should continue to promote the convenience of foreign investment, give full play to the competitive effects and demonstration effects of foreign-funded enterprises, expand the opening up process, formulate preferential policies for attracting investment, improve the efficiency of administrative examination and approval, enhance the attractiveness of foreign-funded enterprises, and promote regional innovation capabilities through FDI. However, it should be noted that foreign technology spillover effects have a threshold effect. FDI can help improve economic efficiency only after the absorption capacity has reached a certain level. Therefore, while actively facilitating investment, R&D investment should be increased, guiding enterprises to independently develop innovation, and give foreign-funded enterprises the freedom they need to promote technological progress.

While promoting the convenience of foreign investment, China must also pay attention to the impact of foreign-funded enterprises on the Chinese ecological environment. The empirical results show that reasonable approvals and policy guidance can be used to realize the dual goal of achieving foreign investment and improving environmental quality. Therefore, various types of policy orientation and support should consider the environmental pollution situation as well as the level economic development in each region. Government departments and enterprises at all levels must selectively and specifically attract high-quality and highly efficient foreign investment. In addition, government departments and enterprises at all levels need to guide foreign investment to gradually expand from general processing to R&D, high-end design and high value-added manufacturing. Special emphasis should be placed on the reasonable guidance and supervision of foreign-funded enterprises, the elimination of or the greatest possible reduction in preferential treatment for polluting enterprises, and the introduction of technologies that are conducive to cleaner production processes and energy conservation.

For further studies, researchers can conduct a decomposition analysis of direct and indirect effects, and compare various regions in China. Under different economic development levels and industrial structures, environmental pollution presents regional heterogeneity. Therefore, further analysis of the regional differences in environmental pollution in China is needed.

DOI: 10.54254/2754-1169/15/20230953

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