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Original Research

Research on the Impact of Foreign Direct Investment Quality on Green Total Factor Productivity: Evidence from China

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Abstract

Green total factor productivity (GTFP) is an important indicator to measure the green development of the economy. In the context of increasing investment promotion, improving GTFP is an important means of promoting sustainable development. It is also an important way to promote low-carbon development. Based on the panel data of 29 provinces and cities in China (excluding Xinjiang, Tibet, Hong Kong, Macao and Taiwan) from 2011 to 2020, this paper adopts the entropy method to construct a comprehensive index of the quality of foreign direct investment (QFDI) and employs the systematic generalized method of moments (GMM) to estimate the impact of QFDI on GTFP. Meanwhile, this paper also uses the threshold model for further testing. The results show that QFDI has a significant positive effect on China's GTFP. In terms of dimensions, foreign capital with high technology spillover ability, high management level and high profitability has a significant promoting effect on GTFP. However, the positive effect of foreign capital scale is weak. And foreign capital export capacity has no significant effect on GTFP. The impact of QFDI on GTFP has a single threshold effect based on human capital and R&D investment. From a regional perspective, QFDI has a greater role in promoting GTFP in coastal areas than in inland areas. This paper provides important suggestions for policymakers to improve foreign investment policies and promote green development.

Keywords: quality of foreign direct investment, green total factor productivity, sustainable development, green development, GMM

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Introduction

In September 2020, China formally proposed the "dual carbon" goal of achieving carbon peak by 2030 and achieving carbon neutrality by 2060 at the 75th United Nations General Assembly. In 2021, the State Council issued the "Guiding Opinions on Accelerating the Establishment and Perfection of an Economic System for the Development of Green and Low-carbon Cycles," which pointed out that it is necessary to establish and improve an economic system for the development of green and low-carbon cycles. The government should ensure the realization of peak carbon and carbon neutrality targets and promote China's green development to a new level [1]. Green has become an important direction that should be followed in order to achieve sustainable economic development. In this context, the green total factor productivity (GTFP) index, measured by introducing undesired outputs such as SO_2 and CO_2, water resource consumption, and land built-up area into the input and output function have gradually attracted the attention of scholars [2, 3]. The improvement of GTFP is the result of the coordinated development of social economy, resources and environment. How to improve the efficiency of enterprises under the existing resource conditions and promote the improvement of social GTFP is the key to achieve sustainable economic development.

In 2023, the work report of the Chinese government singled out "foreign investment" as an important element. The government emphasized the need to increase the attraction and utilization of foreign investment [4]. As an important part of international long-term capital flows, foreign direct investment (FDI) can have an impact on the host country's economy through ways such as increasing capital, promoting employment, and technology spillovers. It is worth noting that although the number of foreign investments utilized by China is increasing year by year, the motives and types of industries in which foreign investment enters the host country are different. The impact of this on the host country's economy also varies considerably. At present, it is still unclear whether the quality of foreign direct investment (QFDI) introduced into China has steadily improved and whether foreign investment has pushed the economy in a green direction.

Most of the existing literature is based on the panel data of Chinese provinces and cities and examines the impact of QFDI and its characteristic dimensions on GTFP from the perspective of the quantity of (FDI). By constructing the QFDI composite index, this paper focuses on the impact of QFDI and its characteristic dimensions on GTFP. And this paper further examines the possible threshold effect and regional heterogeneity. The contribution of this paper is as follows. First, this paper constructs the QFDI composite index by entropy value method to investigate the impact of its quality on GTFP. Secondly, it examines the impact of QFDI on GTFP from the five characteristic dimensions of QFDI and clarifies what characteristics of FDI can promote the green development of the host country. Thirdly, based on the threshold model, human capital (HUM) and R & D investment (RD) variables are selected to measure the ability of the region to absorb FDI. This can shed light on how the absorptive capacity of the host country affects the green development effect of QFDI. Fourthly, the sample provinces and cities are divided into coastal and inland areas to test the regional heterogeneity of QFDI's impact on GTFP, which can provide reference for promoting regional green and sustainable development through differentiated investment attraction strategies. The research conclusions can provide a useful reference for China to grasp the direction of attracting investment and drive sustainable economic development through high-quality foreign investment, and provide experience for countries similar to China's economic development.

Literature Review

On the measurement method of GTFP, the early application is more for stochastic frontier analysis (SFA) and data envelopment analysis (DEA). However, the parametric method represented by SFA has difficulties dealing with the situation of multiple inputs and outputs, and the setting of production function is subjective. Most of the literature uses DEA to measure GTFP. Chung (1997) [5] proposed the Malmquist-Luenberger (ML) index, which decomposes GTFP into technological progress and technical efficiency. Subsequently, the measurement method combining ML index and DEA model has been widely used in the world [6, 7]. At the same time, some scholars have found that the ML index model is sensitive to the sample period and may have no feasible solution. In order to overcome the shortcomings of the ML index, Oh (2010) [8] proposed the Global Malmquist-Luenberger (GML) index based on ML. Some scholars have also improved the DEA model by introducing the slack of input and output to estimate the direction distance function, which is called the Slacks-Based Measure (SBM) model [9].

Regarding the impact of FDI on GTFP, the existing scholars' research views can be roughly divided into the following categories. First, it is believed that FDI has a significant positive effect on GTFP, supporting the "pollution halo" hypothesis [10]. Wang (2019) [11] found that agricultural FDI has a significant promoting effect on agricultural GTFP and its decomposition terms. Second, it is believed that FDI has a significant inhibitory effect on GTFP, supporting the "pollution haven" hypothesis [12]. Li (2022) [13] used the panel data of 260 prefecture-level cities in China to empirically believe that FDI will significantly reduce the level of GTFP in prefecture-level cities by reducing the level of green technology progress. For every 1% increase in foreign direct investment intensity, the average level of GTFP decreases by 4.1%. Third, it is believed that FDI has no significant impact on GTFP, but the benign interaction with other factors can promote the growth of GTFP. For example, some scholars believe that the coordinated development of FDI with factors such as industrial structure (OIS) optimization [14], outward direct investment [15, 16], and system [17] can promote the improvement of China's GTFP level. In addition, the impact of FDI on GTFP has industrial or regional heterogeneity. For example, Cui (2019) [18] found through empirical research that FDI has a more significant promotion effect on GTFP in the eastern part of China as well as in the light textile and machinery manufacturing industries. Zhao (2020) [19] argued that FDI in the upstream region of the Yellow River in China has a positive impact on GTFP, while FDI in the middle and lower reaches of the river has a negative impact on GTFP. Fu (2018) [20] distinguishes the sources of FDI. They argued that FDI from Hong Kong can boost China's GTFP, while FDI from Japan inhibits the growth of GTFP.

In summary, the existing literature does not effectively distinguish between the "quantity" and "quality" of FDI when examining its impact on global total factor productivity. They only examine the impact of FDI on global total factor productivity from a quantitative perspective. However, a study that treats FDI as homogeneous is biased, because it does not explain which characteristics of FDI bring benefits to importing countries.

Hypothesis Formulation

High-quality foreign investment is usually characterized by higher profitability, management and technological spillovers. These contribute to productivity and green development in host countries. For example, in terms of profitability, foreign capital with high profitability can increase local government revenue. According to the environmental Kuznets theory, regional environmental quality will be improved while income growth. The improvement of environmental quality is conducive to the further development of the local economy and the increase of green total factor productivity. At the same time, foreign-funded enterprises with strong profitability will have more surplus funds for green innovation. This can increase green output and promote the growth of GTFP. In terms of management level, the stronger the management ability, the stronger the ability of foreign capital to allocate resources. It is more conducive to enterprises to broaden the production possibility boundary under the existing technical level. The higher the management level of a foreign-funded enterprise, the more its managers tend to follow the government's environmental protection system. This is conducive to the development of green innovation and energy saving and emission reduction. At the same time, this demonstration effect will also promote the green production of more enterprises.

The higher the level of technology spillover of foreign capital, the more the host country benefits from the advanced technology or equipment and management experience of foreign-funded enterprises. The environmental systems of developed countries are relatively strict, and foreign capital holds an advantageous position in terms of environmental management technology. Host countries can capitalize on the technological advantages of foreign investment to improve the construction of local environmental infrastructure projects. This will promote the diffusion of advanced environmental technology throughout society. Through technology spillovers, host countries can make leaps in their own technology in a relatively short period of time. This is because the cost of innovation and development is smaller and less risky than that of independent R&D. In terms of average scale, when the scale of foreign-funded enterprises is large, it is easier to achieve economies of scale in production and reduce the average production cost. Its capital and talent reserves are generally more abundant, which is conducive to the RD and innovation of enterprises. The entry of foreign capital will intensify the market competition in the host country, forcing local enterprises to increase RD and accelerate green innovation to maintain or enhance their market competitiveness. In this process, the production technology level and labor efficiency of domestic enterprises can be rapidly transformed. Based on this, the study proposes the following hypothesis:

Hypothesis 1: QFDI has a positive effect on GTFP.

At the same time, the host country's ability to absorb FDI directly affects the strength of FDI spillover effects. When a region's technology absorptive capacity is very weak, it cannot really translate technology into their own production activities. Excessive technology gap and low HUM level are not conducive to the spillover of FDI low-carbon technology [21]. When the level of human capital is within the appropriate range, firms can fully utilize the positive impact of human capital. Higher levels of technology and more efficient production will enable enterprises to gain more benefits. This is also conducive to enterprises to improve their competitiveness by utilizing foreign capital, and this advantage can only be utilized if the absorptive capacity of the enterprise reaches a certain level. This requires enterprises to improve themselves through technological innovation. In addition, the inflow of foreign capital will form a certain crowding-out effect on domestic capital. This may not result in high-quality FDI. If the regional absorptive capacity is strong, local enterprises can quickly absorb the advanced production technologies and clean environmental protection technologies. So that the spillover effect and demonstration effect of FDI can be brought into full play. This can promote the sustainable development of the local economy. Many scholars use two variables of RD and HUM to measure the region's absorptive capacity and independent innovation capability. Based on this, the study proposes the following hypothesis:

Hypothesis 2: The impact of QFDI on GTFP has a threshold effect based on RD.

Hypothesis 3: The impact of QFDI on GTFP has a threshold effect based on HUM.

Material and Methods

Model Setting

Considering that the growth of GTFP is a gradual process, there may be an accumulation effect. Therefore, the research adopts the dynamic panel model, adds the lag term of GTFP, and uses the two-step system GMM estimation for regression analysis to alleviate the endogenous problem of the model. The model is specifically set as follows:

$$\ln GTFP_{it}=\alpha_1+\alpha_2\ln GTFP_{it-1}+\alpha_3\ln QFDI_{it}+\alpha_4\ln MX_{it}+\alpha_5\ln HUM_{it}+\alpha_6\ln OIS_{it}+\alpha_7\ln RD_{it}+\alpha_8\ln URB_{it}+\alpha_9\ln ER_{it}+\alpha_{10}\ln MAR_{it}+\varepsilon_{it} \quad (1)$$

In Equation (1), i denotes province or municipality, t denotes time. $GTFP_{it-1}$ is the one-period lag of GTFP. MX, HUM, OIS, RD, URB, ER, MAR represent foreign trade, human capital level, industrial institutions, green innovation inputs, urbanization level, environmental regulation and marketization. α_i is the coefficient of explanatory variables, ε_{it} is the error term.

The interval division of the threshold model of [22] is based on the characteristics of the data itself, which can not only explore the determined threshold value, but also avoid model errors caused by human factors. Therefore, based on Hansen's method, the following panel threshold model is constructed:

$$\ln GTFP_{it}=\beta_0+\beta_1\ln QFDI_{it}I(RD\le\rho_1)+\beta_2\ln QFDI_{it}I(\rho_1<RD\le\rho_2)+\ldots+\beta_n\ln QFDI_{it}*I(\rho_{n-1}<RD\le\rho_n)+\beta_{n+1}\ln QFDI_{it}I(RD>\rho_n)+\beta\Sigma X+\varepsilon_{it} \quad (2)$$

$$\ln GTFP_{it}=\gamma_0+\gamma_1\ln QFDI_{it}I(HUM\le\sigma_1)+\gamma_2\ln QFDI_{it}I(\sigma_1<HUM\le\sigma_2)+\ldots+\gamma_n\ln QFDI_{it}I(\sigma_{n-1}<HUM\le\sigma_n)+\gamma_{n+1}\ln QFDI_{it}I(HUM>\sigma_n)+\sigma\Sigma X+\varepsilon_{it} \quad (3)$$

In Equations (2, 3), ρ and σ are threshold values. I (·) is the indicator function. β_i and γ_i represent the influence coefficient of QFDI on GTFP when RD or HUM is at a specific level. ΣX is the control variable.

Variables Selection

The GTFP level of each province in China was calculated using the SBM directional distance function and the GML index. First, the SBM model was used to construct the production possibility set and the directional distance function that includes undesirable outputs, as illustrated in Equations (4,5):

$$P^t(x^t)=\left\{\begin{array}{c}(y^t,b^t):\sum_{i=1}^{I} Z_i^t y_{im}^t \ge y_{im}^t,\forall m;\\ \sum_{i=1}^{I} Z_{ik}^t b_{ik}^t=b_{ik}^t;\sum_{i=1}^{I} Z_i^t y_{in}^t \le x_{im}^t,\forall n;\sum_{i=1}^{I} Z_i^t=1,Z_i^t\ge 0,i=1,\ldots,I\end{array}\right\} \quad (4)$$

In Equation (4), $P^t(x^t)$ represents the production possibility set, $Z_i t$ represents the cross-sectional observation weights, x represents input factors, y represents desired outputs, b represents undesirable outputs; n (n = 1,...,N), m (m = 1,...,M), and k (k = 1,...,K) represent the number of input factors, desired output, and undesirable outputs, respectively.

$$S_V^G(x^{t,i'},y^{t,i'},b^{t,i'},g^x,g^y,g^b)=\max_{s^x,s^y,s^b}\frac{\frac{1}{N}\sum_{n=1}^{N}\frac{S_n^x}{g_n^x}+\frac{1}{M+1}\left(\sum_{m=1}^{M}\frac{S_m^y}{g_m^y}+\sum_{k=1}^{1}\frac{S_k^b}{g_k^b}\right)}{2}$$

$$\text{s.t.}\sum_{i=1}^{I} Z_i^t x_{in}^t+S_n^x=x_{i'n}^t,\forall n;\ \sum_{i=1}^{I} Z_i^t y_{im}^t-S_m^y=y_{i'm}^t,\forall m;$$

$$\sum_{i=1}^{I} Z_i^t b_{ik}^t+S_k^b=b_{i'k}^t,\forall k;$$

$$\sum_{i=1}^{I} Z_i^t=1,Z_i^t\ge 0,\forall n;S_m^y\ge 0,\forall m;S_k^b\ge 0,\forall k \quad (5)$$

Table 1. Input-Output Indicators.

Variables	Primary indicator	Secondary indicator
Green total factor productivity (GTFP)	Input	Capital stock (unit: 100 million yuan).
		Total energy consumption (unit: 10,000 tons).
		End-of-year employment figure for each province (unit: 10,000 persons).
	Desired output	Gross regional product (unit: 100 million yuan).
	Undesirable output	Regional CO_2 emissions and industrial SO_2 emissions (unit: 1 million metric tons).
		Wastewater (unit: 10,000 metric tons). General industrial solid waste volume (unit: 10,000 metric tons).

In Equation (5), $(x^{t,i'}, y^{t,i'}, b^{t,i'})$ represent the input, desired output, and undesirable output vectors for the i'th province. (g^x, g^y, g^b) represents the direction vectors for input, desired output, and undesirable output, respectively. (S^x_n, S^y_m, S^b_k) represents the slack vectors of inputs and outputs.

Based on this, the GML index was calculated, and the specific formula is as follows:

$$GML_t^{t+1} = \frac{1+S_V^G(x^t, y^t, b^t; g)}{1+S_V^G(x^{t+1}, y^{t+1}, b^{t+1}; g)} \quad (6)$$

GML productivity index is a concept that represents the change in GTFP between two successive periods. $GML_t^{t+1}>1$ indicates an enhancement in GTFP in the t+1 period, compared to the t period, while the opposite indicates a decline in GTFP. Following [23], the study set the GTFP value in 2011 as 1 and, through cumulative multiplication, gradually calculated the GTFP values for each province/municipality in China.

Table 1 presents the input-output indicators the study used to calculate the GTFP. The calculation of capital stock follows [24], where they conducted the estimation using the total fixed asset investment. The specific formula for calculating the capital stock is as follows:

$$\pi_{it} = \pi_{it-1}(1-\delta_{it}) + Q_{it} \quad (7)$$

π_{it} represents the capital stock of province i in year t, Q represents the total fixed asset investment, and δ is the depreciation rate of fixed capital, set at 9.6% [24].

Explanatory Variable

Domestic and foreign scholars have not reached a consistent conclusion on the evaluation of FDI quality. FDI can bring knowledge spillover and technological innovation to the importing country, which is the flow of a package of resources including capital, management and production. This article refers to the research of scholars such as [25] and [26]. Based on the availability and authority of data, the QFDI is investigated from five aspects, as shown in Table 2. Among them, if the export orientation of FDI is higher, it shows that the entry of foreign capital is more about seeking cheap labor and resources. When subject to ER, in order to reduce costs, these foreign capitals are more likely to choose to move into other industries or withdraw directly than to make technical improvements. On the contrary, if the export orientation of foreign capital is low, these foreign capitals are more likely to seek huge domestic markets. When this part of foreign capital is subject to ERs, it is more inclined to improve technology and find or develop green products to maintain a competitive advantage [27]. Therefore, this study believes that FDI with lower export orientation can more effectively promote the green development of the host country's economy, and its quality is higher.

The entropy method is used to calculate the index weight. Firstly, the index data of each dimension of FDI is dimensionless processed to make it standardized between [0,1]. The entropy method is used to weight the indexes of each dimension of FDI, and the weight is multiplied by the standardized normative value. Finally, the QFDI composite index of each region is obtained by weighted summation. The specific calculation steps are as follows:

The study performed data standardization using the following Equations (8,9), where i represents the province (i = 1,,29), while j denotes the measurement indicator (j = 1,…,5), X_{ij} represents the value of the jth indicator of the kth province, and X'_{ij} represents the standardized value of the jth indicator of the kth province:

Positive indicators:

$$X'_{ij} = \frac{X_{ij} - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}} \quad (8)$$

Negative indicators:

$$X'_{ij} = \frac{\max\{X_j\} - X_{ij}}{\max\{X_j\} - \min\{X_j\}} \quad (9)$$

The calculation of information entropy for each dimension indicator is illustrated in Equation (10), where *u* represents the number of years (the selected

Table 2. Dimensions of QFDI indicators.

First grade index	Second index	Measure index	Indicator direction
Quality of foreign direct investment (QFDI)	Export capacity	Export volume of foreign-funded enterprises / total regional export volume	Negative
	Average scale	The actual utilization of foreign capital in the region / the number of foreign-funded enterprises in the region	Positive
	Technology spillover	Actual utilization of foreign capital / fixed investment of the whole society	Positive
	Management level	The asset contribution rate of FDI industry / the asset contribution rate of above-scale industry	Positive
	Profitability	FDI industry cost profit margin / above-scale industry cost profit margin	Positive

Table 3. Descriptive statistical results of variables.

Variables	Mean	Std. dev	Minimum	Maximum
GTFP	1.091	0.139	0.869	1.844
QFDI	0.257	0.107	0.097	0.686
R & D investment (RD)	0.017	0.011	0.002	0.064
Human capital (HUM)	9.253	0.931	7.474	12.782
Foreign trade (MX)	0.271	0.300	0.008	1.548
Industrial structure (OIS)	0.429	0.089	0.158	0.591
Urbanization level (URB)	0.586	0.122	0.350	0.896
Environmental regulation (ER)	0.743	0.178	0.228	0.989
Marketization degree (MAR)	6.955	1.998	2.330	12.000

QFDI indicator data in this study covers the years 2011-2020, and thus u = 10):

$$E_j=-\frac{1}{\ln(u)}\sum_{i=1}^{u}\frac{X'_{ij}}{\sum X'_{ij}}\ln\frac{X'_{ij}}{\sum X'_{ij}} \quad (10)$$

The calculation of weights for each indicator is illustrated in Equation (11):

$$W_j=\frac{1-E_j}{\sum_{j=1}^{5}(1-E_j)} \quad (11)$$

The calculation of the composite QFDI index is illustrated in Equation (12):

$$QFDI=\sum_{j=1}^{5}W_jX'_{ij} \quad (12)$$

Other Variables

Threshold variables include: (1) RD, which is expressed by the ratio of regional R & D internal expenditure to GDP. (2) HUM, expressed by the average years of education in each region.

Other control variables include: (1) OIS, which is represented by the ratio of the added value of the secondary industry to GDP. (2) URB, calculated by the regional urban population / total population. (3) MX, calculated by the regional total import and export trade / GDP. (4) ER, we used the entropy method and selected regional industrial wastewater emission data (industrial wastewater, SO2, and soot) to comprehensively evaluate ah regional ER level. The specific formulas are the same as Equations (8-12). (5) MAR, using the marketization index reported by [28], the latest year data is extrapolated from the report.

Data Declaration

Due to the lack of some year data in Xinjiang, Tibet, Hong Kong, Macao and Taiwan in China, the study analyzes the panel data of 29 provinces and cities in China (excluding Xinjiang, Tibet, Hong Kong, Macao and Taiwan), with a year span of 2011-2020. The data come from "China Statistical Yearbook," "China Industrial Statistical Yearbook," "China Environmental Statistical Yearbook," and statistical bulletins or yearbooks of various provinces and cities. The study used the interpolation method to fill in individual missing data. Table 3 is the descriptive statistical results of the relevant variables.

Results and Analysis

Benchmark Regression Analysis

Table 4 is the dynamic panel regression results. In the process of adding variables one by one, the QFDI coefficient is significantly positive. The AR(1) in column (7) is -2.19 with a p-value of 0.029 which indicates that the model rejects the null hypothesis at the 5% level. The AR(2) is 0.76 with a p-value of 0.447 which indicates that the model is not autocorrelated. The P value of the Hansen test is greater than 0.1, and the null hypothesis is accepted, which shows the validity of the selected instrumental variables. The QFDI coefficient in column (7) is 0.087, indicating that QFDI has a positive effect on GTFP. When QFDI increases by 1%, it will promote GTFP growth by 0.087%, hypothesis 1 is established. High-quality foreign capital can improve the green technology level of enterprises through the spillover of high-tech, increase the income of host countries through its high profitability, increase RD and accelerate green innovation of local enterprises through demonstration imitation and market competition effect, and ultimately promote the improvement of GTFP and the sustainable development of economy.

Regarding the other variables in column (7), the coefficients of RD, HUM, ER and MAR are significantly positive, which has a certain role in promoting the improvement of GTFP. The influence coefficient of OIS is negative, indicating that the growth of the proportion of the secondary industry in China is not conducive to the improvement of GTFP. The possible

Table 4. Dynamic panel regression results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	GTFP	GTFP	GTFP	GTFP	GTFP	GTFP	GTFP
LnGTFP (-1)	1.133*** (134.37)	1.006*** (102.03)	1.002*** (79.57)	0.920*** (22.58)	0.922*** (48.42)	0.886*** (20.48)	0.913*** (21.70)
LnQFDI	0.117*** (13.96)	0.082* (1.71)	0.081** (2.23)	0.077*** (4.75)	0.074** (2.25)	0.088*** (4.04)	0.087*** (4.44)
LnMX	-0.026** (-2.25)	-0.037*** (-9.82)	-0.038 (-0.20)	-0.087** (-2.37)	-0.052** (-2.26)	-0.117*** (-8.44)	-0.090* (-1.76)
LnHUM		0.374*** (11.37)	0.403*** (11.05)	0.195* (1.92)	0.319*** (5.27)	0.018 (0.17)	0.314** (2.06)
LnOIS			-0.004 (-0.20)	-0.071** (-2.15)	-0.015 (-1.33)	-0.009 (-0.25)	-0.081** (-2.19)
LnRD				0.139*** (6.05)	0.086** (2.08)	0.203** (2.15)	0.190*** (4.73)
LnURB					-0.047*** (-3.67)	-0.019* (-1.76)	-0.207*** (-2.58)
LnER						0.148* (1.90)	0.116* (1.75)
LnMAR							0.071** (2.35)
C	0.140*** (12.66)	-0.751*** (-8.74)	-0.816*** (-9.14)	0.204 (1.14)	-0.374** (-2.08)	0.689** (2.09)	0.062 (0.26)
AR (1)	-2.63 (0.009)	-2.66 (0.008)	-2.65 (0.008)	-2.21 (0.027)	-2.52 (0.012)	-1.77 (0.077)	-2.19 (0.029)
AR (2)	1.24 (0.214)	0.92 (0.360)	0.87 (0.382)	1.03 (0.303)	1.34 (0.18)	1.22 (0.222)	0.76 (0.447)
Hansen	24.72 (0.311)	22.76 (0.357)	22.58 (0.310)	22.85 (0.244)	23.95 (0.245)	20.67 (0.241)	22.24 (0.222)

Note: ***, **, * respectively represent 1 %, 5 %, 10 % significance level, the following table is the same. The explanatory variable is z value in parentheses. The p value is in the parentheses of AR (1), AR (2) and Hansen, and the following table is the same.

reason is that China is still in a period dominated by traditional manufacturing, and the rapid development of industrialization often comes with energy consumption or negative impact on the environment. The influence coefficient of URB is negative. The possible reason is that if resources and environment are considered, the quality and speed of urbanization development in China do not match, and the utilization rate of resources in some areas is low, which makes the URB play a negative role in GTFP. The impact of MX on GTFP is also negative. The possible reason is that in the international division of labor, China's export structure is mainly based on processing trade, which will have a negative impact on domestic energy and environment.

It is more conducive to enterprises to broaden the production possibility boundary under the existing technical level while promoting the rational utilization of resources. The higher the management level of foreign-funded enterprises, the more strictly their management tends to abide by the relevant environmental systems of the government and strive to carry out green innovation and energy conservation and emission reduction, which will also form a better demonstration effect and promote green production of more enterprises.

Robustness Test

Fixed effect (FE) generalized the least squares (GLS) and one-step system GMM estimation were used for regression analysis. The regression results of the first two estimation methods are shown in column (1) and column (2) in Table 5. The QFDI coefficients are 0.067 and 0.074, which are significant at 5% and 10% levels, respectively. The regression results of one-step system GMM estimation are shown in Column (3) of Table 5. The QFDI coefficient is 0.081, which is significant at the 1% level, and the results of AR and Hansen tests meet the requirements. The influence coefficients of QFDI obtained by the above three estimation methods are all positive, which is consistent with the previous two-step system GMM estimation results, indicating the robustness of the previous regression results. In order to avoid the possible influence on the estimation results due to the existence of outliers in the variables, the two-step system GMM estimation is re-used for regression

Table 5. Robustness test results.

Variables	(1)	(2)	(3)	(4)
	FE	GLS	One-step system GMM	Winsorize
LnGTFP (-1)			0.860*** (60.70)	0.920*** (55.07)
LnQFDI	0.067** (2.42)	0.074* (1.78)	0.081*** (3.20)	0.084** (2.36)
Control variable	Control	Control	Control	Control
C	0.178** (2.35)	-0.977* (-1.73)	-1.056*** (-2.63)	0.037** (2.51)
AR (1)			-2.45 (0.014)	-2.59 (0.010)
AR (2)			-1.45 (0.147)	-0.90 (0.367)
Hansen			25.87 (0.993)	24.46 (0.986)

Note: (1) and (2) are t values in parentheses. The explanatory variables of (3), (4) and (5) are z values in parentheses.

Table 6. Quantile regression results.

Variables	(1)	(2)	(3)
	τ = 25%	τ = 50%	τ = 75%
LnQFDI	0.069*** (2.68)	0.092** (2.16)	0.076** (2.31)
Control variable	Control	Control	Control

Note: z value in parentheses.

after removing the 1% maximum and minimum values of the explanatory variables and explanatory variables. As shown in column (4) of Table 5, the QFDI coefficient is 0.084, which is significant at the 5% level, which is not much different from the influence coefficient of QFDI (0.087) in the previous benchmark regression. This further shows that the previous regression results are robust and effective.

The study also divides the samples according to the 25%, 50% and 75% quantiles of GTFP, and uses quantile regression to study the direction and degree of influence of QFDI on GTFP at different quantiles, so as to test the robustness of the benchmark regression results. The regression results are shown in Table 6. For GTFP at different quantiles, the influence of QFDI on it is slightly different, but the direction of influence is positive. Among them, QFDI has the greatest positive effect on GTFP at 50% quantile, with a coefficient of 0.092. The quantile regression results show the robustness of the original model estimation to a certain extent.

Table 7 shows the results of sub-dimensional regression. Among them, the FDI technology spillover coefficient is the largest, which is 0.091, which is significant at the 5% level, indicating that FDI characterized by high-tech spillover ability has the greatest promotion effect on GTFP. Secondly, the level of FDI management is 0.059, which is significant at the level of 1%, indicating that every 1% increase in FDI management level promotes 0.059% increase in China's GTFP. The coefficient of FDI profitability is significantly 0.026 at the 5% level, indicating that FDI with high profitability also has a certain role in promoting GTFP. Although the average scale coefficient of FDI has passed the significance test, the influence coefficient is small, indicating that the increase of FDI scale has a weak effect on China's GTFP. At the same time, it can be seen that the average scale coefficient of FDI is much smaller than the QFDI coefficient (0.087) in the previous benchmark regression analysis, indicating that the "FDI quantity" oriented investment attraction policy cannot give full play to the driving role of foreign investment in China's economic green development. The export capacity coefficient of FDI did not pass the significance test, and the foreign capital with high export tendency had no significant impact on GTFP.

Regional Heterogeneity Analysis

Table 8 is the result of regional heterogeneity regression. In this paper, 29 provinces are divided into coastal and inland areas by referring to [29, 30]. The QFDI coefficient of the coastal area is 0.089, which

Table 7. Sub-dimensional regression results.

Variables	(1)	(2)	(3)	(4)	(5)
	GTFP	GTFP	GTFP	GTFP	GTFP
LnGTFP (-1)	0.955*** (82.59)	0.989*** (87.25)	0.928*** (57.15)	0.941*** (54.39)	0.897*** (22.09)
Export capacity	-0.006 (-0.95)				
Average scale		0.008* (1.77)			
Technology spillover			0.091** (2.08)		
Management level				0.059*** (3.25)	
Profitability					0.026** (2.33)
Control variable	Control	Control	Control	Control	Control
C	-1.226*** (-10.65)	-0.360*** (-3.66)	-1.249*** (-9.85)	-0.867*** (-6.77)	0.026 (0.881)
AR (1)	-2.92 (0.003)	-2.85 (0.004)	-2.97 (0.003)	-2.81 (0.005)	-2.76 (0.006)
AR (2)	1.48 (0.139)	0.99 (0.323)	1.43 (0.154)	1.46 (0.143)	1.16 (0.246)
Hansen	23.62 (0.211)	22.02 (0.231)	23.03 (0.236)	23.43 (0.175)	21.85 (0.239)

Note: The z value is in the explanatory variable brackets.

is significant at the 1% level, indicating that each 1% increase in QFDI in the coastal area will increase its GTFP by 0.089%. The coefficient of QFDI in inland areas is 0.035, which is significant at 5% level. The results show that the effect of QFDI on GTFP in coastal areas is greater than that in inland areas. The possible reason is that coastal areas with high economic development level and good industrial foundation are more attractive to foreign investment. Under the concept of green development, most coastal areas continue to raise the entry threshold for foreign investment and are more inclined to introduce high-tech foreign investment. The "neighbor group" effect is also an important way for enterprises in coastal areas to acquire knowledge and improve technology. The economic development of inland areas can also enjoy the benefits of foreign direct investment. However, compared with the coastal areas, the introduction of FDI in inland areas is relatively late, the scale is small, and the number of foreign-funded enterprises is relatively small. Some enterprises are in relatively remote areas, which is not conducive to the exchange and learning between enterprises. The "cluster effect" of enterprises is not obvious in coastal areas. At the same time, due to the constraints of regional economic development, HUM level and other factors, the ability of inland areas to absorb high-quality FDI is limited. This weakens the contribution of FDI in the interior to GTFP.

Table 8. Regional heterogeneity regression results.

Variables	Coastal	Inland
	(1)	(2)
LnGTFP (-1)	1.208*** (8.67)	0.820*** (24.36)
LnQFDI	0.089*** (2.97)	0.035** (2.27)
Control variable	Control	Control
C	-3.501** (-2.45)	0.316 (0.65)
AR (1)	-2.57 (0.010)	-2.07 (0.039)
AR (2)	-0.29 (0.772)	0.20 (0.840)
Hansen	1.63 (0.850)	12.28 (0.997)

Notes: The z value is in the explanatory variable brackets.

Threshold Regression Analysis

As shown in Table 9, the RD variable passed the single threshold test at a significant level of 10%. The P values of other thresholds were all greater than 0.1, which did not pass the test, indicating that the impact of QFDI on GTFP had a single threshold effect

Table 9. Threshold existence test.

Threshold variables	Threshold number	F	P	BS	Critical value		
					1%	5%	10%
RD	Single	32.19	0.053	300	40.701	32.680	25.838
	Double	36.06	0.146	300	83.415	57.921	44.294
	Triple	15.59	0.496	300	97.476	73.210	56.556
HUM	Single	51.77	0.003	300	47.256	35.415	29.593
	Double	29.37	0.153	300	88.519	63.481	42.747
	Triple	21.76	0.426	300	94.440	51.374	40.752

Table 10. Threshold estimates and confidence intervals.

Threshold variables	Threshold number	Estimated value	Confidence interval
RD	Single	0.041	[0.015, 0.056]
HUM	Single	10.016	[9.504, 11.054]

based on RD, and hypothesis 2 was established. Variable HUM also only passes the single threshold test, which is significant at the 1% level, indicating that the impact of QFDI on GTFP has a single threshold effect based on HUM, and Hypothesis 3 is established. It can be seen from Table 10 that the threshold value of RD is 0.041, and the threshold value of HUM is 10.016. According to the sample data, most regions in China have not reached the threshold value of RD and HUM.

Table 11 is the threshold regression results. When the RD level is lower than the threshold value (0.041), the influence coefficient of QFDI is 0.021, which is significant at the 10% level. It shows that every 1% increase in the quality of FDI can promote the growth of GTFP by 0.021%. When the RD level crosses the threshold value, the influence of QFDI on GTFP is significantly improved, and the influence coefficient becomes 0.077, which is significantly positive at the 1% level. Similarly, when the level of HUM is below the threshold (10.016), the influence coefficient of QFDI is 0.016, which is significant at the 1% level. When the HUM level crosses the threshold value, the QFDI coefficient becomes 0.054, and the effect on GTFP is significantly improved. The results show that the strength of the region's ability to absorb FDI significantly affects the green effect of QFDI. Only when the regional absorptive capacity reaches a certain level, can "introduction" bring high-quality development to the region in a real sense. In the samples examined by the research institute, although the levels of RD and HUM in various provinces and cities in China have continuously improved in recent years, most regions have not yet crossed the threshold value, and China's ability to absorb FDI still has much room for improvement.

Table 11. Threshold regression results.

Variables	(1)	(2)
LnQFDI-RD≤ρ1	0.021* (1.91)	
LnQFDI-RD>ρ1	0.077*** (5.21)	
LnQFDI-HUM≤σ1		0.016*** (3.39)
LnQFDI-HUM>σ1		0.054** (2.17)
Control variable	Control	Control
C	-1.825*** (-4.56)	0.082 (0.63)

Note: The value of t is in brackets.

Discussion

The above empirical results show that the improvement of the quality of foreign direct investment can effectively promote the increase of green total factor productivity. This result is consistent with the results obtained by Li et al.2021 [31] for Korea and Wu et al. (2020) [32] for countries along the Belt and Road. And the paper finds that technology spillover capability has the largest positive impact by further testing, followed by management level and profitability. This is consistent with Han et al. (2011) [33] who found that technology spillovers can significantly increase productivity. The possible explanation given in this paper is that technology spillovers can significantly contribute to the improvement of production technology of local firms. When firms have more advanced production technologies, this implies an increase in their production capacity and profitability. This can also help firms to reduce the pollution generated during the production process [34-36]. These are conducive to green total factor productivity improvements. At the same time, improved management of foreign direct investment can help capital to be better allocated. This is conducive to better development of different enterprises utilizing foreign investment. It is more conducive to enterprises promoting the rational utilization of resources. This proves that the country and the government need to further improve the quality of foreign direct investment.

The threshold model proves that the level of human capital and innovation capacity positively affects the absorptive capacity of foreign investment beyond a certain range. This would further increase green total factor productivity. The result is consistent with the findings of Medase et al. (2019) [37] for Nigeria. The paper confirms that this facilitation effect is concurrently present in China. This also reaffirms the important role of technological development in increasing green total factor productivity. The explanation given in this paper may be that an increase in the level of human capital implies an increase in the quality of the firm's labor force. This can lead to more productive capacity and higher levels of technology for firms. This will drive up business profitability and finally contribute to local green total factor production [38]. Combined with the heterogeneity analysis, the coastal region needs to vigorously promote the improvement of its own technological level and human capital level. This can lead to further development of inland areas.

Conclusions

Based on the 2011-2020 panel data of 29 provinces and cities in China, this paper measures the levels of QFDI and GTFP using entropy method and SBM-GML model. Then we use systematic GMM estimation and threshold model to study the impact of QFDI on GTFP. The conclusions remain valid after the robustness test. The study draws the following conclusions. First, QFDI has a significant positive effect on GTFP. Specifically, FDI technology spillover ability has the greatest positive effect on GTFP, followed by FDI management level and profitability. The scale of FDI has a weak effect on GTFP, and the export capacity of FDI has no significant effect on GTFP. It shows that in the process of attracting foreign investment, compared with the quantity of foreign investment, we should pay more attention to the quality of foreign investment, and should focus on FDI with high technology level and high management level. Secondly, the impact of QFDI on GTFP has a single threshold effect based on HUM and RD. The improvement of labor quality and innovation ability can enhance the absorptive capacity of FDI in the region, which is particularly important for the green effect of high-quality FDI. Thirdly, the impact of QFDI on China's GTFP has obvious regional heterogeneity. The difference of location advantage and resource endowment makes QFDI in coastal areas play a greater role in promoting GTFP. Based on this, the following suggestions are proposed. First, relevant government departments can take the bias of technological progress as an important criterion for the introduction of FDI, and actively introduce FDI that promotes technological progress towards the development of abundant factors in the country. Relevant government departments should conduct a comprehensive assessment of the quality of foreign investment from the aspects of profit, management and technology. Secondly, increase RD and personnel training and enhance the region's ability to absorb high-quality FDI. Local governments should continue to deepen education reform, optimize school training programs at all levels, and increase the training of high-level innovative talents in the green industry. Thirdly, relying on regional resource endowments to implement precise policies to weaken the regional heterogeneity of FDI's green development effect. Encourage inland areas to undertake foreign industrial transfer and promote the development of regional export-oriented industrial clusters. At the same time, the formulation of regional policies should consider the development characteristics of the surrounding areas. The Yangtze River and Yellow River basins are geographically located across the eastern, central and western regions. Based on this key central region, inter-regional enterprise cooperation should be strengthened to promote regional economic coordination and sustainable development.

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Conflict of Interest

The authors declare no conflict of interest.

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