Can FDI Facilitate Green Total Factor Productivity in China?-Evidence from Regional Diversity

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Can FDI Facilitate Green Total Factor Productivity in China？-Evidence from Regional Diversity

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Abstract：
The development of foreign direct investment conforms to the theoretical principles of green total factor productivity and is key to promoting regional industry upgrading. By using three-stage data envelopment analysis (DEA) based on city-level data, this paper investigates the effect of foreign direct investment on regional green total factor productivity (GTFP) across China. The results show that foreign direct investment affects regional GTFP through the mechanism of technology spillover effect and human capital spillover effect. Under different environmental regulation intensity and marketization, the relationship between FDI and green total factor productivity is non-linear level. The phenomena of "pollution paradise" and "bottom line race" survived at low marketization regional and foreign direct investment will inhibit the improvement of regional green total factor productivity in China.

Key words: Green Total Factor Productivity; Regional Diversity; Pollution Paradise; Bottom Line Race; environment policy

1. Introduction

The world economy is undergoing regional industry upgrading. As the largest energy consumer country, China's energy consumption has increased year by year (see Fig1), accounting for 24% global energy consumption and 34% of the global energy consumption growth[1]. Motivated by the prevalence of economic targets at all levels of territory administration in China, local governments also tend to replace longer-term goals with short-term economic growth (Li X, Liu C, Weng X, et al. al., 2019). However, China`s economic development facing the growing pressure of resources and environmental constraints, and sustained environmental degradation has negatively affected the quality of China's economic growth, public health and seriously hurt government`s reputation (Fu J, 2008). In response to the crisis of environment and energy, Chinese government put forward the concept of "beautiful China", emphasizing that the construction of ecological civilization should be placed in a prominent position, and pollution prevention should be included in the government's key tasks[2]. With the Chinese government attaches more importance to the environment and the relevant environmental laws and regulations are issued, enterprises will bear the rising costs about environmental protection, foreign direct investment (FDI) flows to China will also be affected.

[1] Data source：《BP Statistical Yearbook of World Energy (2019)》
[2] http://www.xinhuanet.com//politics/19cpcnc/2017-10/18/c_1121820882.htm

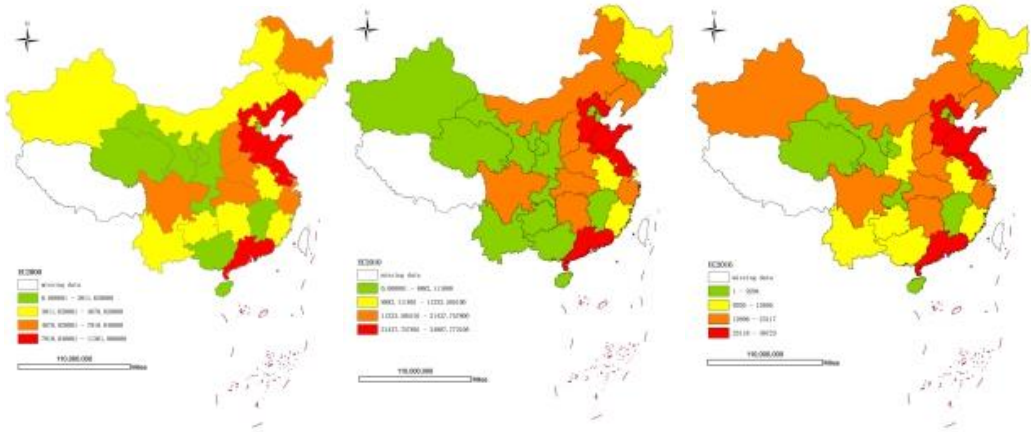

Fig1. Spatial quartile maps of Energy consumption (unit: 10,000 tons of standard coal) in China from 2000 to 2016.

For developing countries, FDI is an important channel for undertaking international technology transfer, cultivating the competitiveness of local industries, and realizing capital accumulation, technology accumulation and human capital accumulation. China's rapid economic growth since the 1980s also benefited from the positive role of FDI in local industrial upgrading, technological innovation and talent training (Kui-Yin C, et al., 2004; Ullah A, et al., 2020). However, existing researches have not reached a consistent conclusion about the impact of FDI on the ecological environment of developing countries. There are two points about it: the "pollution haven hypothesis " (for example, see Reppelin, 1999; Ashford, et al., 2002; Eskeland, et al., 2003; Abdouli, et al., 2017) and the "pollution halo" hypothesis (Birdsall, et al., 1993; Abdouli, et al., 2018). Kuznets (1955) proposed that the relationship between environmental pollution and economic growth was inverted U-shaped. In the early stages of economic development, developing countries face environmental degradation with multinational companies transferring pollute companies, which pursue the max profit and avoid environmental cost, developing countries become "pollution paradise" (Eskeland, et al., 2003). Pazienza P (2019) proved the impact of FDI on the intensity of carbon dioxide emissions is an inverted "U" shape in OECD countries. Series researchers show that "pollution paradise" hypothesis has been confirmed in China, increasing FDI has a negative impact on environment. Results from a top-down amplification of economic growth targets along the jurisdiction levels, local governments tend to attract foreign investment with lower pollution costs (Luo Y, et al., 2010; Chen Q, et al., 2014). On the contrary, other researches proved that the positive effect of FDI on the improvement of host country's environment. Both FDI and international trade provided impetus and opportunities for developing countries to develop advanced environmental protection technologies and improved the environmental quality (Birdsall, et al., 1993). Antweiler et al. (2001) showed that technological progress caused by trade reduced pollution in China and played a positive role in improving environment. Karen et al. (2004) proved that the technological effect of FDI in China had a significant positive impact on the environment with analyzing 2500 large and medium-sized industrial enterprises. Abdouli et al. (2018) verified the "pollution halo" effect of FDI in BRICS countries, once FDI reached the threshold level, it would have positive impact on reducing carbon dioxide emissions. Singhania et al. (2021) researched the correlation between FDI, institutional, financial development and sustainability in 21 developed and developing countries with high carbon emissions, and the results showed that FDI had a significant positive impact on environment.

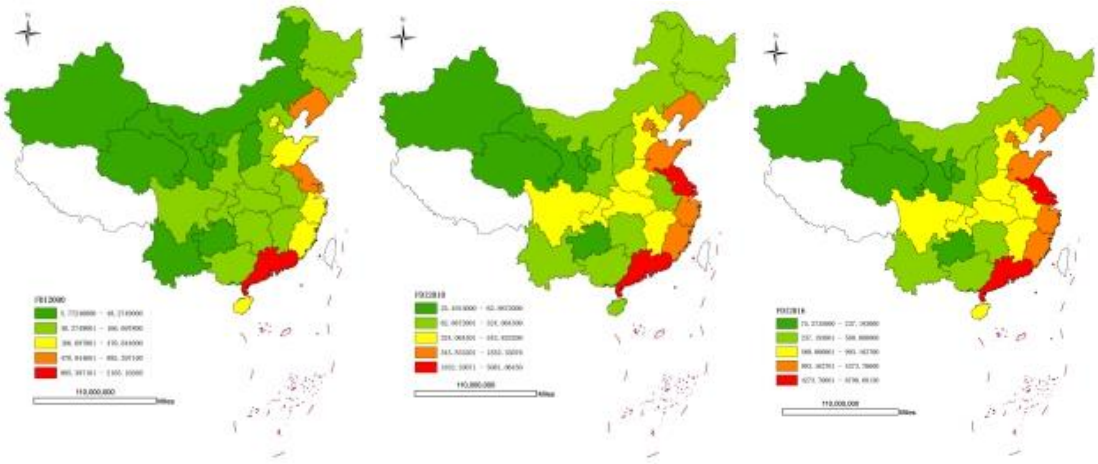

Fig2. Spatial maps of foreign direct investment (unit: Thousands of dollars) in China from 2000 to 2016.

Previous researches have noticed the effects of FDI on China`s economic development transformation and production efficiency, but the role of FDI in promoting Green total factor productivity is not fully clear, the mechanisms of FDI on GTFP are still controversies. Due to different regional endowment and development level, traditional efficiency measure methods which ignore influence of random factors and the external environment factors, may cause measurement errors in a certain extent, distort the analysis of the impact of FDI on GTFP. On the other hand, purely researching Regional heterogeneity of GTFP without considering foreign investment, it is not conducive to discover the deep impact of China's integration into the world market on its economic development transformation from the perspective of open economy. This paper contributes to the existing literature in the following two aspects: First, after eliminating external environmental factors and random factors, we re-measure regional GTFP, and reexamine the impact of FDI on environment, further enriching the research this field. Second, the objective existence of regional development differences leads to the heterogeneity of FDI's environmental effects. Therefore, this paper uses panel data to analyze the mechanism of FDI's effect on GTFP and its regional heterogeneity.

2. Literature and Hypothesis

FDI mainly affects the host country’s GTFP through three channels: technology spillover, innovation spillover, and human capital spillover. First, technology spillover effects. On the one hand, FDI mostly enters China in the form of investment and plant construction. Since companies in the same industrial value chain need to use uniform standards and technical specification, industrial linkages will force host country companies to adopt more advanced technologies. It also encourages local companies to increase productivity through "learning by doing" (Javorcik, 2004), save factor inputs, and reduce industrial waste emissions. On the other hand, due to multinational enterprises needs to implement the environmental standards unified with the home country, it could promote the improvement of the host country’s environmental protection technology, and effectively control pollution emissions (Eskeland et al., 2003). Second, innovation spillover. After multinational enterprise enters the host country, it will compete with local enterprises in the product market, production factor market and human resource market to capture limited resources, intensify the factor market competition (Magnus, 1998). It encourages local enterprises to carry out technological research and development to improve competitiveness, and improve the productivity of the host country. Third, human capital spillover effect. By training local employees, transnational

enterprises internalize human capital in local employees. With the flow of employees between enterprises, human capital spillover is helpful to improve the human capital of enterprises in host countries (Noorbakhsh, 2001). However, FDI inflow also has a certain "crowding out effect" on enterprises in the host country (Ari Kokko, 2014). The impact of above three effects depend on whether enterprises in the host country break through the dependence path of introduction technology of FDI, form a virtuous cycle of "introduction -- absorption -- innovation -- output". If the enterprises in the host country cannot absorb technology, carry out independent innovation and form high-quality labor pool, FDI will inhibit the improvement of GTFP in the host country. Therefore, this paper proposes hypothesis 1 and 2:

H1: Technology spillover effect, innovation spillover effect and human capital spillover effect brought by FDI will affect the GTFP of the host country.

H2: The influence of FDI on GTFP is subject to regional development differences.

Whether FDI can promote the improvement of green productivity in host countries is influenced by factors such as the level of local environmental regulation and marketization (Alfaro, 2004; Asiedu E, 2006). Because enterprises in developed countries are often constrained by strict environmental regulations of home country, and put large investment in environmental protection and pollution treatment. In order to avoid environmental costs, enterprises in developed countries often choose to set up multinational companies and relocate high-polluting and energy-consuming industries to developing countries. In order to pursue economic growth, developing countries often set low environmental threshold to obtain "comparative advantage" and attract FDI. In this case, countries with laxer environmental regulation become "pollution paradise". China pursues economic development and its regional development is prominent imbalance, so foreign investment is essential to help the country achieve industrialization. In the past few decades before 2012, the requirement of FDI is not stringent, the objective existence of "Race to the Bottom" among local governments, FDI bring a considerable amount of high-pollution and energy-consuming plants. Therefore, the degree of marketization and environmental regulation level play a moderating role on the "FDI-GTFP" relationship, mainly reflected in the following aspects: first, strict environmental regulation inhibits the inflow of low-quality FDI and attracts clean FDI, which is conducive to the improvement of regional GTFP. Second, the higher degree of regional marketization level, the local government administrative intervention in economy development is smaller, that means the greater the competition between enterprises and factors flow more freedom. It is advantageous to weed out low quality FDI in marketplace, and also benefit to local companies to absorb advanced management experiences and technology by frequent technical exchanges and staff turnover. Hypothesis 3 is proposed in this paper:

H3: The influence of FDI on GTFP is nonlinear under different intensity of environmental regulation and marketization level.

3、Methodology and Data

3.1. Model and Method of Estimation

Three-stage Data Envelopment Analysis

Existing research on China's green total factor productivity mainly focuses on industry green total factor productivity (Zhu X, et al., 2018), regional green total factor productivity (Yangjun Ren, 2019; Wei-Bing LI, et al., 2019; Liu S, et al. 2020; Xia F, Xu J, 2020) and urban green total factor productivity (Liu and Xin, 2019). And the models such as BBC-DEA, DEA-SBM, and DEA-Malmquist are mainly used for calculate GTFP. Considering previous studies often ignore the

influence of external environmental factors and random factors, this paper will use the three-stage DEA (Fried, 2002) to measure regional green total factor productivity. The main steps of the three-stage DEA are as follows:

In the first stage, use traditional BBC-DEA model (proposed by Charnes, Cooper, and Rhodes (1978)) to calculate efficiency. The model equation as following: there are n DMU and $\bar{n}$ SU, each SU has m inputs and n outputs. Let x_{ip} and $\overline{x_{ij}}$ respectively denote the i_{th} input of the p_{th} DMU and the j_{th} SU, while y_{rp} and $\overline{y_{rj}}$ respectively denote the r_{th} input of the p_{th} DMU and the j_{th} SU. Therefore, the BBC-DEA model of the p_{th} decision-making unit is shown in equation (1).

$$\mathrm{MIN}\left[\theta-\varepsilon\left(\sum_{j=1}^{m}s^{-}+\sum_{j=1}^{s}s^{+}\right)\right] \tag{1}$$

$$\mathrm{s.t.}\sum_{j=1}^{\bar{n}}\overline{x_{ij}}\gamma_j+s^{-}=\theta x_{ip},\mathrm{i}=1\cdots\mathrm{m} \tag{2}$$

$$\sum_{j=1}^{\bar{n}}d\overline{y_{ij}}\gamma_j-s^{+}=y_{rp},\mathrm{r}=1\cdots\mathrm{s} \tag{3}$$

$$\sum_{j=1}^{\bar{n}}\gamma_j=1 \tag{4}$$

$$\gamma_j\geq 0, j=1,2,\cdots n, s^{+}\geq 0, s^{-}\geq 0$$

Where θ is the relative efficiency value of the evaluated DUM, $s^{-}$and $s^{+}$are slack variables, the constant d is the movement factor that reflects the dynamic adjustment of the system, ε is the non-Archimedean infinitesimal, the $\gamma_{jt}(j=1,2,\cdots n)$ is the weight coefficient.

In the second stage, conduct stochastic frontier analysis model(SFA)(Aigner, Lovell and Schmidt (1977)). We set the slack of input as the explained variable and the environmental factors are as the explanatory variables, SFA is used to analyze the influence of environmental factors on the decision-making unit. The SFA model is shown in equation (5).

$$S_{ij}=f^{i}(z_j;\beta^{i})+v_{ij}+u_{ij} \tag{5}$$

S_{ij} represents the slack variable of the i_{th} input of the j_{th} decision-making unit. z_j are environmental variables and β^{i} are parameters to be estimated. $v_{ij}\sim N(0,\sigma_{ui}^{2})$ are random interference, $u_{ij}\sim N^{+}(\mu,\sigma_{ui}^{2})$ are invalid management, they are independent of each other.

For making each DUM in the same natural state, to measure and calculate the efficiency value that purely reflects the management level of each DUM, we adjust the input items of each DUM according to the calculation results$(\widehat{\beta^{i}},\widehat{\sigma_{ui}^{2}})$ of the SFA regression model. At the same time, in order to ensure that the adjusted inputs are positive, as shown in equation (3), we use the worst external environment and maximum random interference as the benchmark, and make adjustment by increasing the input of other DUMs, x_{ij} are actual inputs and x_{ij}^{A} are adjusted inputs.

$$x_{ij}^{A}=x_{ij}+\left[max_j(z_j;\beta^{t})-z_j\beta^{t}\right]+\left[max_j(v_{ij})-v_{ij}\right] \tag{6}$$

In the third stage, run DEA model again. The original inputs are replaced by the adjusted inputs from step 2 and the outputs remain unchanged. Traditional DEA model is run again to get the efficiency without the influence of environmental factors and random errors, which can more accurately reflect China's regional green total factor productivity. According to the adjusted input value x_{ij}^{A} of each DUM, we run the DEA model again to calculate the new efficiency value. After removing the influence of random interference and external environmental factors, the adjusted efficiency value can better reflect the actual efficiency level. When the efficiency value $\theta=1$, the

DUM is effective, otherwise it is non-effective. For non-effective DUM, we can calculate the input redundancy $\Delta X_{pt} = (1-\theta)X_{pt} - S^{-}$ and the insufficient output $\Delta Y_{pt} = S^{+}$ by the projection analysis based on the front surface.

We first use panel regression method to test the total impact of FDI on GTFP.

$$GTFP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 c_{it} + \varepsilon_{it} \quad (1)$$

Secondly, the mediating effect test is conducted to examine the channels that FDI affects GTFP.

$$GTFP_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 c_{it} + \varepsilon_{it} \quad (2)$$

$$GTFP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 X_{it} + \beta_3 c_{it} + \varepsilon_{it} \quad (3)$$

$GTFP_{it}$ is green total factor productivity of the i_{th} region in the t year. FDI_{it} is the core explanatory variable of this paper and refers to the foreign direct investment. X includes three variables: innovation level, R&D investment level and human capital accumulation level. The interaction term is mainly used to investigate the mediation effect of research hypothesis. To prevent endogeneity problems caused by missing variables, we control a set of variables influencing GTFP. ε_{it} is the random error.

In order to test the nonlinear impact of FDI on GTFP under different levels of marketization and environmental regulation, While further discussing the heterogeneous influence of FDI on GTFP under different levels of innovation, R&D investment and human capital accumulation, we adopt the panel threshold regression model proposed by Hansen(1999). The advantage of this model is that it not only estimates the threshold value, but also testes the significance of the endogenous "threshold effect". In this paper, environmental regulation level, marketization level, innovation level, R&D investment level and human capital accumulation level are taken as threshold variables respectively. The threshold panel model is following:

$$GTFP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 FDI_{it} I(Z_{it} < \delta) + \beta_3 c_{it} + \varepsilon_{it} \quad (4)$$

$GTFP_{it}$ is the same as shown above. Z_{it} includes Environmental regulation level, marketization level, innovation level, R&D investment level and human capital accumulation level, which were used as the threshold variables of shadow GTFP respectively. $I(\cdot)$ Is indicative coefficient; δ is the calculated threshold value, different threshold variables correspond to different threshold value; β_2 is the threshold regression coefficient of the core variable $FDI_{it}I$.

3.1. Variables

The explained variable: GTFP. The explained variable is GTFP, measured by three-stage DEA. In this paper, we select total energy consumption, material capital stock, the number of employees as input indicators. We also select GDP as the expected output indicator, and carbon dioxide emissions as the undesired output indicator. Considering at the second stage, we need to eliminate those facts that affect the efficiency of GTFP and cannot be change in a short time, including two key factors for full-time equivalent (FTE) of R&D and full-time equivalent (FTE) of R&D personal. GTFP is also affected by large development gap between provinces in China, particularly the economic gap, we select the secondary industry's proportion in GDP and the full-time equivalent (FTE) of R&D as environmental factors.

Table 1 Describe of Variables.

Variable type	Variable name	symbol	Variable description	unit	Mean	Standard deviation
Input variable	Energy Consumption	EC	Total energy consumption	10,000 tons of standard coal	10,779.18	7702.26

	Material Capital	MC	Physical capital stock	(people/10,000 yuan) (price in 2000)	17.45	58.88
	Labor input	Lab	Number of employed persons in urban	Ten thousand people	780.15	633.40
Output system	Economic development	Eco	*GDP*	yuan(Price in 2000)	9293.96	9305.57
	Carbon Emission	Co^2	Carbon dioxide emissions	Ten thousand tons	27513.56	21,524.37
Environmental factor	Industrial development	Ind	The proportion of the secondary industry in GDP	%	46.44	7.78
	R&D investment level	Rd	Full-time equivalent of R&D personnel	Person year	73,569.85	90,715.93

Core explanatory variable: FDI. FDI is measured by the ratio of actual utilization of foreign capital to GDP.

Control variables： (1) *Economic development level*, measured by per capita GDP; (2) *Energy structure*, measured by the proportion of thermal power generation in total power generation; (3) Infrastructure construction, measured by per capita urban road area; (4) *Population Quantity*, measured by the total population; (5) *Urbanization rate*, measured by the proportion of urban population in the total population; (6) *Physical capital accumulation level*, measured by the stock of physical capital; (7) *Investment level*, measured by the fixed assets of the whole society Total investment measurement.

Mediated variables and threshold variables: (1) *innovation level* measured by the number of domestic patent applications granted per capita; (2) *R&D investment level* measured by the full-time equivalent of R&D personnel; (3) *Human capital accumulation level* measured by actual labor human capital. The policy regulatory factors are represented by *Environmental Regulation (ER)* and *Marketization Degree (Market)*, *ER* is measured by the level of regional environmental regulation by the proportion of emissions tax levied in GDP, while *Market* is measured by the marketization index.

3.2 Data source

Considering available data, we exclude the data from Tibet, Hong Kong, Macau, and Taiwan. The panel datasets constructed by 30 provinces from 2000 to 2016 year. The primary data is calculated from the China Urban Statistical Yearbook and China's Energy Statistical Yearbook. The worth mention is the energy consumption data from the statistical Yearbooks of provinces, the marketization index measured from the Report with China's Marketization Index by Fan Gang(2019) and the human capital accumulation data comes from the actual labor human capital of each province calculated by the CHLR project[3]. The index of Carbon dioxide emissions collects from the eight types of energy consumption, including diesel consumption; coke consumption; coal consumption; kerosene consumption, gasoline consumption; fuel oil consumption; crude oil consumption; Natural gas consumption. Then evaluation the coefficient of energy conversion to the carbon. The inter-provincial material capital stock is calculated based on the relevant data and methods of Zhang Jun (2008), the measuring equation as $K_{it} = K_{it-1}(1 - \delta_{it}) + I_{it}$ .Table 2 shows

[3] http://humancapital.cufe.edu.cn/rlzbzsxm/zgrlzbzsxm2020.htm

the descriptive statistics of variables.

Table 2 Descriptive statistics of variables

Variable name	Variable name	symbol	Variable description	unit	Mean	Standard deviation
Explained variable	Green total factor productivity	*GTFP*	Efficiency after removing environmental interference factors	--	0.89	0.15
Core Explanatory variable	Foreign direct investment	*FDI*	Total foreign investment/gdp	%	0.434	0.542
	The level of economic development	*pgdp*	GDP per capita	Yuan / person	49.382	35.178
	Clean energy utilization	*ce*	Proportion of thermal power generation in total power generation	%	0.78	0.224
control variables	Infrastructure construction level	*inc*	Urban road area per capital	Square meter	12.069	4.336
	Population size	*pop*	population	Ten thousand people	2498.416	1670.947
	Urbanization rate	*urban*	The proportion of urban population in total population	%	48.175	15.307
	Social investment level	*inv*	Total investment in fixed assets of the whole society	Ten thousand yuan	116286.7	139419.6
	Material capital	*k*	Material capital accumulation level (price in 2000)	100 million yuan	17.448	58.88
	Innovation level	*inn*	Material capital accumulation level (price in 2000)	Pieces/10,000 people	4.233	7.175
Mediated variables and threshold variables	R&D investment level	*Rd*	Full-time equivalent of R&D personnel	Person year	73,569.85	90,715.93
	Human capital level	*rlab*	Labor force human capital	--	3598.689	2742.471
	Environmental regulation	*er*	The percentage of emissions tax in GDP	%	0.2418638	0.3610417
	Marketization level	*market*	Marketization index	--	6.642	2.083
Other variables	Energy consumption per unit of GDP	*enc*	Total energy consumption/gdp	ton of standard coal/yuan(Price in 2000)	1.99942	2.000756

Industrial structure	*ins*	The proportion of the secondary industry in GDP	%	46.437	7.778
Economic scale	*ec*	Gross national product	yuan(Price in 2000)	9293.956	9305.565
emission intensity	*ei*	Exhaust emissions(Sulfur dioxide;nitrogen dioxide;carbon dioxide)/gdp	TONE/ten thousand yuan(Price in 2000)	289.8263	332.4328

Note: The marketization index from the China's Marketization Index Report by Provinces.

4. Results

4.1 Baseline results

Considering the estimation bias caused by regional heterogeneity and time factors, the dynamic panel regression model with the two-way fixed effect is used to estimate the parameters, the estimation results are shown in column 1-3. The basic estimation result is shown in column 1, column 2 and 3 performs robustness test by replacing explained variables. In addition, considering traditional estimation methods are powerless in controlling potential endogenous problems, refer to Blundell et al. (2000), the system GMM method can be used to estimate the dynamic panel model, the estimation results are reported in column 4-6. As the results shown in column 1, the impact of FDI on regional GTFP is significantly positive at the 5% level with controlling series fixed affects, indicating that FDI will promote GTFP in China. As mentioned above, existing researches have been controversial on the relationship between FDI and GTFP, the empirical results of this paper prove the positive role of FDI in promoting GTFP. Although the purpose of foreign investment entering China is to seek relatively cheap production costs and relatively loose environmental regulations, and transfer industries with high pollution and high energy consumption from home country to China, however, the more standardized production process and technology brought by FDI can also effectively improve resources utilization and promote environment. We perform robustness test with replacing GTFP with energy consumption per unit of GDP(*ENC*) and emission intensity (*EI*) respectively, the estimation results are shown in column 2-3. The coefficients of *ENC* and *EI* is significantly negative at the 5% level, which once again proves the "pollution halo effect" of FDI in China. The column 4-6 list the estimation results of GMM model, we use the FDI term with a lag period as the instrumental variable. Although the regression results were not significant after replacing GTFP with ENC and EI, the coefficients direction was consistent.

Table3 Regression

	Two-Way Mixed Effects Model			**GMM model**		
	（1）	（2）	（3）	（4）	（5）	（6）
	GTFP	ENC	EI	GTFP	ENC	EI
FDI	0.0226**	-0.363**	-69.99**	0.0262*	-0.207	-31.54
	（2.37）	(-2.17)	(-2.13)	(1.91)	(-1.10)	(-0.92)
pgdp	0.00159***	-0.0359***	-5.923***	0.00225***	-0.0459***	-5.117***
	（4.91）	(-6.33)	(-5.81)	(4.21)	(-5.48)	(-3.42)
es	0.00166	-2.303**	-373.4	0.254*	-6.083***	-295.0

	（0.03）	(-2.22)	(-1.61)	(1.88)	(-3.12)	(-0.79)
Inc	0.00714***	-0.192***	-40.04***	0.00987***	-0.239***	-39.47***
	（4.73）	(-7.13)	(-8.25)	(4.04)	(-6.23)	(-5.67)
pop	-0.0000172	0.000562*	0.0492	-0.0000161	-0.0000209	0.0248
	(-0.91)	-1.71	-0.83	(-0.55)	(-0.05)	(0.31)
urban	0.000428	-0.0281***	-1.883	0.000878	-0.00522	-2.369
	（0.89）	(-3.44)	(-1.20)	(1.18)	(-0.46)	(-1.06)
inv	-0.000000104***	0.00000176***	0.000377***	-0.000000193***	0.00000315***	0.000441***
	(-4.56)	(4.32)	(5.08)	(-4.12)	(4.48)	(3.54)
k	0.00011	0.00449*	1.081**	0.0000184	0.00767**	1.358**
	（0.76）	（1.75）	（2.25）	(0.08)	(2.36)	(2.40)
PROVINCE、YEAR	Control	Control	Control	Control	Control	Control
_cons	0.727***	9.419***	1555.8***	0.503***	11.17***	1168.6***
	（9.9）	（7.29）	（5.43）	(3.96)	(6.12)	(3.43)
N	451	480	300	451	480	300

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses

4.2 Mechanism analysis

In order to investigate the underlying channels through which FDI may affect GTFP, we introduce the cross terms of innovation level (*Inn*), R&D investment level(*Rd*) and Human capital level(*Rlab*) and FDI respectively, and test the coefficients. The estimation results are shown in Table4.

The estimation results reported in columns (2), (4) show that the interaction terms of FDI and innovation level and R&D investment level have a significant inhibitory effect on GTFP at the 1%,5% level respectively. These results indicate that innovation and technology spillover brought by foreign direct investment does not improve regional green total factor productivity. As mentioned above, the positive effect of innovation and technology spillover requires certain conditions that local enterprises should have corresponding absorption and transformation capacity. If technology is only introduced in single-direction dissemination without improving absorptive capacity of local industries, the technology introduction brought by FDI will not improve the economic growth rate of the host country (Keller, 1998; SUYANTO, et al., 2010). Although China has actively introduced foreign investment since the 1980s, the technology absorption capacity of local enterprises is relatively weaker, especially for a large number of small and medium-sized companies, which can not find ways to move away from relying solely on technology import. This phenomenon is associated with the heterogeneous FDI, in the context of tournament-based organization, local governments of China tend to do its best to attract foreign investment to get the better of an adversary, so the quantity of FDI is more important than the quality of FDI for them. In addition, the goal of number of multinational enterprises and investments entering to China is to avoid environment costs, use an abundant supply of cheap labour and resources. These type of FDI without bring positive demonstration effect and promoting GFTP.

Table 4 Estimated results

	（1）	（2）	（3）	（4）	（5）	（6）

	GTFP	GTFP	GTFP	GTFP	GTFP	GTFP
FDI		0.0288***		0.0234**		0.0372***
		(2.87)		(2.46)		（-3.47）
Inn	-6.484**	-3.253				
	(-3.16)	(-1.14)				
Inn *FDI		-4.036*				
		(-1.65)				
Rd			-0.000000348***	-0.000000109		
			(-3.70)	(-0.71)		
Rd*FDI				-0.000000403*		
				(-1.82)		
Rlab					-0.0000214**	-0.0000149*
					(-2.88)	(-1.88)
Rlab*FDI						-0.0000199**
						(-2.50)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
PROVINCE、YEAR	Control	Control	Control	Control	Control	Control
_cons		0.776***		0.751***		0.769***
		(11.58)		(10.89)		（10.2）
N		451		451		451

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses

The estimation results reported in column (6) show that the interaction term between *FDI* and *Rlab* has a significant negative effect on GTFP with at 5% level, indicating that FDI does not promote regional GTFP in China through human capital spillover effect. Technological progress is inseparable from improving the quality of the population, for developing countries, the level of human capital directly affects the ability to imitate and absorb the advanced technology of developed countries, and determines whether developing countries can achieve economic catch-up with developed countries. This results reveal that multinational enterprises may not help local enterprises to train technicians, which participate in GVC as OEM (Haskel, et al., 2007), local Chinese employees do not take important positions such as R&D and senior management in enterprises.

4.3. Estimation results of Panel threshold regression

We use the Panel Threshold Regression model to further investigate the nonlinear impact of FDI on GTFP, estimation results are reported in Table 5. In order to select the appropriate number of thresholds and threshold values, it is necessary to conduct threshold tests on variables respectively. The results are reported in Table 5 show that marketization level(*Market*), innovation level(*Inn*), R&D investment level (*Rd*) and human capital level (*Rlab*) pass the double threshold test at the 1% significance level, and environmental regulation level (*ER*) pass the double threshold test at the 5% significance level. The threshold values obtained after the threshold effect test are (3.37,5.82), (2.182,3.095), (0.001,0.002), (4187.8,116842) and (466.564,8274.15) respectively.

Table5 Threshold effect test

Market	*Inn*	*Rd*	*Rlab*	*ER*

	F value	p value	10%	F value	p value	10%	F value	p value	10%	F value	p value	10%	F value	p value	10%
Single	80.102	0.000	29.154	18.856	0.020	8.550	52.413	0.000	6.216	80.932	0.000	37.988	17.238	0.02	9.905
Double	19.266	0.000	4.552	13.650	0.017	7.780	26.747	0.000	-20.286	28.703	0.000	2.967	3.855	0.057	2.942

Note: The *P* value is the result obtained after 300 simulations using the Bootstrap method

The estimation results in columns 1-3 (Table 6) show that when the marketization level is low, the coefficient of is FDI significantly negative, and as the marketization level breaks through the threshold value, the FDI coefficient becomes significantly positive. It indicates that in the early stage of economic openness with the high level of market segmentation and local protectionism, local governments aim to attract FDI and loose environmental standards. Moreover, due to the limited inter-regional factor flow, the technology and human capital spillover effect brought by foreign investment just have partially positive influence on the improvement of regional productivity. But with the increasing marketization level, the environmental benefits brought by FDI will quickly become apparent, relating to the local governments voluntarily restrict the standards to reject the FDI with potential environmental risks and strengthen regional cooperation. The estimation results in columns (4) - (7) show that even when the environmental regulation level is low, the coefficient of FDI is still significantly positive, and with the improvement of environmental regulation level, the coefficient of FDI keeps increasing. It indicates that if local governments start environmental governance, it is difficult for FDI with pollution risks to enter China, while clean FDI can effectively improve the clean production capacity of local enterprises. In the circumstances, foreign enterprises should strictly implement unified environmental standards and apply advanced clean technology in the production process. But if environmental regulation is too strict for multinational firms to get profit, it will withdraw from the market and find the other destination with lower environmental costs, local firms will lose the opportunity to learn by doing. The crowding-out effects can explain the negative impacts of FDI leading by strict environmental regulation on regional GTFP.

Table 6 Threshold regression

	Market			*ER*			
	<3.37	（3.37,5.82）	>=5.82	<2.182	(2.182,3.095）	(3.09,5.786)	>=5.786
FDI*I	-0.161***	-0.156***	0.195*	0.0438***	0.0660*	0.00755	-0.0251
	(-7.47)	(-7.36)	(1.76)	（2.84）	（1.84）	（0.24）	(-1.56)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.470***	0.526***	0.282***	0.507***	0.504***	0.504***	0.342***
	(12.60)	(13.51)	(6.32)	（13.27）	（13.22）	（13.22）	（8.35）
N	451	451	451	451	451	451	451

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses

Table 7 reports the further analysis of the innovation, technology and human capital spillover effect of FDI on GTFP. The estimation results in columns (1) - (3) show that when the independent innovation level of local enterprises is low, FDI has a significant negative impact on regional GTFP. However, with the local innovation level increasing, the environmental benefits of FDI will gradually emerge. It indicates that only when the local firms have the capacity to abort advanced technology, technology spillover effect of FDI can play positive role in promoting GTFP. On the contrary, if local firms can`t be able to digest the advanced technology with path dependence of technology import, FDI have negative influence on the development of indigenous innovation ability. The regression with R&D investment level and human capital accumulation level as

threshold variables has similar results.

Table7 Threshold regression

	Inn			*Rd*			*Rlab*		
	<0.001	(0.001,0.002)	>=0.002	<4187.8	(4187.8,116842)	>=116842	<466.564	(466.564,8274.15)	>=8274.15
FDI*I	-0.0869***	0.0782***	0.0899***	-0.0612***	0.0931***	0.0607**	-0.0927***	0.155***	0.245***
	(-4.04)	(3.53)	(3.72)	(-3.59)	(4.32)	(2.55)	(-4.83)	(2.99)	(5.11)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.643***	0.636***	0.386***	0.527***	0.520***	0.398***	0.429***	0.411***	0.289***
	(16.84)	(16.86)	(10.41)	(12.93)	(13.09)	(10.68)	(11.32)	(11.12)	(7.72)
N	451	451	451	451	451	451	451	451	451

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses

4.4. Heterogeneity analysis

Table 8 reports the group regression estimation results divided by economic region of China, showing that FDI have heterogeneous influences on GTFP in different economic regions. Columns (1), (2) report the estimation results of eastern and central regions. Although the coefficients are not significant, it can partially explain that FDI has a positive impact on GTFP in eastern and central regions. Meanwhile FDI play a significant negative impact on GTFP in western and northeastern regions. The results indicate that the regional heterogeneous affects brought by FDI on GTFP relating to regional development level and resource endowment, which has heterogeneity and needs further analysis.

Table8 Regional heterogeneity analysis

	Eastern	Central	Western	Northeastern
	GTFP	GTFP	GTFP	GTFP
FDI	0.0148	0.159	-0.221***	-0.246**
	(1.19)	(1.11)	(-2.85)	(-2.27)
Control variables	Yes	Yes	Yes	Yes
_cons	0.862***	0.825***	0.785***	1.024***
	(5.35)	(6.43)	(7.02)	(3.04)
N	136	105	165	45

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses；According to the division method of Chinese administrative regions, the provinces are divided into Northeastern, Eastern, Central, and Western China. The Northeastern provinces include Jilin, Liaoning, and Heilongjiang. The Eastern provinces include Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan. Central provinces include Henan, Hubei, Hunan, Anhui, Jiangxi, and Shanxi. The Western provinces include Chongqing, Sichuan, Guizhou, Yunnan, Guangxi, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Inner Mongolia.

According to the estimation results in Columns (2) and (3) of Table 9, we find that in regions with large economic scale (divided by the median of economic scale), FDI has no significant positive effect on GTFP, while in regions with small economic development scale, FDI can significantly improve GTFP. The possible reason is that, compared with the regions with smaller economic scale, the regions with larger economic scale have entered the development stage of diminishing marginal utility with the investment has tended to saturation, formed mature

development paths, so the environmental benefits brought by FDI are limited. The estimation results in Columns (4) and (5) show that the industrial structure level (divided according to the median value of industrial structure level) has significant impact on improving environmental benefits of FDI. In regions with more advanced industrial structure, the government sets a higher standard for investors, and prefer to the clean FDI with the development of environment-friendly industrial structure. At the same time, local enterprises can adopt foreign advanced technology and clean production model to improve production efficiency and reduce pollution.

Table 9 Regional heterogeneity analysis

	Regions with larger economies	Regions with smaller economies	Regions with high level of industrial structure	Regions with low level of industrial structure
	GTFP	GTFP	GTFP	GTFP
FDI	0.0111	0.0286**	0.0625***	-0.00284
	-0.61	-2.41	-5.45	(-0.09)
Control variables	Yes	Yes	Yes	Yes
_cons	1.050***	0.589***	0.809***	0.839***
	-11.79	-5.45	-6.83	-8.6
N	167	284	236	215

Note: * p < 0.10, ** p < 0.05, *** p < 0.01; Standard errors in parentheses. We divided regions into high-low level based on the median.

5.Conclusions

The relationship between environmental protection and economic growth has been a hot topic in the past decades, however, energy consumption has risen with countries' industrialization since the industrial revolution. As the world's biggest energy consumer, China should play an important role in fighting global warming and reducing carbon emission. The community of shared future for mankind proposed by the Chinese government focus on ecological crisis response with mobilizing international support. Especially, China tries to build an environment-friendly society, the clean production is an essential means to achieve this goal. This paper enriches the existing literature by discovering the potential effects of FDI on the Green total factor productivity of developing countries (especially the understudied region of China) and testing the threshold effects of regional marketization and environment regulation level and the absorptive capacity of local firms to analyze to what extent regional Green total factor productivity benefit from foreign investment.

First of all, the results show that FDI has a positive impact on regional GTFP in China. Based on these results, we verify the pollution halo effect of FDI, and argue the important role of FDI playing in promoting clean production and environmental protection in China. Second, through innovation spillover effect, technology spillover effect and human capital spillover effect, FDI has heterogeneous impacts on GTFP. Considering the absorption capacity of local firms, only when the innovation level, R&D investment level and human capital level break through the threshold values, the spillover effects of FDI can have positive impact on regional green total factor productivity. On contrary, the crowing effects of FDI may lead to a pollution paradise phenomenon. There is a nonlinear relationship between FDI and GTFP with different level of marketization and environmental regulation. With increasing improvement of marketization level, the environmental benefits of FDI decrease first and then increase, indicating that the free flow of factors and regional cooperation are helpful to weaken the crowding effects of FDI. However, results also show that there is a reciprocal U kink of regional environment regulation level. once local governments start environmental regulation, FDI have a positive impact on regional green total factor productivity.

However, if the environmental regulation level is close to a turning point, foreign capital will shift to other destinations for lower environmental cost. Generally speaking, environment regulation is benefit to regional sustainable development. Last, the impacts of FDI on GTFP represent the characteristics of regional heterogeneity. Western region and northeast region are the "pollution paradise" in China, and the environmental benefits of FDI vary in regions with different economic scales, and industrial structure levels.

Based on the results, it is necessary to set standards of the introduction of FDI to promote clean production in China. Due to the unique political system of China, local governments tend to attract FDI without considering potential ecological costs in the future, and participate in the economic competition rather than cooperate with neighbors, leading to the low environment benefits of FDI and waste of resources. Therefore, Chinese governments have to improve the multi-layered cooperation system to gradually reduce inefficiency caused by bad local competition. In addition, the governments also need to focus on cultivating the independent innovation capacity of local enterprises. FDI can bring advanced technology to China, but if local firms just depend on technology introduction rather than increase R&D investment, it will have negative impact on local industrial development in long period. To cultivate local technological market and high quality labor source market, the governments should provide more support including subsidy as well as infrastructure construction such as training school, community libraries and practical bases.

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Authors contributions

Jialu YOU: Literature review,Visualization, Final draft and editing;

H XIAO: Methodology, Software; Data curation, Writing Original draft.

Consent to participate

We, the authors (author and co-author), agreed to participate in this study on FDI and Green Total Factor Productivity in China without compulsion. This is a voluntary consent to participate in this research and we do agree on and with everything in the manuscript.

Consent for publication

We have read the author`s guide, rules and ethics for publication in Environmental Science and Pollution Research. All authors agree for the manuscript to be published in Environmental Science and Pollution Research.

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The authors declare that they have no competing interests.

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