



An empirical model on the impact of foreign direct investment on China's environmental pollution: analysis based on simultaneous equations

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Abstract

This paper analyses the link between foreign direct investment (FDI) and economic growth and their subsequent impact on environmental pollution in China. The simultaneous equation method was used with data from 31 provinces in China covering the period between 1995 and 2016. The findings indicate that the effect of FDI on economic growth, industrial structure, and environmental pollution control positively impacts on China's industrial pollution control and environmental conditions, implying that China should encourage foreign capital investments that come with advanced production technology and green production processes. This will enhance efficient resource utilization, adherence to environmental standards, and ensuring sustainable economic development.

Keywords Foreign direct investment · Environmental pollution · Simultaneous equations · Sustainable development · Economic growth

Introduction

China over three decades has increasingly attracted more and more foreign direct investment (FDI) because of its economic explosion and emerging market prospects. According to the Chinese Ministry of Commerce, the economy had recorded a steady growth resulting from sound structures and further opening up leading to a 877.56 billion yuan (\$136.33 billion) FDI in 2017 (MOC 2018). That is a 7.9% year-on-year rise in FDI ranking second in the world after USA (WIR 2018). China in recent times is considered the fastest and promising emerging country in the world. This progression however comes with a huge cost to the environment. China's environment has been gradually degraded as it continuous to open up

its economy to foreign investment. Environmental challenges affect the daily activities of the citizenry and for that every aspect of their well-being particularly in urban and productive areas. Reports from IEA (2011) indicates that public health in China is affected as a result of emission of greenhouse gases (GHGs) from fossil fuels which is relied on to propel economic growth. Currently, the Chinese atmospheric environment is contaminated with unwholesome airborne fine particulate emitted by coal burning. This results into about three eighths of the Chinese populace inhaling polluted causing cardiovascular diseases, asthma, strokes, and lung cancer (Rohde and Muller 2015). China has a yearly record of approximately 1.6 million deaths associated with outdoor air pollution (Rohde and Muller 2015). Reports indicate that the continuous disposal of chemical waste into drinking water sources has rendered the quality of water largely not good for consumption (Albert 2016; CHO 2018; Zmarak 2006; Tingting 2017). The repercussion is that about half of China's population does not have access to potable water whereas two thirds of rural China relies on stained water (Gibson 2018). The question therefore arises whether FDI inflow is a cause of deterioration in China's environmental quality?

Most of the recent literature point towards empirical analysis of the relationship between FDI inflow and environmental

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quality. In line with this, many researchers have focused on empirical testing of the so-called pollution haven hypothesis (Baek and Choi 2017; Baghebo and Apere 2014; Zheng and Sheng 2017). The findings from these researchers indicate that the pollution haven hypothesis attempts to explain how intensive industrialization is moving from developed countries. This movement is characterized by global environmental awareness and the need for a cleaner environment and higher tax imposition in developed countries to countries with less environmental standards. That is, there is going to be a transition of economic activities and for that matter pollution-intensive capital flow from developed to developing countries with lower environmental standards so as to avoid high environmental governance costs. This means that pollution-intensive industries in developed countries may shift to developing countries and FDI inflows will worsen developing countries (Hu et al. 2018).

Closely related to the pollution haven hypothesis is the “race to the bottom hypothesis” (Asghari 2012; Polat 2017). Accordingly, this hypothesis was initially implemented to encourage competition for investments within countries. However, this phenomenon was translated into the international arena where countries competed for the flow of FDI into their respective countries. A continuous demand for FDI inflows might lead to the countries reducing their environmental standards and regulations (Asghari 2012). This hypothesis seems to be characteristic of developing countries since they might be willing to sacrifice environmental standards to attract more FDI inflows for the purposes of economic growth (Elliott and Zhou 2013). Although these hypotheses seem reasonable, there are few empirical analyses that provide strong evidence (Bayraktar-Sağlam and Sayek Böke 2017; Sarmidi et al. 2015). However, some researchers prove the existence of race to the bottom hypothesis (Olney 2013; van der Kamp et al. 2017). Interestingly, with the advancement of technology, it can be argued that even if it can be proved that relaxed environmental regulations have caused pollution-intensive FDI to flow to developing countries, this does not mean that pollution in the host country will increase. Some researchers like Gao and Zhang (2013) and Yuan et al. (2013) indicate that developing countries that rely on pollution-intensive FDI companies generally use more environmentally friendly production techniques and pollution treatment technologies than local companies.

Contrary to the race to the bottom hypothesis is the race to the top hypothesis (Dong et al. 2012). This is a hypothesis which implies that globalization has strengthened competition between governments’ public expenditure on development either domestically or internationally. Invariably, the standards of the environment will be set high (Wasseem 2017). A study on China’s polluting industries found that FDI has a clear tendency to spread pollution, and the negative impact on China’s ecological

environment cannot be ignored (Wang et al. 2018). However, Deng and Xu (2015) believes that, as a whole, foreign direct investment does not show a tendency to transfer polluting industries to China on a large scale. The “cleanliness” of attracting foreign investment in developed regions of China is higher than in areas where the domestic economy is underdeveloped. Undoubtedly, FDI inflow to polluting industries has contributed to pollution of the environment year by year; however, the pollution rate has declined in the past 2 years, and there is a convergence trend (Hu et al. 2018).

Some researchers have studied on the impact of FDI inflows on China’s environmental pollution. Liu et al. (2018) analyzed the spatial agglomeration effects and dynamics at work in FDI and environmental pollution in China and concluded that FDI inflows led to diverse effects on different environmental pollutants; however, from a geographic perspective, increased FDI inflows do not really result in higher environmental pollution. A research by Kirkulak et al. (2011) indicates that there is no significant relationship between FDI and atmospheric pollutant emissions; therefore, FDI inflows do not negatively impact on China’s environment. The analytical findings of Yang and Wang (2016) revealed that there is a causal link between FDI and the Chinese environment. Yan and An (2017) made known the fact that there is a negative impact of FDI inflows on China’s environment and also find out why certain patterns between FDI and environmental pollution exists. They indicated that FDI and sulfur dioxide exhibits inverted U-shaped patterns and FDI and PM10 emission exhibits N-shaped pattern.

On the other hand, some researchers have considered how FDI inflows could impact other economic variables. This makes the relationship between FDI and environmental pollution become quite complex. They reviewed FDI effect on the environment as a result of economic output expansion (scale effect), reconfiguration of production and consumption between sectors (composition or structural effects), and changes of the production methods associated to the development and diffusion of technology (technical effects) (OECD 2002; Pazienza 2015). This phenomenon explains that the demand for FDI inflow will lead to high demand and production of polluting products. Thus, economic and industrial activities have a tendency to expand. There is therefore the likelihood of higher environmental emissions, such as increased pollution emissions, increased resource extraction, accelerated urbanization, and damage to the natural reserves. This will lead to the call for pollution control, ecological protection, and public health issues by environmental activists on governments. Furthermore, the governing authorities will therefore have to ensure that the required environmental protection regulations are enforced and adhered to as long as there is a demand for FDI inflows for environmental sustainability.

For example, FDI can improve structural efficiency and also provide investment in an environmental protected society. In contemporary times, many people are cautious about their health status; therefore, the awareness and society's demand for a healthy environment will be higher when FDI inflows and economic growth are promoted (Pazienza 2015). Istamto et al. (2014) and Bazrbachi et al. (2017) revealed that as economic growth is established and enhanced as a result of FDI inflows, per capita income will go up and people will be willing to pay more for a pollution-free environment and also more probably to pay for environmental protection. Yahaya et al. (2016) revealed that effective environmental policy implementation and many indicators of environmental quality have steadily increased as measures to curb and reduce the burden on health care expenses and so are willing to pay more as per capita income is increasing.

This paper attempts to comprehensively measure the impact of FDI on environmental pollution by analyzing the different impacts of FDI on various economic variables. In order to better understand the relationship between FDI inflows and environmental pollution in China, we try to establish simultaneous equations to characterize the different effects of variables, including considering the interaction between FDI and economic growth and the impact of FDI on environmental regulation. At the same time, the industrial pollution data of 31 provinces in China from 1995 to 2016 were used to test the simultaneous equation. This paper contributes to prevailing literature in the following ways: to begin with, we adopted a dynamic simultaneous equation modeling method in the investigation of the three-way relationship between the environmental pollutants (industrial waste water, industrial sulfur dioxide, and industrial soot), FDI inflows, and economic growth while considering the effects of other explanatory variables. Specifically, this paper employed both the two-stage least square (2SLS) and three-stage least square (3SLS) to solve a simultaneous equation system. Both methods are robust, but the 3SLS allows correlation between unobserved disturbances across various equations to be used in the analysis. This modeling method was employed because it investigates simultaneously the following combined causality effects and relationships: (i) from FDI inflows and economic growth to environmental pollutants, (ii) from economic growth and environmental pollutants to FDI inflows, and (iii) from the environmental pollutants and FDI inflows to economic growth. As was anticipated, the findings of the work indicated suggestions of concurrent relations between FDI inflows, economic growth, and emissions from the environmental pollutants across the provinces. The remainder of this paper is categorized as follows: the next section is “[The measurement model and methodology](#).” “[The data](#)” section describes the data used. The fourth

section is “[Results, measurement, and analysis](#).” “[Conclusions and policy recommendations](#)” section concludes the article and offers some policy implications.

The measurement model and methodology

Econometric models

Over the past years, many researchers have focused on study methods like unit root test of time series, trend analysis, Granger causality, and multicollinearity test in their analysis of FDI and environmental-related issues (Ayamba et al. 2018; Sothan 2017). Besides the different results according to the different models, it is considered that these kinds of method might explain it by statistics but could not expose the reason, therefore the need to use simultaneous equations.

The research regarding environmental degradation and FDI-related issues with the use of simultaneous equations is not common. Erik (2016) researched on the impact of FDI on regional air pollution as a way to achieve green growth strategy using simultaneous equations in 16 Korean provinces and self-governing cities from 2000 to 2011. He used six air pollutants as pollution indicators. The simultaneous equation model included decomposing FDI inflows into direct and indirect scale, composition, and technique effects. Boqiong and Jianguo (2011) used simultaneous equations in an empirical study of the environmental effect of FDI in host countries. A Chinese panel dataset of 28 provinces from 1992 to 2008 was used. The simultaneous equation models included the economic scale, industry structure, and pollution density to determine the environmental effect of FDI. Jie (2008) also relied on data of 29 provinces in China from 1978 to 2003, while the pollution indicator he used was industrial sulfur dioxide (SO₂). The simultaneous equation models included the economic scale, industry structure, technology effect, effect of FDI on economy, and technology.

Drawing on the ideas in the above literature, we will consider the role of FDI in the framework of economic growth and environmental pollution. In our model, there is a mutual relationship between economic growth and environmental pollution, while FDI may have at least two channels affecting environmental pollution. On one hand, FDI affects environmental pollution by affecting economic growth, while on the other hand, FDI's own production activities may have a direct impact on the surrounding environment. In addition, FDI may affect the final environmental pollution by affecting industrial structure or environmental pollution control. The relationship between these variables can be represented by the following figure:

Just like Jie (2008), we quantitatively examined the effect of different channels setting the equation measurement test in the following form:

$$\ln Y_{it} = \alpha_1 + \alpha_2 \ln P_{it} + \alpha_3 \ln FDI_{it} + \alpha_4 \ln X_{it} + \sigma_{it} \quad (1)$$

$$\ln P_{it} = \beta_1 + \beta_2 \ln Y_{it} + \beta_3 (\ln Y_{it})^2 + \beta_4 \ln FDI_{it} + \beta_5 \ln X_{it} + \delta_{it} \quad (2)$$

$$\ln FDI_{it} = \gamma_1 + \gamma_2 \ln Y_{it} + \gamma_3 \ln S_{it} + \varepsilon_{it} \quad (3)$$

From the formulae, Y_{it} , P_{it} , FDI_{it} , and S_{it} represent the per capita output of sample point “ i ” in “ t ” period, environmental pollution index, foreign direct investment, and industrial structure, respectively, where X_{it} represents other control variables, including physical capital stock, labor, industrial structure, environmental governance investment, and population density. ε_{it} , σ_{it} , and δ_{it} represent estimated residuals. Equation (1) is actually a variant of the Cobb-Douglas function. The addition of FDI indicates the effect of foreign direct investment on the per capita GDP of the host country. However, it also indicates the role of foreign direct investment in the per capita GDP of the host country. Equation (2) is the regressed Eq. (1) of the classical environmental Kuznets curve (EKC), where both the effects of FDI and other control variables are considered. Equation (3) further considers the impact of per capita GDP and industrial structure on FDI.

Measurement methods

Simultaneous equations come with many methods in its analysis. Popular is the two-stage least square method. The following problems exist in the specific estimation process. First, we must examine the identification problem of simultaneous equations. Due to the large number of exogenous variables in the model, the simultaneous equation model of this paper belongs to over-identification, and the two-stage least square method is the first choice for measurement estimation. Second, when estimating using the two-stage least square method, there is the need to determine the tool variables. The general approach is to estimate all exogenous variables as instrumental variables, but the problem in this paper is the quadratic term of per capita output. According to the usual practice, we use material capital, labor, industrial structure, population density, etc. as the instrumental variables of endogenous variable per capita output, environmental pollution, and environmental pollution control. Therefore, we use the above variables as a tool for the squared per capita output as the variables are estimated. Further, we also use the third-order least square method to analyze the sensitivity of the results. In the results that follow, we will list the results of both methods for comparison.

The data

Data of 31 provinces in China from 1995 to 2016 were used. The relevant raw data were principally calculated and compiled from the Statistical Yearbooks of Chinese Cities and China Regional Economic Statistical Yearbooks. The selection and calculation methods of each variable are described in detail below.

1. Per capita output data. The per capita output is measured by the per capita GDP of each city (per capita GDP). Due to the lack of data on per capita GDP, here we use the GDP of each city divided by the urban population and use the urban GDP deflator in the past years to eliminate the price impact, the per capita GDP after the deflator.
2. Physical capital stock data. Due to the lack of relevant data, it is not directly calculated. According to the perpetual inventory method, the physical capital stock is calculated according to the annual capital depreciation rate of 5%, and the price factor is eliminated by the GDP deflator. This estimate is also divided by the population to obtain a per capita physical capital stock.
3. Labor data. Use the number of employees at the end of each city to measure.
4. Foreign direct investment data. According to the statistical data of the China Urban Statistical Yearbook and multiplied by the intermediate exchange rate of RMB against the US dollar.
5. Industrial structure data. The industrial structure uses the secondary industry as a percentage of GDP (%).
6. Environmental pollution control data. Environmental pollution control is measured by the amount of investment in environmental pollution control in each city over the years, and the price reduction factor is used to eliminate the price factor.
7. Environmental pollution data. To fully reflect the environmental pollution situation, we used three indicators of industrial wastewater, industrial sulfur dioxide, and industrial soot. According to the practice of the previous literature, all three indicators in the measurement estimate are measured by per capita emissions, which are obtained by dividing the total pollution indicators by the population.

The above main variables are all taken in the course of measurement, and the statistical description is shown in Table 1.

Results, measurement, and analysis

Table 2 comprises outcome of estimated output of Eq. (1). The findings of the regressed equations indicate that three pollutants have passed the F test with each having coefficient

Table 1 Statistical description of variables

Variables	Unit	Mean	Standard deviation	Minimum value	Maximum value
$\ln(GDP)$	yuan/person	9.78	0.60	8.30	12.21
$\ln^2(GDP)$	(yuan/person) ²	95.92	11.90	68.94	149.18
$\ln(PCIWW)$	t/person	3.97	0.93	-0.89	7.10
$\ln(PCISD)$	t/10,000	6.14	1.04	-0.088	8.73
$\ln(PCIS)$	y/10,000	5.24	1.14	-0.42	7.76
$\ln(PCMCS)$	yuan/person	10.89	0.63	9.14	12.90
$\ln(L)$	man-year	2.83	0.90	0.48	6.27
$\ln(FDI)$	10,000 yuan	10.46	1.97	3.64	15.39
$\ln(IEPC)$	10,000 yuan	5.51	1.48	-2.03	8.90
$\ln(\%SI)$	%	3.94	0.25	2.79	4.50
$\ln(PD)$	People/km ²	6.71	0.93	2.56	9.55

values. The findings reveal positively significant output elasticity coefficient values of material capital stock and labor force, implying their contribution of factor inputs to economic growth. From Table 2 above, it is observed that the output elasticity of material capital stock and labor force is about 0.6 and 0.13, respectively. The estimated coefficient of the industrial structure also reflects the significant effect of the secondary industry on economic growth. The proportion of the second industry (%) increased by 1%, and the per capita GDP increased by about 0.33%. The estimated coefficient of environmental pollution is in all three pollution indicators negative, and the statistics are not significant. This may reflect the negative impact of industrial pollution on urban economic growth to a certain extent, reminding us to pay attention to the consumption and destruction of resources and environment by economic development and the feedback effect of resource environment on economic growth and social development, to achieve economic, environmental, and coordinated development of society. The estimated coefficient of FDI is positive, and the estimation result of the two-stage least square method is not significant, but in the three-stage least square method, the significant positive effect of FDI on economic growth can be seen. The estimated coefficient is about 0.06, which indicates that FDI inflows increase by 1% and per capita GDP increases by 0.06%. This shows to a certain extent that the efficiency of China’s use of foreign capital is still very limited. Although China’s FDI inflows have been on the rise for many years, many multinational companies only build labor-intensive factories or production plants in China. China only accounts for the lower added value in the global production chain. China cannot really enjoy the huge benefits brought by the opening of the market, so the contribution of FDI to China’s economic growth, especially per capita GDP, is still not obvious. In the future, the use of foreign capital should pay more attention to the quality of FDI. At the same time, it encourages domestic enterprises to participate in competition and cooperation and strives to learn advanced foreign

production technology and management methods. At the same time, it actively trains domestic professional and technical personnel to effectively utilize and absorb FDI technology spillovers, plays the positive role of FDI in economic development, and continuously improves China’s position in the international division of labor.

Table 3 showcases the estimated results of the pollution Eq. (2). Each regression method passed the *F* test. It is worth noting the coefficients of GDP per capita and its squared term, which inform us about the link of environmental pollution and economic growth. Table 3 above indicates an inverted U-shaped relationship between GDP per capita and both per capita industrial SO₂ and industrial soot. It signifies that the pollutants initially rise and later rises as per capita GDP increases. From the estimation coefficient in the table, in addition to industrial wastewater, per capita industrial SO₂ and industrial soot have an inverted U-shaped relationship with GDP per capita, that is, these two types of environmental pollution rise first and then rise with the increase of per capita GDP.

Industrial wastewater also exhibited an inverse U-shaped relationship with per capita GDP, while it indicated an increasing link with per capita GDP in the three-stage and two-stage least square methods, respectively. This implies that as China’s per capita GDP soars, the period 1995–2016 has witnessed an enhanced environmental pollution situation. However, the turning point of each kind of pollutants is different. It could be said that China to some extent has adhered to numerous calls from environmental activists and NGOs to be environmental cautious in their production process. The government should however be relentless in their fight towards drastically reducing environmental pollution. Therefore, they should adopt a multi-faceted approach in curtailing and monitoring environmental pollution. Table 3 reveals results of estimated coefficients of the industrial structure which are not consistent with the two methods. From the results of the three-stage

Table 2 Output equation estimation

Variables	2SLS			3SLS		
	Industrial wastewater	Industrial SO ₂	Industrial soot	Industrial wastewater	Industrial SO ₂	Industrial soot
Intercept term	1.009644 (2.88)***	1.087809 (3.84)***	1.337213 (6.49)***	1.546490 (4.45)***	1.472877 (5.23)***	1.495281 (7.29)***
<i>ln(PCMC/S)</i>	0.644145 (20.67)***	0.663919 (16.19)***	0.648486 (19.77)***	0.527154 (17.74)***	0.549157 (13.70)***	0.544677 (17.15)***
<i>ln(L)</i>	0.092976 (1.21)	0.12983 (2.85)***	0.133094 (3.12)***	0.131064 (1.73)**	0.131148 (2.95)***	0.131749 (3.17)***
<i>ln(%S/I)</i>	0.332701 (3.57)***	0.348449 (3.28)***	0.326711 (3.76)***	0.339422 (3.66)***	0.340238 (3.21)***	0.335817 (3.88)***
<i>ln(P/D)</i>	-0.07783 (-0.98)	-0.07353 (-0.99)	-0.07525 (-0.94)	-0.00027 (-0.00)	-0.01172 (-0.16)	-0.00749 (-0.09)
<i>ln(F/D)</i>	0.047752 (1.04)	0.017173 (0.63)	0.011175 (0.42)	0.075506 (1.67)*	0.066123 (2.52)***	0.066963 (2.65)***
F value	633.28***	650.42***	665.60***			
Adj. R ²	0.76373	0.76871	0.77279			

The *t* values corresponding to the estimated coefficients in parentheses; ***, **, * represent statistical significance of 1%, 5%, and 10%, respectively

least square method, the increase in industrial structure has somewhat mitigated the impact on the environment.

This may mean that China’s secondary industry has made certain efforts in utilizing resources and environmental protection. The urban environment did benefit from 2003 to 2006. However, due to the instability of the results, the role of the industrial structure remains to be confirmed. The estimated coefficient of population density is significantly positive, reflecting that the more dense the populated areas are, the more serious the environmental pollution problem is. On average, the population density increased by 1%, and the per capita industrial wastewater, industrial SO₂, and industrial soot increased by 0.44%, 0.25%, and 0.17%, respectively. The estimated coefficient of investment in environmental pollution control is significantly positive too. That is as environmental pollution investment increases, the more serious the environmental pollution is. The environmental pollution treatment may not achieve the expected reduction of industrial wastewater discharge. This reflects the fact that the treatment of environmental pollution is not solely the responsibility of the government. This revelation is disturbing and should be taken very seriously by the appropriate authorities in charge of the enforcement and adherence of the environmental regulations without fear or favor. Refusal will result in a catastrophic and damaged ecological environment which cannot be restored to its natural state even with the most advanced technologies. This does not however ensure sustainability of environmental and natural resources for use by future generations.

Contrary to the findings of Bao et al. (2011) and Kostakis et al. (2016), it was revealed that the estimated coefficients of FDI have a significantly positive impact on environmental pollution. Therefore, FDI inflow does not have a so-called negative impact on China’s environment. The possible explanation is that although the inflow of FDI is accompanied by the increase of environmental pollution in China, FDI tends to use more advanced production technology and stricter environmental protection standards in China, and the damage to resources and environment in the actual production process is relatively domestic. Enterprises are greener and environmentally friendly. Although the inflow of FDI has aggravated the environmental pollution situation in China in a certain period of time, the advanced production technology and strict environmental standards of multinational companies have gradually enhanced the environmental pollution status of domestic industries. The technology spillovers of multinational companies have also played a positive role in improving the environment in China (Hu et al. 2018; Zhu and Ye 2018). This outcome reinforces that need for still stricter law enforcement. On one hand, the Chinese government must see the technical content and management experience of FDI, while on the other hand, caution must

Table 3 Results of estimated pollution equation

Variables	2SLS		3SLS	
	Industrial wastewater	Industrial SO ₂	Industrial wastewater	Industrial soot
Intercept term	-2.53229 (-2.11)**	-4.91410 (-4.74)***	-17.0945 (-16.10)***	-8.74778 (-8.00)***
<i>ln(GDP)</i>	0.802243 (3.46)***	1.412922 (7.06)***	4.268479 (22.52)***	2.732473 (13.01)***
<i>ln²(GDP)</i>	0.031724 (5.08)***	-0.01044 (-1.94)*	-0.08153 (-17.51)***	-0.08351 (-14.98)***
<i>ln(%SI)</i>	-0.48979 (-2.23)**	0.313149 (1.65)*	-1.36835 (-6.77)***	-0.03672 (-0.18)
<i>ln(PD)</i>	0.454315 (7.71)***	0.249197 (4.89)***	0.435894 (9.16)***	0.171873 (3.21)***
<i>ln(JEPC)</i>	0.098465 (3.54)***	0.101594 (4.23)***	0.051269 (1.86)*	0.073693 (2.86)***
<i>ln(FDI)</i>	-0.57882 (-8.16)***	-0.50215 (-8.19)***	-1.01972 (-17.79)***	-0.58776 (-9.12)***

The *t* values corresponding to the estimated coefficients in parentheses; ***, **, * represent statistical significance of 1%, 5%, and 10%, respectively

be taken on the environmental impact of FDI. The safe and effective introduction of foreign capital can not only expand the opening up to the outside world, but also deepen the domestic market reform which could promote the sound and rapid development of China’s economy.

As can be seen from the results of the FDI equation listed in Table 4, Eq. (3), it is noticed that China’s per capita GDP impacts positively on FDI, implying that a 1% increase in per capita GDP will lead to about a 2.73% increase in FDI inflows. It is not surprising that there is a high demand for Chinese products worldwide thereby creating larger markets for existing and potential to multinational companies. On the other hand, results from Table 4 indicate a negative effect of secondary industry on FDI inflows. This reflects the fact that the development of the secondary industry in China has a certain degree of “crowding out” effect on FDI, which may reflect the meaning of both aspects. First of all, the domestic secondary industry, especially the manufacturing industry, is gradually growing up in competition with multinational companies, which has put some pressure on the inflow of FDI. On the other hand, multinational corporations are looking for low-cost manufacturing plants on a global scale. In recent times, there has been an increase in the labor costs in China while the neighboring countries experience increasing labor markets thereby reducing the FDI inflow to China to these neighboring countries.

From the estimation results of environmental pollution control investment, apart from for industrial wastewater, the coefficient of industrial SO₂ and industrial soot in the FDI equation is significantly negative, which means that FDI inflow is negatively correlated with environmental pollution control investment. This confirms to some extent the existence of the pollution haven hypothesis by Jie (2008). Since the coefficient of FDI in the pollution equation is significantly positive, that is, FDI has a positive effect on environmental pollution control, this may to some extent compensate for the insufficient domestic environmental pollution control investment. However, if combining the environmental pollution control in the pollution equation is not satisfactory, then this shows that there is still a big gap between domestic environmental pollution control and foreign countries. In the environmental pollution control, we can learn from the successful experience of developed countries and understand how to effectively treat domestic environment pollution.

Conclusions and policy recommendations

The research utilized data from 31 provinces in China between 1995 and 2016 to analyze the complex relationship between FDI and economic growth and their subsequent impact on environmental pollution. The simultaneous equation method was used in

Table 4 Results of estimated FDI equation

Variables	2SLS/3SLS					
	Industrial wastewater		Industrial soot		Industrial SO ₂	
Intercept term	-8.19067	(-7.92)**	-8.17105	(-7.90)***	-8.14128	(-7.87)**
<i>ln(GDP)</i>	2.729124	(25.96)***	2.724881	(25.88)***	2.726645	(25.96)***
<i>ln(%SI)</i>	-1.91435	(-8.96)***	-1.90879	(-8.93)***	-1.91787	(-8.98)***
<i>ln(IEPC)</i>	-0.08726	(-2.46)	-0.08745	(-2.47)**	-0.08897	(-2.51)**
<i>F</i> value	248.07***		246.28***		247.73***	
Adj. <i>R</i> ²	0.43114		0.42960		0.43105	

The *t* values corresponding to the estimated coefficients in parentheses; ***, **, * represent statistical significance of 1%, 5%, and 10%, respectively

the analysis. The revelations from the findings indicate that FDI inflows to China have positive impact on the environment which is contrary to some research works. This implies that FDI's impact on economic growth and environmental pollution control ultimately benefits China's industrial pollution control and environmental conditions.

This result will help to further understand the impact mechanism and impact of FDI on environmental pollution. The expansion of industrial production and the expansion of economic scale will bring unprecedented pressure on a country's resources and environment, and FDI greatly affects the environment through these two channels. For example, according to Jones et al. (2012) and Kram et al. (2012), developing countries like Brazil, Indonesia, and India have captured high carbon dioxide emission rates which have catastrophic effects on the natural ecosystem. The rigorous desire for economic development through increased economic activities has led to the destruction of the forest thereby hampering natural habitats, air, and water quality. In order to mitigate these challenges, these countries have adopted green production and a REDD+ (which is an international financial mechanism for reducing greenhouse gas emissions). In addition, the industrial revolution which engulfed the USA in the late eighteenth and early nineteenth centuries extensively enhanced social and economic conditions. This period witnessed a migration from an economy that relied on manual labor to one that is championed by a holistic transition in technology, socioeconomic, and culture thereby leading to an economy dominated by industry and machine manufacture. The influx of FDI activities during this period experienced a spillover effect of technological advancement from Europe which led to a sustained growth in the economy as well as income of the populace. However, environmental pollution rose within this period resulting from the usage of new sources of fuel in the production process, establishment of huge manufacturing factories, and the increase in unsanitary urban centers. To curb this menace, environmental protection regulations were instituted to ensure cleaner air and water quality (Bruland and Mowery 2004). Furthermore, it is indicated that advanced and high-income countries like Australia, Belgium and Canada underwent economic transition

at the expense of their natural resources and environment which had detrimental effect on the well-being of their respective citizenry. The period of this economic evolution observed intensive increase in economic activities from foreign investors who relied on carbon-based manufacturing processes as well as from energy-intensive extractive activities and agriculture production in the primary sector. As the natural resources in the primary sector were extensively exploited with the use of fossil fuels to propel economic growth, the emission rate of carbon dioxide was also increasing thereby having a direct or indirect effect on public health. The way out from these disastrous environmental predicaments and to ensure a healthy populace was to adopt technological advanced innovation in the production process which could encourage and lead to a more efficient utilization of the natural resources (Jorgenson 2012; Jorgenson and Clark 2011; Rice 2008). These are but a few examples from which China could learn from their experiences and encounter with environmental challenges and how these countries managed and are still controlling this environmental canker.

The impact of industrial structure on industrial pollution shows no significant negative effect in the empirical results. This reflects that the domestic industrial structure needs further adjustment, and the resource utilization efficiency and environmental protection of the industry need to be improved and strengthened. That is to say, the empirical results indicated that the industrial structure does not negatively affect the environmental quality. Although the findings show a negative impact of industrial structure on the environment, there is the need for the Chinese government to strictly ensure that FDI inflow is accompanied by the usage of sophisticated production and green technologies in the production process. This will help to improve efficiency and hence quality of product as well as minimize the wastage of resource usage. Also, it is incumbent that the policy makers ensure the implementation, enforcement, and compliance of environmental protection regulations by foreign investors, where corresponding punishments are meted out to defaulters of the regulations. At the same time, we also found an inverted U-shaped curve (environmental Kuznets curve) between economic growth and environmental pollution. FDI, through a

positive correlation between negative correlations with industrial structure and economic growth, is ultimately negatively correlated with industrial pollution. In addition, FDI also affects environmental pollution control ultimately affecting environmental pollution. The inflow of FDI has brought green production technology and governance experience, which has alleviated the pressure on domestic environmental pollution control investment to a certain extent and promoted the improvement of domestic environmental pollution control efficiency.

The above findings admonish us to pay attention on how the environment could be affected by FDI. In contemporary times, China has become the world's leading recipient of FDI inflows. The quality and structure of FDI inflow should be of much concern, implying that China should not only focus on attracting FDI but also make adequate use of it without compromising the environmental quality. Advanced foreign technology should be introduced while environmental standards improved, particularly in the production processes. Green production processes should be encouraged through structural transformation and technological upgrading to effectively make use of resources.

References

- Albert E (2016) China's Environmental Crisis. Retrieved from <https://www.cfr.org/backgrounder/chinas-environmental-crisis>. Accessed Oct 2018
- Asghari M (2012) What is "Race-to-the-Bottom" Effect on FDI Inflow? *Iranian Economic Review (IER)* 17(2):76–93
- Ayamba EC, Chen H, Udimal TB, Osei A (2018) Foreign direct investment, growth of output indicators and economic growth in China: empirical evidence on causal links. *Int J Econ Financ Issues* 8(3):315
- Baek J, Choi YJ (2017) Does foreign direct investment harm the environment in developing countries? Dynamic panel analysis of Latin American countries. *Economies* 5(4):39
- Baghebo M, Apere TO (2014) Testing the "pollution havens hypothesis (PHH)" in Nigeria from 1970–2013. *Mediterr J Soc Sci* 5(23):598
- Bao Q, Chen Y, Song L (2011) Foreign direct investment and environmental pollution in China: a simultaneous equations estimation. *Environ Dev Econ* 16(1):71–92
- Bayraktar-Sağlam B, Sayek Böke S (2017) Labor costs and foreign direct investment: a panel VAR approach. *Economies* 5(4):36
- Bazrbachi A, Sidique SF, Shamsudin MN, Radam A, Kaffashi S, Adam SU (2017) Willingness to pay to improve air quality: a study of private vehicle owners in Klang Valley, Malaysia. *J Clean Prod* 148:73–83
- Boqiong Y, Jianguo C (2011) An empirical model of the environmental effect of FDI in host countries: analysis based on Chinese panel data
- Bruland K, Mowery DC (2004) Innovation through time. Georgia Institute of Technology
- Cho S (2018) China's experience in tackling water scarcity through sustainable agricultural water management. Retrieved from <http://blogs.worldbank.org/water/china-experience-tackling-water-scarcity>. Accessed Nov 2018
- Deng Y, Xu H (2015) International direct investment and transboundary pollution: an empirical analysis of complex networks. *Sustainability* 7(4):3933–3957
- Dong B, Gong J, Zhao X (2012) FDI and environmental regulation: pollution haven or a race to the top? *J Regul Econ* 41(2):216–237
- Elliott RJ, Zhou Y (2013) Environmental regulation induced foreign direct investment. *Environ Resour Econ* 55(1):141–158
- Erik H (2016) The impact of foreign direct investments on regional air pollution in the Republic of Korea: a way ahead to achieve the green growth strategy?
- Gao X, Zhang W (2013) Foreign investment, innovation capacity and environmental efficiency in China. *Math Comput Model* 58(5–6):1040–1046
- Gibson C (2018) Water Pollution in China is the Country's Worst Environmental Issue. Retrieved from <https://borgenproject.org/water-pollution-in-china/>. Accessed Oct 2018
- Hu J, Wang Z, Lian Y, Huang Q (2018) Environmental regulation, foreign direct investment and green technological Progress—evidence from Chinese manufacturing industries. *Int J Environ Res Public Health* 15(2):221
- IEA (2011) CO2 emission from fuel combustion highlights. OECD/IEA, Paris
- Istamto T, Houthuijs D, Lebre E (2014) Willingness to pay to avoid health risks from road-traffic-related air pollution and noise across five countries. *Sci Total Environ* 497:420–429
- Jie H (2008) Foreign direct investment and air pollution in China: evidence from Chinese cities. *Région et Développement* n 28:132–150
- Jones HP, Hole DG, Zavaleta ES (2012) Harnessing nature to help people adapt to climate change. *Nat Clim Chang* 2(7):504–509
- Jorgenson AK (2012) The sociology of ecologically unequal exchange and carbon dioxide emissions, 1960–2005. *Soc Sci Res* 41(2):242–252
- Jorgenson AK, Clark B (2011) Societies consuming nature: a panel study of the ecological footprints of nations, 1960–2003. *Soc Sci Res* 40(1):226–244
- Kirkulak B, Qiu B, Yin W (2011) The impact of FDI on air quality: evidence from China. *Journal of Chinese Economic and Foreign Trade Studies (JCEFTS)* 4(2):81–98
- Kostakis I, Lolos S, Eleni S (2016) Foreign direct investment and environmental degradation: further evidence from Brazil and Singapore
- Kram T, Neumann K, van den Berg M, Bakkes J, van Meijl J, Tabeau A (2012) Global integrated assessment to support EU future environment policies (GLIMP) (9279250922). Retrieved from
- Liu Q, Wang S, Zhang W, Zhan D, Li J (2018) Does foreign direct investment affect environmental pollution in China's cities? A spatial econometric perspective. *Sci Total Environ* 613:521–529
- MOC (2018) China says FDI up 7.9% in 2017. Beijing Retrieved from http://english.gov.cn/archive/statistics/2018/01/16/content_281476015941646.htm. Accessed Sept 2018
- OECD (2002) Environmental benefits of foreign direct investment: a literature review, document of the working party on global and structural policy. OECD Publishing, Paris
- Olney WW (2013) A race to the bottom? Employment protection and foreign direct investment. *J Int Econ* 91(2):191–203
- Pazienza P (2015) The environmental impact of the FDI inflow in the transport sector of OECD countries and policy implications. *Int Adv Econ Res* 21:105–116
- Polat B (2017) Rate of return on foreign investment income and employment labour protection: A panel analysis of thirty OECD countries. *Cogent Economics & Finance (CE&F)* 5(1):1273588
- Rice J (2008) Material consumption and social well-being within the periphery of the world economy: an ecological analysis of maternal mortality. *Soc Sci Res* 37(4):1292–1309
- Rohde RA, Muller RA (2015) Air pollution in China: mapping of concentrations and sources. *PLoS One* 10(8):e0135749
- Sarmidi T, Nor AHSM, Ridzuan S (2015) Environmental stringency, corruption and foreign direct investment (FDI): Lessons from global evidence. *Asian Academy of Management Journal of Accounting and Finance (AAMJAF)* 11(1):85–96

- Sothan S (2017) Causality between foreign direct investment and economic growth for Cambodia. *Cogent Economics & Finance (CE&F)* 5(1):1277860
- Tingting D (Producer) (2017) In China, the water you drink is as dangerous as the air you breathe. Retrieved from <https://www.theguardian.com/global-development-professionals-network/2017/jun/02/chinawater-dangerous-pollution-greenpeace>. Accessed Oct 2018
- van der Kamp D, Lorentzen P, Mattingly D (2017) Racing to the bottom or to the top? Decentralization, revenue pressures, and governance reform in China. *World Dev* 95:164–176
- Wang X, Sun C, Wang S, Zhang Z, Zou W (2018) Going green or going away? A spatial empirical examination of the relationship between environmental regulations, biased technological Progress, and green Total factor productivity. *Int J Environ Res Public Health* 15(9):1917
- Wasseem M (2017) The Race to the Top: Institutional Clusters and World FDI Shares. *Mina*. In: Wasseem
- WIR (2018) World investment report 2018: key messages and overview. New York and Geneva, 2018: United Nations conference on trade and development, Geneva
- Yahaya A, Nor NM, Habibullah MS, Ghani JA, Noor ZM (2016) How relevant is environmental quality to per capita health expenditures? Empirical evidence from panel of developing countries. *SpringerPlus* 5(1):925
- Yan M, An Z (2017) Foreign direct investment and environmental pollution: new evidence from China. *Econ Lett* 4(1):1–17
- Yang J, Wang Y (2016) FDI and environmental pollution nexus in China
- Yuan P, Cheng S, Sun J, Liang W (2013) Measuring the environmental efficiency of the Chinese industrial sector: a directional distance function approach. *Math Comput Model* 58(5–6):936–947
- Zmarak S (2006) Addressing China's growing water shortages and associated social and environmental consequences. The World Bank, Washington, DC
- Zheng J, Sheng P (2017) The impact of foreign direct investment (FDI) on the environment: market perspectives and evidence from China. *Economies* 5(1):8
- Zhu S, Ye A (2018) Does the impact of China's outward foreign direct investment on reverse green technology process differ across countries? *Sustainability* 10(11):3841

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