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Impact of FDI inflows on green TFP based on carbon emissions transmission mechanism

Junfeng Liu[a,b], Shaobo Wang[c] and Shiwen Wang[a]

[a]School of Business, Suzhou University of Science and Technology, Suzhou, China; [b]Postdoctoral Research Station, Suzhou International Development Group Co., Ltd, Suzhou, China; [c]Institute of County Economic Development, Lanzhou University, Lanzhou, China

ABSTRACT

Economic globalization and green development have become the consensus of all countries in the world. The importance of FDI, carbon emissions and green total factor productivity is self-evident. This study analyses the impact of FDI inflows on green TFP and the role of carbon emissions in FDI inflows and green TFP. The empirical analysis employed kernel density estimation, OLS, mediation effect model, and panel quantile regression methods using China's provincial panel data spanning over 2001–2019. The facts show that China's carbon emissions have been reduced because of environmental regulations and green TFP is still rising in fluctuation. The results from OLS and mediation effect model indicate that the impact of FDI inflows on green TFP present an asymmetric inverted U-shape and FDI influences green TFP by changing carbon emissions. The panel quantile regression results also show that FDI has a stronger impact on green TFP in less developed regions. This paper believes that the introduction of FDI should be appropriate and should be accompanied by corresponding environmental regulations, in order to promote green TFP in countries around the world.

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1. Introduction

Since the 21st century, due to the increasing environmental pollution, green development has gradually become the focus of academia and government (Zheng et al., 2023). Carbon emissions and green total factor productivity (TFP), which are closely related to green development, have become urgent problems in the socio-economic field (Uzair Ali et al., 2022; Lee & Lee, 2022). The existing literature discusses the influential factors of green TFP from the perspectives of green innovation, financial development and population (Zhao et al., 2022). This paper believes that the inflow and utilization of foreign direct investment (FDI) in the context of economic

CONTACT Junfeng Liu liujunfengchina@163.com

globalization have an important impact on the economies of various countries (Eapen et al., 2019), so FDI will also affect green TFP (Yu et al., 2021), however, it is still controversial whether FDI has a positive or negative impact on green TFP.

In 2020, China proposed the goals of peak carbon dioxide emissions and carbon neutrality at the 75th United Nations General Assembly. In combination with these goals, this paper aims to improve green TFP and promote high-quality economic development. Therefore, we discuss the impact of FDI on green TFP, and the role of carbon emissions between FDI and green TFP based on China's provincial panel data, in order to provide China's experience for the utilization of FDI, the improvement of green TFP and high-quality economic development of other countries in the world, and put forward some measures and suggestions for the green and sustainable development of the global economy.

The marginal contributions of this paper are as follows. First, some papers believe that FDI inflows contribute to the improvement of green TFP, while opponents believe that FDI inflows have a negative impact on green TFP. Our conclusion is different from the existing literature. We find that FDI inflows have an asymmetric inverted U-shaped effect on green TFP. Second, some existing studies have not solved the potential endogenous problem, but green TFP also affects FDI inflows. Therefore, two-way causality can produce endogenous problem, this paper uses IV-2SLS to account for potential endogenous problem. Third, we investigate the impact of FDI inflows on green TFP under different levels of green TFP through panel quantile regression, and find that the marginal promotion effect of FDI inflows on regions with poor green TFP is stronger.

The remaining paper is structured as follows. The second part is the literature review, which reviews the research basis of the thesis theme. The third part is methodology and data, which introduces model, data and facts. The fourth part includes the empirical results, and the fifth part discusses the results in detail. The sixth part summarizes the full paper and provides policy implications.

2. Literature review and hypotheses

2.1. The impact of FDI inflows on TFP

Some scholars believe that the spillover effect of FDI contributes to the improvement of TFP (You & Xiao, 2022; Yasin & Sari, 2022). On the one hand, the inflows of FDI not only make up for the capital gap caused by insufficient capital supply in regional economy, but also promote the optimization and upgrading of regional industrial structure through international trade (Chen et al., 2012), and improve human capital level (Tekin, 2012) to promote TFP. On the other hand, FDI inflows have a positive spillover effect on regional TFP, especially technology spillover effect (Han et al., 2022). Technology spillovers play an important role in promoting regional technological progress (Kayalvizhi & Thenmozhi, 2018), while technological progress is a prerequisite for improving regional TFP (Du & Li, 2019). In addition, technology spillovers lead to the optimization of resource allocation, the growth of industrial output and the transformation of economic growth mode, which improves the efficiency of economic operation (Aitken & Harrison, 1999) and provides the necessary growth

foundation for the improvement of TFP. Therefore, FDI inflows will the TFP of host countries through capital injection, international trade and spillover effects.

Opponents argue that FDI inflows have a restraining effect on TFP of host countries. On the one hand, FDI inflows have negative spillover effects. The inflows of FDI will squeeze agents of productions and product markets of enterprises in host countries, and the intensification of competitive pressure makes FDI inflows unfavorable to the improvement of TFP of host countries (Damijan & Knell, 2005). On the other hand, the positive spillover effects caused by FDI inflows are not noticeable. Generally speaking, when the host country introduces FDI, technology and experience will be reluctantly brought to the host country by foreign investors, who will protect their technology and experience, forming technology transfer barriers, which makes the positive spillover effect of FDI inflows insignificant, and thus cannot effectively promote TFP (Zhou et al., 2020). In addition, although FDI inflows have a positive spillover effect, the positive spillover effect also depends on the host country's own absorption capacity (Sugiharti et al., 2022), if the absorption capacity of FDI inflows country is relatively weak, even if FDI inflows have positive spillover effect, which will soon reach the critical value, namely saturation state, and then the inflows of FDI will crowd out the market of local enterprises. It may inhibit TFP (Gui-Diby, 2014).

2.2. The impact of FDI inflows on carbon emissions

Existing studies show that there is a close relationship between FDI inflows and carbon emissions (Y. Huang et al., 2019; Apergis et al., 2023), however, there is a great controversy among scholars on whether FDI can inhibit or promote carbon emissions (Guoyan et al., 2022; Pan et al., 2023). There is no doubt that FDI inflows have mitigating effects on carbon emissions (Perkins & Neumayer, 2012). According to the 'pollution halo hypothesis', the inflows of FDI will produce technology spillover effect. Enterprises in the host country will realize the progress of green technology through imitation and learning based on their own absorption capacity (Letchumanan & Kodama, 2000), thus optimizing generation capacity and reducing carbon dioxide emissions (Huang et al., 2017). At the same time, the inflows of FDI will crowd out inefficient enterprises in the host country and promote the upgrading of industrial structure and the improvement of energy utilization efficiency (Liang, 2014), thus reducing carbon dioxide emissions. FDI in general has not taken place at the expense of carbon emissions (Sun et al., 2023). However, FDI inflows still have an aggravating effect on carbon emissions (He, 2006). According to the 'pollution paradise hypothesis', developed countries usually transfer enterprises with high pollution, high energy consumption and high emissions to developing countries, thus leading to the increase of carbon emissions in the destination countries of FDI (Bakhsh et al., 2017). At the same time, in order to attract foreign investment, the host country will lower the introduction standard of FDI and leave polluting enterprises with high energy consumption to their own ways. With scale effect, the carbon emissions of the host country will gradually increase (Omri et al., 2014).

2.3. The impact of carbon emissions on TFP

Studies on the impact of carbon emissions on TFP are rare, and it is generally believed that reducing carbon emissions can help improve TFP. For example, Wen et al. (2018) pointed out that the implementation of carbon emissions trading system can help reduce carbon emissions and promote the improvement of TFP. Ma and Wu (2022) studied TFP with carbon emissions constraints and believed that carbon emissions promoted TFP, but also led to resource consumption. And some scholars believe that increasing carbon emissions only promote TFP (Wang et al., 2022). Most scholars have studied the impact of carbon emissions on economic growth based on the Environmental Kuznets Curve (EKC). For example, Lu (2018) supported that carbon emissions and economic growth have a two-way causal relationship. Li et al. (2019) acknowledged that carbon emissions and economic growth have inconsistent characteristics, and pointed out that sample data in different periods are the root cause of the inconsistent characteristics. Karimi et al. (2021) believed that increasing carbon emissions were beneficial to promote economic growth, while reducing carbon emissions does not reduce economic growth in the short term.

Based on the literature review, the following conclusions can be drawn: first, in terms of the perspective of research, literature focusing on the transmission mechanism of carbon emissions and green TFP is rare. Second, from the perspective of research content, most existing literature focuses on the impact of FDI inflows on TFP and carbon emissions, and there are few studies on the relationship of these three factors. Third, regarding research results, the FDI inflow is an important factor affecting TFP of carbon emissions, but the final results tend to inhibit or strengthen which are still controversial. Therefore, this paper attempts to bring FDI inflows, carbon emissions and green TFP into a unified analytical framework, and takes 30 provinces of mainland China as research samples to investigate the direct effect of FDI inflows on green TFP, to explore the role of carbon emissions in the process of FDI inflows affecting green TFP, and provide policy basis for the introduction of FDI and the improvement of green TFP in countries around the world.

2.4. Hypotheses

According to papers on the impact of FDI inflows on TFP, this paper believes that FDI may have both promoting and inhibiting effects on green TFP. Therefore, this paper puts forward the following hypothesis.

H1: FDI inflow has a nonlinear impact on green TFP.

With reference to the literature of FDI inflows affecting carbon emissions and carbon emissions affecting TFP, we find that carbon emissions play an important role in the process of FDI inflows affecting green TFP. Therefore, this paper puts forward the following hypothesis.

H2: FDI can affect green TFP through carbon emissions, for which are the intermediary variable of FDI inflows on green TFP.

This paper takes China as the sample. Due to the differences in economic development and green TFP in eastern, central and western China, we believe that the

impact of FDI inflows on green TFP may vary with the change of green TFP. Therefore, this paper puts forward the following hypothesis.

H3: the marginal promotion effect of FDI inflows on regions with lower green TFP is stronger.

3. Methodology and data

3.1. Model selection

3.1.1. Main effect model

The above literature review indicates that FDI inflows can effectively affect TFP. In order to accurately investigate the influence degree and direction of FDI inflows on green TFP of each province in China, this paper sets a main effect model to reveal the influence of FDI inflows on green TFP. The model is then set as follows:

$$gtfp_{it} = \alpha_0 + \theta_1 fdi_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (1)$$

3.1.2. Mediating effect model

The mediating effect model is used to explain the influence of the independent variable on the dependent variable through which intermediary variable. According to the research content, this paper intends to test whether carbon emissions is the mediating variable between FDI inflows and green TFP through the mediating effect model. Therefore, on the basis of the three-step mediation testing process (Baron & Kenny, 1986; Li & Liu, 2022), the Bootstrap method is used to test the mediation effect.

Firstly, the baseline regression in this research is set as follows (1).

Secondly, do the regression of intermediary variable:

$$caem_{it} = \alpha_0 + \varphi_1 fdi_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (2)$$

Thirdly, the following equation adds intermediary variable carbon emissions on the basis of baseline regression:

$$gtfp_{it} = \alpha_0 + \alpha_1 fdi_{it} + \alpha_2 caem_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (3)$$

In the above econometric model, i and t represent regional individual and year respectively, *gtfp* denotes green TFP, *fdi* represents FDI inflows, as an intermediary variable, *caem* is carbon emissions, control refers to the control variables, code is the unobservable regional individual fixed effect, year is the time fixed effect, ε_{it} is the random disturbance term. In this paper, the region is 'clustered' based on the regression of bidirectional fixed effects model, which generates robust standard error of coefficient estimation. Model (1) is used to test the impact of FDI inflows on green TFP, Model (2) is used to discuss the impact of FDI inflows on carbon emissions,

and Model (3) is used to test the impact of FDI inflows and carbon emissions on green TFP.

Meanwhile, in order to test the possible direct and mediating effects of nonlinear regression, the quadratic term of FDI inflows is added to the above econometric model, and the model is set as follows:

$$gtfp_{it} = \alpha_0 + \theta_1 fdi_{it}^2 + \theta_2 fdi_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (4)$$

$$caem_{it} = \alpha_0 + \varphi_1 fdi_{it}^2 + \varphi_2 fdi_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (5)$$

$$gtfp_{it} = \alpha_0 + \alpha_1 fdi_{it}^2 + \alpha_2 caem_{it} + \alpha_3 fdi_{it} + \sum \beta_i control_{it} + code_i + year_t + \varepsilon_{it} \quad (6)$$

3.2. Variable descriptions and data sources

The dependent variable is green TFP (*gtfp*). Existing measurement methods of green TFP are diversified (Y. Zhang et al., 2023). Referring to existing literature, this paper adopts Stochastic Frontier Analysis (SFA) method and Malmquist index to calculate green TFP, and the input variables are labor and capital. Labor is the total number of employees, and capital is the capital stock calculated by the perpetual inventory method. Expected output is actual GDP, and unexpected output is sulfur dioxide emissions in industrial waste gas and chemical oxygen demand in industrial waste water.

The independent variable is FDI inflows (*fdi*). Ashraf et al. (2016) respectively measured FDI by the proportion of FDI inflows in GDP, greenfield investment in GDP, and cross-border mergers and acquisitions in GDP, and pointed out that the proportion of FDI inflows in GDP was the most commonly used FDI measurement index. Therefore, based on the study of Ashraf et al. (2016), this paper adopts the utilization rate of foreign direct investment to measure FDI inflows, that is, the proportion of actual foreign direct investment in GDP.

The intermediate variable is carbon emissions (*caem*). This paper downloads the carbon emission data of China's provinces from 2001 to 2019 from China Emission Accounts and Datasets, which was used in the research of Shan et al. (2020). Finally, the calculated carbon emissions were logarithmically treated as a proxy variable of carbon emissions (*caem*).

In terms of control variables, the following variables are selected: (1) inflation rate (*inflat*) is measured by consumer price index (CPI). (2) Economic development level (*lnrgdp*) is measured by logarithm of per capita GDP. (3) Openness (*open*) is measured by the proportion of total imports and exports in GDP. (4) Human capital level (*humcap*) is measured by the proportion of the number of students in the total population. (5) Industrial structure (*indstr*) is measured by the proportion of added value of the secondary industry in GDP. (6) Infrastructure construction (*infra*) is measured by the proportion of the total passenger traffic in the total population. (7) Population concentration degree (*popu*) is measured by urban population density. (8)

Informatization level (*infor*) is measured by the ratio of the total amount of post and telecommunications services to GDP at the end of the year.

In the process of reform and opening up, China has introduced a large amount of foreign capital, but has also produced a lot of carbon emissions as well as affected green TFP. Therefore, this paper takes a total of 570 panel data from 30 provinces in China (excluding Hong Kong, Macao, Taiwan and Tibet) from the year of 2001 to 2019, and relevant data from China Statistical Yearbook and China Emission Accounts and Datasets as samples. Table 1 shows descriptive statistics. We find that the key variables *fdi*, *caem* and *gtfp* are distributed normally without extreme values, indicating that the sample data change gradually and are selected reasonably.

3.3. Stylized facts

3.3.1. Time evolution trend of carbon emissions

According to the carbon emissions (*caem*) index values of China's provinces, in order to make the analysis process clear and intuitive, five years (2001, 2005, 2009, 2013 and 2017) are selected to draw the kernel density map of time evolution trend (Figure 1) based on the research of Wang and Luo (2022) in this paper.

According to the kernel density map, the analysis is as follows: (1) in terms of the location features, the kernel density curve of carbon emissions continuously moved to the right before 2013, indicating that the intensity of carbon emissions gradually has increased. However, the kernel density curve of carbon emissions remained relatively stable from 2013 to 2017, presenting that carbon emissions intensity kept stable during this period. This paper argues that carbon emissions intensity gradually increased before 2013 due to the needs of rapid economic development. Since 2013, China has strengthened ecological and environmental governance, and the economy has shifted to a stage of high-quality growth. As a result, the growth rate of carbon emissions intensity has slowed down and remained relatively stable. (2) As to span characteristics, on the whole, the span of the carbon emissions kernel density curve shows a narrowing trend during the study period, indicating that the carbon emissions level gap between provinces gradually decreases. This paper believes that since the 21st century, China's economy has experienced a phase of high-speed growth to high-quality growth, so the regional economic development gap has narrowed, and the carbon emissions demand gap among most provinces has gradually become narrow. (3)

Table 1. Descriptive statistics.

Variables	Mean	sd	Min	Max	p25	p50	p75	N
gtfp	0.903	0.301	0.0208	4.360	0.881	0.967	1.021	570
fdi	0.0244	0.0210	0.000107	0.146	0.00972	0.0184	0.0337	570
caem	5.278	0.953	−0.0726	7.438	4.796	5.309	5.901	570
inflat	1.024	0.0189	0.977	1.101	1.014	1.021	1.032	570
lnrgdp	1.105	0.610	0.299	3.261	0.721	0.914	1.279	570
open	0.305	0.373	0.0127	1.737	0.0861	0.132	0.344	570
humcap	1.719	1.658	0.278	28.57	1.047	1.610	2.008	570
indstr	45.42	8.184	16.16	61.50	41.60	46.66	51.30	570
infra	16.59	10.18	0.478	70.45	10.18	14.09	20.12	570
popu	24.24	13.52	0.560	63.07	14.13	21.91	31.72	570
infor	5.882	3.244	1.435	23.56	3.528	5.211	7.482	570

Source: Author's Estimation.

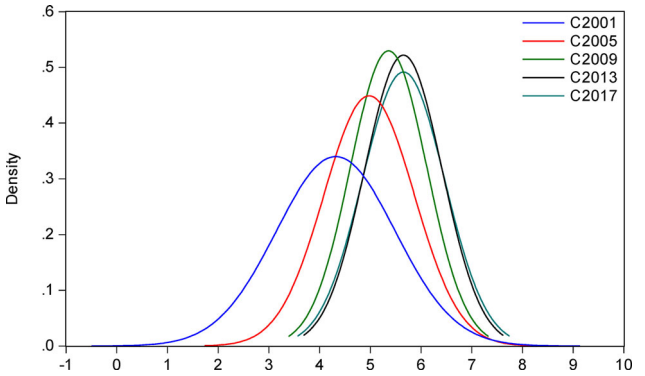

Figure 1. The distribution density of carbon emissions.
Source: Author's Estimation.

Finally, according to peak characteristics, during the study period, the peak of carbon emissions shows an overall upward trend, and gradually changed from a wide peak distribution to a sharp peak distribution, indicating that the spatial distribution of carbon emissions intensity was relatively concentrated. This paper believes that from 2001 to 2017, a small number of developed regions need rapid increase of carbon emissions due to their own development, while most provinces with moderate development level still maintain stable and consistent carbon emissions intensity, thus gradually widening the gap between the two poles of carbon emissions.

3.3.2. Spatial evolution trend of green TFP

Combined with the calculation method of green TFP in variable descriptions, this paper calculates the green TFP of each province. The 570 green TFP values in 30 provinces in China from 2001 to 2019 are divided into four types according to 25% quantile, 50% quantile and 75% quantile. The specific classification criteria are as follows: (1) lowest level [0.0208, 0.8813]; (2) lower level (0.8813, 0.9665]; (3) higher level (0.9665, 1.0209]; (4) Highest level (1.0209, 4.3603]. Meanwhile, five years (2001, 2005, 2009, 2013 and 2017) are selected to display the spatial evolution of green TFP at these five points of time synchronously (Figure 2) and analyse its spatial evolution characteristics.

According to Figure 2, in the first stage, green TFP of all Provinces in China in 2001 is at a low level. In 2005, the green TFP of some provinces increases, which turns into lower level, higher level or highest level. The trend from 2001 to 2005 shows that the rapid economic growth is conducive to the improvement of green TFP during this period. In the second stage, all provinces are at the lowest level or lower level in 2009, and the number of lowest level provinces is more than that of lower-level provinces, and there are not higher and highest level areas. By analysing the trend from 2005 to 2009, it can be concluded that China's economic development are severely impacted by the global economic crisis, which inhibits the green TFP of all provinces in China. In the third stage, in 2013, green TFP of all provinces in China improves respectively, and all of them are at lower or higher level. There are not provinces at the lowest level. This paper believes that in the post-financial crisis era, the quality of economic development and green TFP in various regions of China

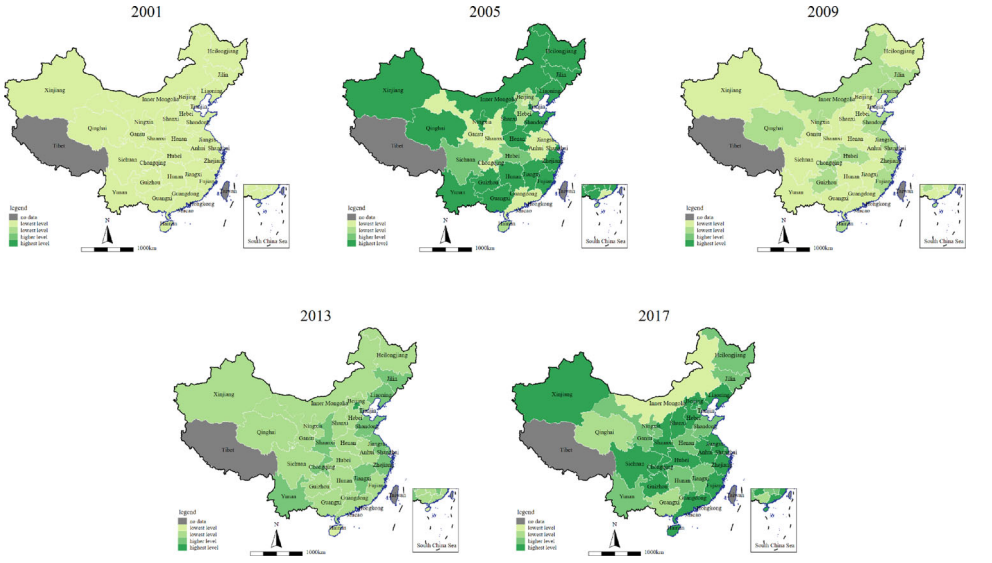

Figure 2. Spatial distribution map of green TFP in China.
Source: Author's Estimation.

have recovered respectively under the dual effects of government policies and market regulation. In the fourth stage, in 2017, there is not any province's green TFP at the lowest level, but most provinces changed into higher or highest-level areas, and the number of highest-level areas was significantly more than that of higher-level areas. This paper argues that influenced by the inertia of economic development, the opportunities of the Belt and Road Initiative and the improvement of marketization level, the green TFP in all regions increased significantly from 2013 to 2017.

Based on the analysis of the temporal evolution trend of carbon emissions and the spatial evolution process of green TFP, the conclusions can be drawn as follows: first, carbon emissions are on the rise from 2001 to 2017, while the increase trend of carbon emissions slowed down with the strengthening of environmental regulations in recent years. Second, despite the impact of external market factors such as the global financial crisis on China's economic development, the growth of green TFP was still on the rise from 2001 to 2017 due to the internal stability of China's economy. Third, the change trend of carbon emissions and green TFP from 2001 to 2017 is inconsistent, so the specific impact of carbon emissions on green TFP needs to be further investigated through empirical test.

4. Results

This section will test the relationship among FDI inflows, carbon emissions and green TFP in three parts. First, the direct impact of FDI inflows on green TFP is tested. Secondly, this paper tests whether the intermediary effect of carbon emissions exists, that is, whether FDI inflows can affect green TFP through carbon emissions, and analyses the impact of carbon emissions on green TFP. Finally, quantile regression is used to test the influence of FDI on green TFP under different levels of green TFP.

4.1. The direct impact of FDI inflows on green TFP

4.1.1. Baseline results

According to the literature review, the inflows of FDI has an uncertain effect on green TFP. This paper speculates that FDI inflows may have a non-linear effect on green TFP. In order to accurately assess the impact of FDI inflows on green TFP, this paper reports both linear and nonlinear regression processes (Table 2). The linear regression results of columns (1) and (2) are not significant, while the nonlinear regression results of columns (3) and (4) are significant, indicating that FDI inflows has an asymmetric inverted U-shaped relationship with green TFP. And the coefficient of the square term remains relatively stable, indicating that the regression results are robust. This result verifies the correctness of H1. According to the column (4), the empirical value of FDI at the maximum value of inverted U-shaped curve can be calculated as 0.0545. This paper argues that, in the initial stage, FDI flows into the host country to compensate for the adverse impact of insufficient capital, and the positive spillover effect of FDI inflows can effectively promote green TFP. However, with the continuous inflows of FDI, the positive correlation becomes weaker and weaker, and the positive spillover effect of FDI inflows will eventually be saturated. Therefore, when FDI exceeds the threshold of 0.0545, the disadvantage of insufficient capital are covered, and the marginal promoting effect of FDI inflows will be reduced to zero, and positive spillover effects of FDI inflows are also maximized. Positive

Table 2. Direct impact of FDI inflows on green TFP.

model	(1)	(2)	(3)	(4)
variable	*gtfp*	*gtfp*	*gtfp*	*gtfp*
fdisq			−46.3320**	−31.3206**
			(14.5652)	(15.2544)
fdi	−1.2195*	0.2978	2.8553*	3.4121**
	(0.7097)	(0.6151)	(1.4881)	(1.5279)
inflation	5.4994***	1.6663	5.4667***	1.8291
	(0.6492)	(1.4510)	(0.6320)	(1.4872)
lnrgdp	0.1748***	0.1913***	0.1654***	0.2293***
	(0.0402)	(0.0490)	(0.0409)	(0.0516)
open	−0.1648**	−0.0244	−0.1697**	−0.0185
	(0.0711)	(0.0428)	(0.0648)	(0.0413)
humcap	0.0160*	0.0015	0.0158	0.0001
	(0.0093)	(0.0027)	(0.0094)	(0.0023)
indstr	−0.0032	−0.0002	−0.0032	−0.0009
	(0.0026)	(0.0021)	(0.0023)	(0.0018)
infra	0.0021**	−0.0012	0.0014	−0.0014
	(0.0010)	(0.0016)	(0.0010)	(0.0017)
popu	0.0038***	−0.0018	0.0036***	−0.0019
	(0.0007)	(0.0013)	(0.0007)	(0.0013)
infor	0.0038	−0.0042	0.0050*	−0.0025
	(0.0031)	(0.0054)	(0.0029)	(0.0048)
_cons	−4.8720***	−0.9210	−4.8698***	−1.1454
	(0.5445)	(1.4582)	(0.5439)	(1.5015)
year	NO	YES	NO	YES
code	NO	YES	NO	YES
N	570	570	570	570
R-sq	0.270	0.682	0.283	0.685

Notes: Clustered standard errors are reported in (). Significant at *10%, **5%, ***1%. Same as the following tables.
Source: Author's Estimation.

spillover effects of FDI inflows are no longer effective, and the inflows of FDI will be detrimental to green TFP.

4.1.2. Endogenous and robust test

According to the above regression results, this paper preliminarily believes that FDI inflows can effectively affect green TFP, and the two variables show an inverted U-shaped relationship. In order to verify the reliability that directly affects the nonlinear baseline results, this paper also conducts a series of endogenous and robustness tests (Table 3).

In order to tackle endogenous concerns, this paper uses the IV-2SLS method for endogenous test, and the choice of instrumental variable is as follows: first, consistent with the traditional treatment method, the lagged independent variable FDI inflow are taken as the instrumental variable (IV), which is also reappraise by the two-stage least squares (2SLS). The estimation result is shown in column (1) of Table 3. Second, the 'average value of FDI inflows in the region in other years except this year' is used as the instrumental variable for reassess. The estimation result is shown in column (2) of Table 3. The reasons for its selection are as follows: on the one hand, it meets the 'correlation' condition of instrumental variable. FDI inflows in a province is often related to FDI inflows in other years of the province. Therefore, 'the average value of FDI inflows in other years except this year' not only reflects the FDI inflows in other stages of the province, but also affects the FDI inflows in the province in that year. On the other hand, it meets the requirements of the 'exogenous' assumption of instrumental variable. The instrumental variable excluding a specific individual year is not directly related to the green TFP of that year. Third, similar to the second method, the 'average value of FDI inflows in other regions except local areas in this year' is used as a instrumental variable for estimation again. The estimation result is shown in column (3) of Table 3. According to the regression results of columns (1), (2) and (3), although the coefficients of FDI quadratic and primary terms have changed, the nonlinear inverted U-shaped relationship and the optimal FDI inflows level have not changed, showing that endogenous has no substantive impact on the regression results.

A series of robust tests are carried out in this paper (Table 3). First, in order to avoid the adverse effects of extreme values, this paper carries out a 1% winsorize on

Table 3. Endogenous and robust test of direct impact.

Model	(1)	(2)	(3)	(4)	(5)	(6)
Variable	*gtfp*	*gtfp*	*gtfp*	*gtfp*	*gtfp*	*gtfp*
fdisq	−62.5172**	−43.8212**	−110.7478**	−55.3926**	−20.8535	−75.9750**
	(26.9502)	(16.7588)	(36.8961)	(20.5627)	(12.7616)	(30.8942)
fdi	6.1583**	4.6551**	11.3098**	2.5536	3.7353*	6.5613**
	(2.3986)	(1.8004)	(3.7358)	(1.6938)	(1.9465)	(2.4324)
_cons				−4.6684***	5.1705**	−0.8141
				(0.3616)	(1.5161)	(1.7427)
controls	YES	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES	YES
code	YES	YES	YES	YES	YES	YES
N	540	570	570	570	570	494
R-sq	0.036	0.037	−0.030	0.397	0.871	0.670

Source: Author's Estimation.

the sample data before and after, column (4) is the regression result of winsorize data. Second, because the measurement method of green TFP and TFP is relatively close, this paper replaces the dependent variable green TFP with TFP to re estimate. See column (5) for the estimation results. Third, due to the special political status and economic level of the four municipalities directly under the central government, Beijing, Tianjin, Shanghai and Chongqing, this paper removes the four municipalities directly under the central government and carries out regression again. The estimated result is shown in column (6). According to the regression results of columns (4), (5) and (6), it is noted that the two-way fixed estimation results in the baseline result have certain robustness.

4.2. Mediating effect test and quantile regression

4.2.1. Mediating effect test

Another purpose of this paper is to study whether carbon emissions are the intermediary variable of FDI inflows affecting green TFP. Therefore, this paper reports the intermediary effect test of FDI affecting green TFP through carbon emissions and there are more details in column (1), column (2) and column (3) of Table 4. According to the Table 4, the impact of FDI inflows on carbon emissions shows a significant U-shaped relationship. Since carbon emissions have no significant impact on green TFP, the bootstrap test is carried out on it. The test result shows that carbon emissions are the intermediary variable of FDI inflows affecting green TFP.

Further analysis of the nonlinear intermediary effect shows that: first, carbon emissions have a positive impact on green TFP, but the significance is insufficient. Second, FDI inflows have a significant positive U-shaped impact on carbon emissions, that is, the early FDI inflows have effectively reduced carbon emissions, but with the increase of FDI inflows, carbon emissions have also increased. This paper believes that the initial inflows of FDI, due to its spillover effects, are conducive to green technological progress, which reduces carbon emissions; However, China provides preferential policies and low barriers to entry when introducing FDI. The gradual increase of enterprises with high pollution, high energy consumption and emissions lead to the intensification of carbon emissions when FDI increases. Third, although

Table 4. Mediating effect test and quantile regression.

Model	(1)	(2)	(3)	(4)	(5)	(6)
Variable	*gtfp*	*caem*	*gtfp*	*gtfp*	*gtfp*	*gtfp*
fdisq	−31.3206**	46.8454*	−32.4563**	−18.7063**	−28.7520***	−37.1150***
	(15.2544)	(25.4592)	(15.7395)	(6.8053)	(7.3494)	(10.4818)
fdi	3.4121**	−5.4438	3.5441**	1.8881**	2.7548***	3.5326**
	(1.5279)	(3.5144)	(1.5812)	(0.7630)	(0.8240)	(1.1752)
caem			0.0242			
			(0.0436)			
_cons	−1.1454	4.8864**	−1.2638	−0.7803	−0.7938	−1.1079
	(1.5015)	(1.8848)	(1.6175)	(0.6336)	(0.6842)	(0.9758)
controls	YES	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES	YES
code	YES	YES	YES	YES	YES	YES
N	570	570	570	570	570	570
R-sq	0.685	0.891	0.686			

Source: Author's Estimation.

the impact of carbon emissions on green TFP is not significant, carbon emissions still have a crucial effect in the process of FDI inflows affecting green TFP. Because the impact of FDI inflows on green TFP and carbon emissions is nonlinear, according to China's actual situation, this paper believes that the indirect effect of carbon emissions is negative in the initial stage, but not greater than the positive direct impact of FDI inflows on green TFP, while the impact of FDI inflows on green TFP through carbon emissions is still positive. In the later stage, the indirect effect of carbon emissions is positive, making up for the negative effect of FDI inflows on green TFP. Therefore, although carbon emissions play a significant role in the process of FDI inflows affecting green TFP, the intermediary effect of carbon emissions still exists. This result verifies the correctness of H2.

4.2.2. Quantile regression

Due to the particularity of the geographical distribution of China's provinces, the economic development of different provinces has the characteristics of unbalanced development. Therefore, this part will use the quantile regression method to analyse the impact of FDI inflows on green TFP. Columns (4), (5) and (6) of Table 4 report the regression results of 25%, 50% and 75% quantiles respectively. Taking the optimal FDI inflows value as an example, with the increase of quantile (25%→50%→75%), the optimal FDI inflows value shows a downward trend (0.0505→0.0479→0.0476). This shows that the best FDI inflows level is lower in regions with better green TFP, that is, the marginal promotion effect of FDI inflows on regions with poor green TFP is stronger. This paper argues that the regions with high green TFP have significantly better economic development level and factor abundance than those with low green TFP due to the impact of geographical and economic environment, so the regions with low green TFP are more sensitive to FDI inflows. This result verifies the correctness of H3.

5. Discussions

Global economic growth is facing difficulties and countries are generally pursuing green development, this paper analyses the relationship among FDI inflows, carbon emissions and green TFP through empirical tests based on Chinese provincial panel data and reviewing existing literature, and tries to answer the following questions: whether FDI inflows promote the green TFP or not? What role does carbon emissions play in the impact of FDI inflows on green TFP? What are the differences in the effects of green TFP at various levels on FDI inflows? The specific results are as follows.

Firstly, this paper finds that FDI inflows and green TFP show an asymmetric inverted U-shaped relationship. This conclusion shows that there is a causal relationship between FDI inflows and green TFP (Lin & Chen, 2018). Different from the existing research, this paper finds through empirical test that neither positive promotion nor negative inhibition existed between the two elements, but there is an inverted U-shaped inconsistency characteristic. In other words, FDI has both positive and negative impacts on green TFP. In this paper, it is believed that technology

spillover can promote the improvement of green TFP in the initial stage of FDI inflows (Yu et al., 2021), but in the later stage, with the increase of FDI inflows, the expansion of pollution leads to the decrease of green TFP. The nonlinear impact of FDI on green TFP is one of the contributions of this paper.

Secondly, we summarized the relationship among FDI, carbon emissions and green TFP. The conclusion of this paper shows that FDI inflows affect green TFP by carbon emissions. In order to attract more FDI, host countries reduce environmental regulations, which leads to the continuous increase of carbon emissions (Demena & Afesorgbor, 2020). But this paper finds that the technology spillover brought by a small amount of FDI helps reduce carbon emissions, while the influx of a large amount of FDI later brings environmental problems and leads to the increase of carbon emissions. Therefore, although most papers only focus on the unilateral role of FDI in promoting or inhibiting carbon emissions, this paper argues that FDI has both inhibiting and promoting effects on carbon emissions, which is similar to Song et al. (2021). The results of this paper reveal that carbon emissions are the intermediary variable of FDI affecting green TFP.

Thirdly, this paper also finds that regions with higher green TFP are less sensitive to FDI inflows. Existing literature has conducted a large amount of analysis on the heterogeneity of FDI and carbon emissions, but the heterogeneity conditions and results are quite different. Song et al. (2021) pointed out that the promoting effect of FDI on carbon emissions collapsed at the beginning and then picked up, but fell in the end, and the promoting effect of FDI on carbon emissions in eastern China is significantly higher than that in central and western China. Zhang et al. (2020) proposed that FDI in central and eastern China had a restraining effect on carbon emissions, while FDI in western China had a promoting impact on carbon emissions. Different from the existing literature, this paper compares the optimal FDI inflows values under green TFP at various levels based on quantile regression, which complements the existing research. This is another contribution of this paper.

6. Conclusions, recommendations and prospects

The trend of green economic transformation and high-quality economic development is overwhelming. Therefore, how to rationally utilize foreign capital and environmental regulation to improve green TFP has become the focus of this paper. This paper finds that FDI inflows are not always beneficial to green TFP, and the tendency of these two factors are not consistent, which rises up in the initial stage and then dropped with an asymmetric inverted U-shaped feature. The curve of the influence of FDI inflows on carbon emissions is also with nonlinear characteristics, that is, FDI reduced emissions first but then raised them. The positive impacts of carbon emissions on China's green TFP are not significant, but FDI can affect green TFP through carbon emissions, for which are the intermediary variable of FDI inflows on green TFP. In addition, this paper believes that regions with low green TFP need continue to increase FDI attraction.

Based on the above views, this paper puts forward the following policy suggestions for FDI inflows and green TFP improvement. First, considering the relationship

between FDI inflows and green TFP presents as an asymmetric inverted U-shaped curve with regional differences. Therefore, the central government needs to control the cross-border capital and keep its scale and flow relatively controllable. When absorbing foreign capital, we should guide it to those regions with strong capital demand as much as possible and narrow the unbalanced development caused by regional differences of foreign capital inflows. Local governments should not only formulate reasonable policies to introduce foreign investment with appropriate preferential policies, but also actively acquire production factors with core competitiveness represented by advanced technologies to improve their own green TFP. Second, environmental requirements such as carbon emissions reduction and green development are great issues that governments of all countries need to solve. Therefore, countries should weigh carbon emissions reduction and green TFP based on their own economic development, in addition, improve their own economic and social environment, reasonably introduce and utilize FDI, and maintain carbon emissions at an appropriate level, take solid and well-ordered steps toward the goals of reducing carbon emissions, centralize resources to promote the development of advantageous industries and regions to boost green TFP in different perspectives.

This study has some limitations. Firstly, FDI is important for carbon emissions and green TFP. It is better to measure FDI with data of prefecture-level cities or counties. However, lacking of data at the prefecture-level cities, our paper only uses provincial FDI, so the research is relatively macro. Secondly, this paper focuses on the impact of FDI on green TFP. In fact, carbon emissions also affect green TFP, but we have not discussed the relationship between carbon emissions and green TFP in details. Therefore, in the future, we will study the impact of FDI on carbon emissions and green TFP, and explore the relationship between carbon emissions and green TFP, when the data of FDI in prefecture-level cities are available.

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ORCID

Junfeng Liu http://orcid.org/0000-0002-3511-0993

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