The impact of coordinated development of two-way FDI on regional green technology innovation capability

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Abstract. With the coordinated development of IFDI and OFDI *(IOFDI)* proposed as a link between the domestic and international dual cycles, IFDI helps the domestic cycle and widens its scope, while OFDI integrates into the external cycle and seeks depth, jointly promoting the high-quality transformation of China's economy. The nation and academics have long attentively monitored green technology innovation as a crucial pillar for the economy's superior growth. Thus, this study investigates how China's green innovation potential might be enhanced through the coordinated growth of two-way FDI. It examines the diversity of regions from a regional standpoint. The central and western regions have negative coefficients, but the eastern region has a positive one. This research examines the sequential changes in the impact of government quality thresholds on green technological innovation in the setting of coordinated development of two-way FDI, while also taking government quality into account as a threshold variable in the model.The findings indicate that government quality has a single threshold effect. At the same time, this study also makes pertinent recommendations to optimize the role of the government and encourage the coordinated growth of green technological innovation across regions.

Keywords: FDI, green technology innovation.

1. Introduction

Today, China’s extensive factor-driven economic development model is becoming increasingly weak, leading to a lack of innovation momentum, the disappearance of the demographic dividend, and environmental and resource degradation. Therefore, it is crucial to speed up the transformation of the economy to high-quality development. The 19th National Congress of the Communist Party of China first proposed that accelerating the economy toward high-quality development should be the new direction and goal of China's economic development in the new era. Since then, high-quality development has become the primary task in China's comprehensive building of a modern socialist country, emphasizing the importance of quality, efficiency and sustainability in economic development.

Subsequently, the 20th National Congress of the Communist Party of China proposes to "speed up the construction of a new development pattern and focus on promoting high-quality economic development" and to promote a new development pattern that "takes domestic circulation as the main body and domestic and international circulations promote each other"[1]. China's IFDI and OFDI have increased dramatically since the "going in and going global" plan was put into place. China is now the second-largest country in the world for attracting foreign investment, with its actual use of foreign investment rising from US$108.31 billion in 2008 to US$180.96 billion in 2021, according to data. By 2021, it will rank second in the globe with a foreign investment flow of 178.82 billion dollars, up from 55.91 billion dollars in 2008. This demonstrates the increasing tendency of coordinated development and the gradual equalization of the scale of IFDI and OFDI. The 14th Five-Year Plan and the Outline of Long-Range Objectives through 2035 proposed “the coordinated development of inward and outward FDI”[2]. The coordinated growth of IFDI and OFDI serves as a link between the domestic and international cycles. IFDI helps expand the domestic cycle, while OFDI integrates with the external cycle, seeking depth and jointly promoting the high-quality transformation of China's economy.

Meanwhile, the central government's latest "Implementation Plan for Further Improving the Market-Oriented Green Technology Innovation System" states that by 2025, a market-oriented

green technology innovation system will be further established, and significant progress will be made in terms of the main body of green technology innovation, basic innovation capability and innovation environment.

The leading role of the government is emphasized. Based on the country's high attention to the development of green innovation, scholars have also paid close attention to it. Scholars have explored the way to improve green innovation from various dimensions, including trade openness, OFDI and IFDI, which are the three main channels of international technology spillovers. Therefore, under the current development pattern of dual circulation, measuring the impact of the coordinated development of two-way FDI on green innovation and exploring the role of the government in this process are of great practical significance for China's strategy to effectively promote high-level opening-up and green development.

2. Theoretical Framework

2.1 two-way FDI FDI and green innovation.

Song Xiaoling and Li Jinye use data from 30 provinces between 2003 and 2018 to examine how two-way FDI affects green economic efficiency, also test the moderating and threshold effects of technological innovation. The findings indicate that while two-way FDI greatly increases green economic efficiency, the impact differs by area. However, technological innovation also has a moderating influence; it has a positive moderating effect in the central and western areas but a significant negative moderating effect at the national level and in the eastern region. When technological innovation is separated into independent and imitative innovation and applied independently as a threshold variable, the findings indicate that increasing both types of innovation will reduce the two-way FDI's ability to promote green economic efficiency, with imitative innovation having a greater negative impact[3]. Zhang Zhihua et al. using the degree of environmental regulation as a threshold variable, he employed a dynamic geographic panel model to examine the connection between the efficiency of green innovation and the coordinated growth of two-way FDI. According to the study, two-way FDI has a threshold effect on the efficiency of green innovation, and the threshold effect varies by location[4]. Le Wei et al. investigated the spatial spillover effect of coordinated growth of two-way FDI on regional green innovation efficiency using a spatial Durbin model. The findings demonstrate that the coordinated growth of two-way FDI has a major positive impact on green innovation in nearby regions or regions with comparable human capital characteristics, in addition to encouraging the enhancement of local green innovation efficiency.Moreover, this spatial effect shows significant regional heterogeneity[5]. Therefore, it is proposed that ：

Hypothesis 1: Two-way FDI can promote green innovation, and there is regional heterogeneity.

2.2 Quality of government and green innovation.

The quality of government generally refers to the overall level of effectiveness, fairness, transparency, accountability and responsiveness demonstrated by the government in carrying out its functions. Its effectiveness includes the government's efficiency in formulating and implementing policies, the rational allocation of public resources, and its ability to provide public services, which in turn affect business decisions. Due to the current low level of government quality, there are still many shortcomings in guiding business green innovation [6].

On the one hand, policy support is limited. For example, the special funds for corporate green technology innovation are limited, which makes it hard to meet the large capital needs of enterprises in research and development, equipment upgrading, etc.; or due to the lack of government protection for related enterprises, the investment in green technology innovation is not fully compensated due to its public product characteristics, resulting in a lack of driving force for corporate innovation. On the other hand, the coordination mechanism is imperfect. For example, several departments are involved, such as those of environmental protection, science and

technology, and finance. There is a lack of effective communication and cooperation in guiding enterprises to innovate in green technology, resulting in inefficient policy implementation. There is insufficient cooperation among industry, academia and research institutes, and a bridge between enterprises and universities and scientific research institutes has not been fully established, making it difficult for enterprises to obtain cutting-edge green technology knowledge and talent support. In addition, some local protection still remains, making it impossible for local governments to implement relevant environmental policies [7].

Therefore, from the perspective of green development, the formation of high-quality government is crucial. First, a high-quality government can provide a stable and consistent policy environment. When making business decisions, enterprises need to have a certain expectation of the future to determine the scale of investment, development direction, and so on. Stable green development policies can reassure enterprises to carry out long-term planning, increase investment in research and development, and improve product quality and service level. Second, the government's high-quality enforcement of laws and regulations can create a market environment of fair competition for enterprises. Strict law enforcement ensures that enterprises operate within a framework of legal compliance and eliminates unfair competition. As a result, enterprises pay more attention to gaining market share by improving their core competitiveness when making decisions, such as strengthening green technology innovation, optimizing management processes, and improving the quality of employees. Meanwhile, strong law enforcement also protects the intellectual property rights of enterprises, motivates them to carry out green innovation and research and development, and provides an innovation-oriented approach to business decisions. Third, a quality government guides business decisions through scientific and reasonable industrial policies. The government can identify key industrial areas for development and provide appropriate policy support, such as the new energy industry, based on national strategies and regional development needs. When making business decisions, enterprises will consider the government's industrial policy guidance and adjust their business layout to tilt toward government-supported industrial fields in order to obtain more development opportunities and resources. Therefore, effective government governance can lead to more activities that benefit all stakeholders and achieve a "win-win" for the economy and the environment [8]. Therefore, it is proposed that：

Hypothesis 2: In the impact of two-way FDI on green innovation, the quality of government may reflect a threshold effect.

3. Research Design

3.1 Model setting and estimation

This study first explores the linear relationship between the coordinated development of two-way FDI and green innovation, and based on this, the quality of government is taken into account as a threshold variable, choosing the nonlinear panel threshold model proposed by Hansen. Where the nonlinear panel threshold model is basically set as:

$$GTI_{it}=\alpha_0+\alpha_1 OP_{it}+\alpha_2 GDP_{it}+\alpha_3 IC_{it}+\alpha_4 BI_{it}+\alpha_5 HR_{it}+\beta_1 IOFDI_{it}\cdot I(GQ_{it}\le\gamma)+\beta_2 IOFDI_{it}\cdot I(GQ_{it}>\gamma)+\mu_i+v_i+\varepsilon_{it} \quad (1)$$

Equation (1) is only a single panel threshold data model, considering that there may be more than one threshold value for the quality of government, equation (1) is expanded to construct the corresponding multi-threshold panel model as follows.

$$GTI_{it}=\alpha_0+\alpha_1 OP_{it}+\alpha_2 GDP_{it}+\alpha_3 IC_{it}+\alpha_4 BI_{it}+\alpha_5 HR_{it}+\beta_1 IOFDI_{it}\cdot I(GQ_{it}\le\gamma)+\beta_2 IOFDI_{it}\cdot I(GQ_{it}>\gamma)+\ldots+\beta_n IOFDI_{it}\cdot I(GQ_{it}\le\gamma_n)+\beta_{n+1} IOFDI_{it}\cdot I(GQ_{it}>\gamma_n)+\mu_i+v_i+\varepsilon_{it} \quad (2)$$

where i refers to the province and t represents the year, respectively, the explanatory variable is GTI, which indicates green technology innovation, the core explanatory variable is IOFDI, which indicates the level of coordinated development of two-way FDI, and the rest of them are control

variables, in which OP denotes the degree of openness, GDP denotes the level of economic development, IC denotes the level of industrial structure, BI denotes the level of infrastructure, and HR denotes the level of human capital. $I(\cdot)$ is the indicator function , GQ denotes government quality threshold, γ is the threshold estimate, μ is the individual effect, ν is the time effect, and ε is the random disturbance term.

3.2 Variable selection and data description

Explanatory variable: green technology innovation output (GTI). Existing studies have mainly used patent indicators to measure technological innovation, because patent applications are usually consistent with technological progress and can be used to track technology transfer. For this reason, this study adopts the number of green technology patent applications as a measure, and the data are obtained from the CNRDS.

Core explanatory variable: level of coordinated development of two-way FDI (IOFDI).Referring to the practice of Huang Lingyun and others[9], a coupled system model is used to measure the level of coordinated development of two-way FDI, and a coordinated development index is introduced. The calculation formula is as follows:

$$\mathrm{IOFDI} = \{\{\mathrm{IFDI_{it}} \times \mathrm{OFDI_{it}}/[(\mathrm{IFDI_{it}} + \mathrm{OFDI_{it}})/2]\}^{1/2}$$

Where$\mathrm{IFDI_{it}}$ and$\mathrm{OFDI_{it}}$ are the IFDI and OFDI in year t of province i, and the data are from the Statistical Bulletin of Outward FDI. The larger the value of IOFDI, the higher the degree of coordinated development of two-way FDI; and vice versa, the lower it is.

Threshold variable: government quality (GQ). Since the invention of green technology and the protection of intellectual property rights in government efficiency are intimately linked, the degree of protection will have a significant impact on businesses' willingness to innovate in green technology.In this study, the intellectual property protection index in the National Report on the Development Status of Intellectual Property Rights is selected to measure the level of intellectual property protection of each local government, and is used as a proxy for the government quality index of each local government, with the larger value indicating the higher quality of the local government.

Control variables: The entire value of goods imported and exported divided by the GDP of the current year is used to calculate openness (OP); the value of the tertiary industry divided by the value of the secondary industry is used to calculate industrial structure (IC); the GDP of each province, autonomous region, and municipality is used to calculate economic development level (GDP); the logarithm of road length is used to calculate infrastructure level (BI); and the number of students enrolled in higher education institutions divided by the total population is used to calculate human capital level (HR).data obtained from municipal, provincial, and national statistical agencies.

Because of the significant amount of missing data, Hong Kong, Macao, Taiwan, and Tibet Autonomous Region are not included in order to guarantee the veracity of the data. Thus, 30 Chinese provincial administrative units are used as the research object in this paper, with data spanning the years 2010 – 2021. The linear interpolation approach is used to fill up the gaps in the statistics yearbook. Additionally, the 30 provinces are divided into three major regions based on the National Bureau of Statistics' criteria: the eastern, central, and western regions. Table 1 displays results of the sample data's descriptive statistics.

Table1. Variable Descriptive Statistics

variant	average value	standard deviation	minimum value	maximum values
GTP	6,048	8,923	23	56,013
IOFDI	5.222	1.712	1.414	7.809
GQ	64.33	13.60	40.77	93.74
OP	0.270	0.301	0.00757	1.548
GDP	25,666	21,319	1,350	124,370
IC	1.215	0.696	0.500	5.297

BI	11.68	0.852	9.390	12.90
HR	0.0202	0.00562	0.00799	0.0425

4. Empirical Analysis

4.1 Benchmark regression analysis

The influence of IOFDI on regional green innovation is first estimated linearly in this research. The P-value from the Hausman test was 0.0022, which is below 0.05. According to this result, the fixed-effect model is chosen. China is separated into three regions — the eastern, central, and western regions in order to further examine the diverse relationship between IOFDI and green technological innovation in various regions.The specific estimation results are presented in Table 2. The results indicate that Column (1) demonstrates a significantly positive impact coefficient for IOFDI on China's overall green technological innovation, suggesting that an enhancement in IOFDI can positively influence China's overall green technological innovation. The effects of IOFDI on green technological innovation differ depending on the location, as shown in columns (2), (3), and (4). Hypothesis 1 is confirmed by the coefficient, which is negative in the central and western regions and positive in the eastern zone.

Table 2. Benchmark regression results

	population	shore		
GTI		eastern part	Central Region	Western Region
IOFDI	0.1123	0.2859	-2.1354	-0.0169
GQ	-0.0031	-0.0090	-0.0051	-0.0010
OP	-0.8026	0.0668	0.7443	0.1000
GDP	0.0001	0.0001	0.0003	0.0003
IC	0.1775	0.4642	0.0873	0.1490
BI	-0.7839	-1.6623	1.0269	0.1386
HR	-1.9075	4.7968	1.4450	-1.5363
_cons	8.3066	15.8035	-2.3655	-1.5613
R-sq	0.8761	0.9266	0.9071	0.8415

4.2 Analysis of threshold effects

4.2.1 Existence of threshold effects

In order to analyze the threshold effect, as proposed by Hanse's theory, it is first necessary to determine the existence of the threshold effect. Refer to the Bootstrap method to increase the model threshold number in turn for testing. As illustrated in Table 3, when the quality of government is employed as the threshold variable, the nonlinear model only passes the single threshold test at the 1% significance level. Conversely, the double and triple threshold tests fail, indicating that a single panel threshold data model should be used for exploration. This outcome lends further support to Hypothesis 2.

Table 3. Existence of threshold effects

	F-value	P-value
single threshold	58.08	0.0000
double threshold	16.64	0.1333
triple threshold	5.11	0.7000

4.2.2 Threshold estimation

After proving the existence of the threshold effect, the corresponding estimated threshold and confidence interval are shown in Table 4. IOFDI has a single threshold effect of government quality on the innovation of green technology, and the estimated threshold is 87.9300, with a confidence interval of 95%.

Table 4. Threshold estimates

	estimated value	95% confidence interval
single threshold	87.9300	[84.7200,88.7000]

4.2.3 Threshold model regression

The threshold value divides IOFDI into two intervals, and the regression results are shown in Table 5. The results show that GDP and IC are significantly and positively correlated with green technological innovation, while OP, BI and HR are significantly and negatively correlated with green technological innovation. The coefficients of each threshold interval are positive, indicating that IOFDI can always promote green technological innovation. However, when the quality of government is higher than 87.9300, the positive effect of IOFDI on green technological innovation begins to weaken. Therefore, in actual operation, the quality of government can be adjusted according to the threshold value, so as to give full play to the positive effect of two-way FDI to a greater extent.

Table 5. Panel Threshold Model Regressions

GTI	ratio	P-value
OP	-0.6728	0.016
GDP	0.0001	0.000
IC	0.2105	0.040
BI	-0.8192	0.039
HR	-2.1185	0.040
GQ≤γ	0.0971	0.261
GQ>γ	0.0020	0.982
_cons	8.6276	0.036
R-sq	0.8929	

5. Summary

This study examines how the coordinated growth of two-way FDI (IOFDI) affects green technology innovation. According to the results of the benchmark regression analysis, China's green technology innovation is generally positively impacted by IOFDI. From a sub-regional standpoint, the eastern area has a positive impact coefficient for IOFDI on green technology innovation, but the central and western regions have a negative impact coefficient.This discrepancy could be attributed to the regional differences in the capacity to assimilate and utilize the advanced technology and managerial expertise of foreign-funded enterprises. Consequently, the positive spillover effect of IOFDI is not effectively reflected in these regions. Concurrently, the nature of the non-linear threshold of government quality was further investigated, and the temporal changes of the government quality threshold in the impact of IOFDI on green technological innovation were elucidated. In the nonlinear mechanism of IOFDI affecting green technological innovation, the research findings show that: first, there is a single threshold for government quality, and the coefficients of each threshold interval are positive, indicating that the effect of IOFDI on green technological innovation is consistently positive. The beneficial impact of IOFDI on green

technological innovation, however, starts to wane when the threshold value rises over the predicted value. Second, there is a substantial negative association between green technological innovation and OP, BI, and HR, and a significant positive correlation between GDP and IC.

This paper's main goal is to provide policy recommendations that will raise the region's level of green technology innovation. The following suggestions are put up in support of this goal: First, different regions have different effects from IOFDI on green technological innovation. Accordingly, in order to boost the innovation-driving force of comparatively underdeveloped regions and encourage green innovation output, greater attention must be paid to the central and western regions while preserving the eastern region's steady development. This includes enhancing the region's capacity to absorb new technologies.Second, ensuring the efficacy of government quality is crucial. Through IOFDI, the government must play a crucial role in boosting the capacity of green technological innovation, in accordance with the threshold features of government quality. Thirdly, while precisely measuring the level of openness and strengthening the role of infrastructure and human resources in fostering green technological innovation, the government should keep advancing economic development and the optimization and modernization of the industrial structure.

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