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How Does the Digital Economy Contribute to Regional Green Development in China? Evidence-Based on the Intermediary Effect of Technological Innovation

Dongchu Han [1,*] and Mianfang Liu [2,3]

[1] School of Business, Hunan University of Science and Technology, Xiangtan 411201, China
[2] School of Mathematics and Computational Science, Hunan University of Science and Technology, Xiangtan 411201, China
[3] School of Software and Information Engineering, Hunan Software Vocational and Technical University, Xiangtan 411100, China
* Correspondence: handongchu@126.com; Tel.: +86-1810-7322-822

Abstract: This study aims to explore how the digital economy contributes to regional green development through the intermediary effect of technological innovation in China. Taking 30 provinces in China as the regional research objects, this study constructed a measurement index system for the development level of the digital economy and green development level and used the intermediary effect model and the threshold effect model for empirical testing. The empirical results show that: (1) the digital economy has a significant positive impact on the green development of China, and the digital economy can effectively promote green development at the provincial level; (2) technological innovation has a significant intermediary effect and a single threshold effect in the process of the green development of provinces driven by the digital economy; (3) the marginal effect of the digital economy on green development has an inflection point, from strong to weak. This study provides a reference for China to further plan the sustainable development strategy and provides experience for the sustainable development of other countries.

Keywords: digital economy; technological innovation; green development; intermediary effect; China

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1. Introduction

Green development has become a major effort of mankind in exploring the development mode and roadmap in the face of global resource and energy shortages and ecological environment deterioration [1]. Meanwhile, a new round of technological revolution has led human society into the era of digital economy. Digital technology has widely and rapidly penetrated all aspects of the economy and society, triggered profound changes in the economy and society, reshaped the pattern of social governance, and become a wind vane indicating the trends in reform, development, and innovation. In 2019, the China Institute of Information and Communications estimated that the added value of the digital economy in 47 countries reached $31.8 trillion. The proportion of the global digital economy in GDP increased from 40.3% in 2018 to 41.5% in 2019. The status of the digital economy in the Chinese national economy continued to improve, and the proportion of China's digital economy to GDP reached 36.2%, indicating a great potential for development [2]. The rapid development of the digital economy provides an alternative new path for promoting green development.

2. Literature Review

Both green development and the digital economy are related to economic transformation and development. On the one hand, "Green development" refers to the economic and social development mode aiming at efficiency, harmony, and sustainability, which is the organic unity of green subject, green economy, and green governance [3,4]. Green development can be understood as sustainable development, green transformation, a low-carbon economy, and green growth [5]. At present, the relevant literature on green development mainly concentrates on the influencing factors of green development and the measurement of green development. The influencing factors of green development mainly include financial agglomeration [6,7], industrial structure [8,9], technological innovation [10], opening degree [11,12], environmental regulation [13–15], urbanization [16–18], etc. The measurement of green development mainly includes the comprehensive index evaluation method [5,19,20] and the efficiency evaluation method [21,22].

On the other hand, “Digital economy” refers to a series of economic activities with the use of digital knowledge and information as key production factors, a modern information network as an important carrier, and the effective use of information and communication technology as an important driving force for efficiency improvement and economic structure optimization, mainly including digital industrialization, industrial digitization, and digital governance [23–26]. At present, the research on the digital economy focuses on two aspects: one is the measurement and evaluation of the digital economy [27–30]; the other is the empirical study of the digital economy [31–34].

A literature review shows that few studies investigated the relationship between the digital economy and green development. Research has mainly focused on big data and green development, artificial intelligence and green development, the digital economy and green economy, the digital economy, and urban green transformation. For example, Xu et al. (2019) [35] studied big data and green development in China from three aspects: economy, society, and environment, and they believed that big data had a positive impact on green development. Wang et al. (2020) [36] analyzed the opportunities and challenges of AI in promoting green development. They believed that AI could effectively promote green development by establishing some response mechanisms. Qian et al. (2020) [37] investigated the digital economy and green economy policies in the post-COVID-19 economic recovery policies of various countries around the world and concluded that the digital economy and green economy could develop together to help economic recovery as soon as possible. Liu et al. (2021) [38] studied the digital economy and urban green transformation by analyzing their impact mechanism from the perspectives of production, life, and ecological space. They conducted an empirical test using cities in the Yangtze River’s economic belt as an example and concluded that the digital economy could promote urban green transformation.

There are two contradictory views on whether technological innovation can promote regional green development: the first view is that technological innovation can promote regional green development [39,40] and that technological innovation has a threshold effect [39]. Because technological innovation can improve the production process, improve the energy efficiency of products, and reduce energy consumption per unit product, thereby reducing pollution emissions and environmental impact [41]. At the same time, technological innovation can bring about the application of new technologies, give birth to green industries, and directly solve ecological and environmental problems from the source.

However, the opposing party believes that technological innovation may also cause a rebound effect [42]. Technological progress also promotes the expansion of the economic scale and generates new demand for energy sources; thus, it partially or even completely offsets energy savings to interfere with the green transformation development of the region. In view of this, taking into account the rapid development of the digital economy since 2005 and the availability and integrity of research data, we selected the empirical data of 30 provinces (except Hong Kong, Macao, Taiwan, and Tibet) in China from 2005 to 2019 and discuss whether the digital economy has affected the regional green development level through technological innovation by measuring the digital economy and green development level. These studies will provide a reference for China to further plan the sustainable development strategy and provide experience for the sustainable development of other countries.

The possible innovations of this paper are as follows: first, this is one of the first papers studying the relationship between the development level of the digital economy and the level of green development. Second, we investigate whether the digital economy indirectly affects the regional green development level through the intermediary effect of technological innovation. Third, technological innovation is used as a threshold variable to test the differential impact of the digital economy on regional green development under different levels of technological innovation.

The rest of this study is arranged as follows: In Section 3, the model construction and variable description are presented. In Section 4, the empirical results and analysis are discussed. In Section 5, the robustness check is presented. In Section 6, the discussion is presented. In Section 7, the conclusions and policy recommendations are proposed.

3. Model Construction and Variable Description

3.1. Data Source

The data studied in this paper are the static balance panel data of 30 provincial-level regions in China from 2005 to 2019. Hong Kong, Macao, Taiwan, and Tibet have been excluded due to a lack of data availability. The required data mainly come from the official website of the National Bureau of Statistics, the Data Center of the National Research Network, the Science and Technology Database of the National Research Network, the Information Industry Database of the National Research Network, the website of the Ministry of Industry and Information Technology, the China Statistical Yearbook, and the statistical yearbooks of various provinces over the years. Some missing data are filled by interpolation or analogy. The GDP is deflated with 2000 as the base period.

3.2. Model Construction

(1) Benchmark measurement model

First, to test the impact of the digital economy on regional green development, the following benchmark measurement model is established by using OLS based on determining various variables:

$$Gd_{i,t} = \alpha_0 + \alpha_1 De_{i,t} + \alpha_c Z_{i,t} + \varepsilon_{i,t} \tag{1}$$

where i represents the province, t represents the year, t is the time, and i is the ID index in the panel. $Gd_{i,t}$ represents the explained variable (the green development); $De_{i,t}$ represents the explanatory variable (the digital economic); the vector, $Z_{i,t}$, represents a series of control variables; $\varepsilon_{i,t}$ represents a random disturbance term; α_i represents the correlation coefficient; α_0 represents a constant term.

(2) Intermediary effect model

Originally, the intermediary effect model was widely used in psychological research to study whether the independent variable can indirectly affect the independent variable through the intermediate variable and the extent of influence and transmission efficiency of the intermediate variable in this process [43]. At present, it is widely used in the field of economics to study the transmission mechanism between two variables. To investigate the role of technological innovation in the process of regional green development that is affected by the digital economy, technological innovation was selected as the intermediate variable to establish the intermediary effect model of technological innovation:

$$TECH_{i,t} = \beta_0 + \beta_1 De_{i,t} + \beta_c Z_{i,t} + \varepsilon_{i,t} \tag{2}$$

$$Gd_{i,t} = \gamma_0 + \gamma_1 De_{i,t} + \gamma_2 TECH_{i,t} + \gamma_c Z_{i,t} + \varepsilon_{i,t} \tag{3}$$

In Equations (2) and (3), $TECH_{i,t}$ represents the intermediate variable (the technological innovation), and the meaning of the other parameters is the same as that in Equation (1). The test process of the mediation effect is shown in Figure 1, where Sobel test statistics, $z = \beta_1 * \gamma_2 / \sqrt{{\beta_1}^2 {S_{\beta_1}}^2 + {\gamma_2}^2 {S_{\gamma_2}}^2}$, ${S_{\beta_1}}^2$, and ${S_{\gamma_2}}^2$, represent the variance of β_1 and γ_2, respectively. If z passes the significance test, then there is an intermediary effect; otherwise, there is no intermediary effect.

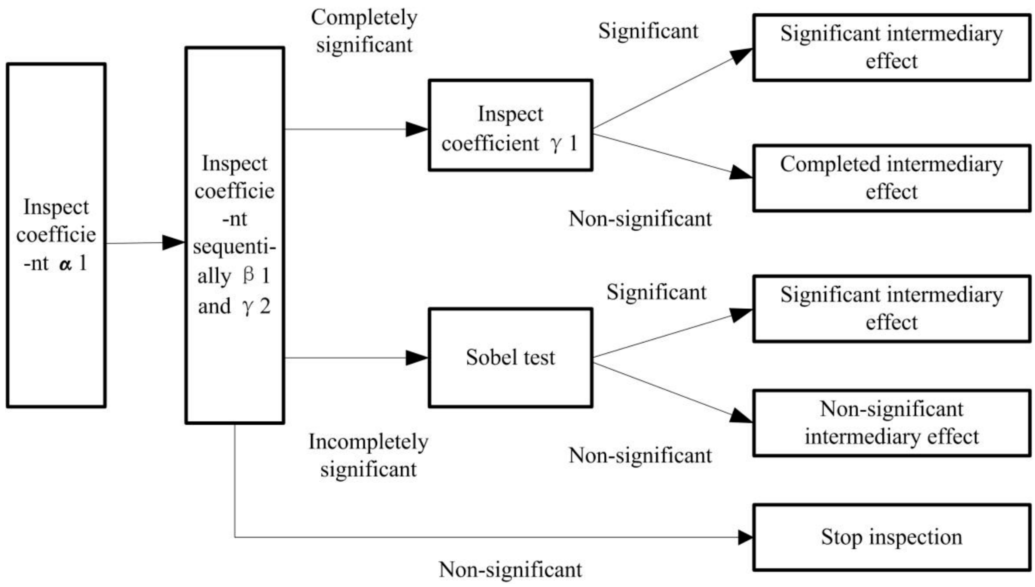

Figure 1. Intermediary effect test process.

(3) Threshold effect model

There are generally two traditional test methods to further test whether there is a threshold effect in the model, that is, adding the interaction term of the variables to test the interaction effect of the two or grouping the variables according to a certain standard for regression, but these two methods have some defects. The existence of a threshold effect can be judged by adding interaction terms, but the significance of the threshold value and inspection threshold value cannot be accurately calculated. Using the grouping regression method, the classification standard of the variables (i.e., the threshold value) depends on people's subjective judgment, so the rationality of the threshold value cannot be guaranteed, and an effective confidence interval cannot be obtained. Therefore, Hansen proposed a new panel threshold regression method in 1999. Compared with the traditional threshold test method, the panel threshold regression has the following advantages: First, it relies on the model test to judge whether the threshold effect exists, rather than setting the piecewise regression equation based on people's subjective experience. Second, the number and value of thresholds can be calculated accurately; the Bootstrap-based "self-sampling" method can effectively test the significance of a threshold and determine the confidence interval of its parameters.

Therefore, to further verify that the digital economy will indirectly affect green development through technological innovation, a panel threshold regression model is established by referring to Hansen's (1999) [44] threshold model and Zhang et al.'s (2020) [45] approach of using technological innovation as a threshold variable to analyze the difference of the marginal effect of the digital economy on the green development of provinces under different levels of technological innovation. Under the circumstance that the number of threshold values is uncertain, a multi-threshold regression model indicating the effect of the digital economy on the green development of the provinces is constructed:

$$\begin{aligned} Gd_{i,t} = \eta_i + \mu_1 De_{i,t} I(TECH_{i,t} < \varphi_1) + \mu_2 De_{i,t} I(\varphi_1 < TECH_{i,t} < \varphi_2) \\ + \ldots\ldots + \mu_n De_{i,t} I(TECH_{i,t} > \varphi_n) + \mu_c Z_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{4}$$

In Equation (4), $TECH_{i,t}$ represents a threshold variable, η_i is a constant term, and vector $Z_{i,t}$ represents the control variables, including the traffic level, economic development level, industrial structure, and foreign direct investment. $I(\bullet)$ is an indicative function and

φ represents the threshold value to be estimated. The meaning of the other parameters is the same as that in Equation (1).

3.3. Variable Description

The variable definitions are shown in Table 1.

Table 1. Variable definition.

Variable Type	Variable Name	Variable Symbol	Measurement	Unit
Explained variable	Green development	Gd	Measured with SBM-DEA model	—
Explanatory variable	Digital economy	De	Measured with entropy weight method	—
Intermediate variable/Threshold variable	Technological innovation	TECH	Number of authorized patents of each province	piece
Control variable	Traffic level	TRAFFIC	Length of highways in each province	kilometer
	Economic development level	PGDP	Per capita GDP of each province	yuan
	Industrial structure	IND	Proportion of tertiary industry output value in regional GDP of each province	percentage
	Foreign direct investment	FDI	Actual amount of foreign capital used in each province in the current year	ten thousand U.S. dollars

The variables are described as follows:

(1) Green development (the explained variable): The DEA (Data Envelopment Analysis) method is commonly used to measure green development, which is a non-parametric method based on linear optimization and is widely used in efficiency evaluation problems in operations research and economics. Referring to the method of Tone (2001) [46], we constructed the SBM-DEA (Slack-Based Measure-DEA) model to measure green development, involving input and output index variables. Referring to related research by Chen et al. (2021) [47], we selected three input indicators to measure green development investment, namely the capital factor input, labor input, and energy and resource input. Among them, the capital factor input is measured by the total investment in fixed assets, and the labor force input is measured by the number of employed persons at the year-end. For the energy and resource elements input, the built-up area and the total electricity consumption are used to measure land resources and energy resources, respectively. Output indicators include economic benefit and ecological benefit. The GDP is selected to represent the economic benefit output, and the urban green space area represents the ecological benefit output (as shown in Table 2).

(2) Digital economy (the explanatory variable): The measurement of the digital economy requires not only the specific indicators available but also the weight of relevant indicators. There are generally two methods to determine the weight: one is the subjective weighting method determined by subjective judgment based on the experience of experts, such as the Delphi method, analytic hierarchy process, etc., and the other one is the objective weighting method determined according to the actual data of the evaluation index system, such as principal component analysis, the entropy method, the correlation method, etc. Therefore, the entropy weight method is used to weigh the evaluation indicators to avoid subjective and human influence. The objective weight of the entropy weight method is determined by the variability of the index. Generally speaking, if the information entropy of an index is smaller, the degree of variation of the index will be greater, and the information provided can play a role in the comprehensive evaluation. The greater the role, the greater its weight. Meanwhile, based on the relevant research of Wang et al.

(2021) [48], we comprehensively considered the conditions, applications, and environment of the digital economy and constructed a provincial-level digital economy evaluation index system. Specifically, the development level of the provincial digital economy is the target layer in the evaluation system. According to the connotation and realistic background of the digital economy, there are three first-class indicators: digital infrastructure, digital industrialization and industrial digitization, and digital governance, which reflect the preconditions, software and hardware benefits, and development environment required by the digital economy from the macro-level (as shown in Table 3).

Table 2. Index system of the evaluation of provincial green development.

Target Layer	Primary Index	Secondary Index	Tertiary Index	Unit
evaluation of the provincial green development (Gd)	input	capital	the total investment in fixed assets	100 million yuan
		labor elements	the number of employed persons at the year-end	ten thousand people
		energy and resource elements	the built-up area	square kilometer
			the total electricity consumption	million kWh
	output	economic efficiency	GDP	100 million yuan
		ecological efficiency	the urban green space area	hectare

Table 3. Index system for the evaluation of China's provincial digital economy development level.

Target Layer	Primary Index	Secondary Index	Tertiary Index	Unit	Property
evaluation of the provincial digital economy (De)	digital infrastructure	hardware foundation	broad band subscribers port of Internet	10,000 ports	positive
		flow basis	capacity of mobile telephone exchanges	10,000 subscribers	positive
	digital industrialization and industrial digitization	hardware benefits	total telecommunication services	100 million yuan	positive
			manufacturing enterprises in the electronic information industry	pieces	positive
		software benefits	revenue scale of software products	100 million yuan	positive
			revenue scale of information service	100 million yuan	positive
	digital governance	governance environment	Internet penetration rate	percentage	positive

(3) Technological innovation (the intermediate variable/threshold variable): The number of patents directly reflects the technological innovation capability of a region. By referring to the approach of Hu et al. (2020) [49], the number of patents authorized in each province is used to measure the technological innovation level of each province.

(4) Control variables: For the purpose of the comprehensive analysis of the impact of the digital economy on the regional green development level, the following indicators affecting green development were selected as the control variables: the traffic level (TRAFFIC), expressed as the length of the roads in each region (Qiu and He, 2017 [50]); the level of economic development (PGDP), expressed as the per capita GDP of each region (Vaghefi, Siwar, and Aziz, 2015 [51]); the industrial structure (IND), expressed as the ratio of the tertiary industry output value to the regional GDP (Zhu et al., 2019 [9]); the foreign direct investment (FDI), expressed as the amount of foreign investment used in the current year (Gao et al., 2021 [12]).

The descriptive statistics of the main variables are shown in Table 4. Some variables are taken from natural logarithms to alleviate the problems of heteroscedasticity and multicollinearity.

Table 4. Descriptive statistical results of the main variables.

	Variable	Observations	Mean	Standard Deviation	Min	Max
Explained variable	Gd	450	0.311	0.155	0.119	1.000
Explanatory variable	De	450	0.111	0.126	0.001	0.909
Intermediate variable/Threshold variable	lnTECH	450	9.371	1.639	4.369	13.176
Control variable	lnTRAFFIC	450	11.547	0.867	9.001	12.728
	lnPGDP	450	10.466	0.657	8.528	12.009
	lnIND	450	3.757	0.196	3.353	4.425
	lnFDI	450	12.683	1.583	6.100	15.096

4. Empirical Results and Analysis

4.1. Empirical Results and Analysis of Intermediary Effect

To solve the effect model selection problem of panel data regression, the Hausman test was performed first. According to the Hausman statistical value of 5.55 (p = 0.3520), the effect of the random effect was better than that of the fixed effect. Therefore, it is more reliable to select the random effect. We carried out empirical regression based on the random effect, and the regression results are in Table 5.

Table 5. Regression results of the intermediary effect model.

Variable Name	Model (1) Gd	Model (2) lnTECH	Model (3) Gd
De	0.4108 **	0.5866 *	0.4029 **
	(2.27)	(1.77)	(2.17)
lnTECH	——	——	0.0064
			(0.55)
lnTRAFFIC	−0.0694 ***	0.3902 ***	−0.0731 ***
	(−2.74)	(4.03)	(−3.13)
lnPGDP	0.0179	1.3654 ***	0.0105
	(1.49)	(13.41)	(0.63)
lnIND	0.0621	1.0979 ***	0.0556
	(0.76)	(3.34)	(0.71)
lnFDI	0.0113	0.0170	0.0104
	(1.40)	(0.48)	(1.27)
Constant	0.5022	−13.8290 ***	0.6001
	(0.94)	(−9.82)	(1.24)
Observations	450	450	450
Number of IDs	30	30	30
RE	YES	YES	YES

Note: Robust z-statistics are in parentheses. ***, **, and *, respectively, indicate significance at the levels of 1%, 5% and 10%.

Model (1) is the panel regression result without any intermediate variables and is the total effect of the digital economy on the green development of the provinces, corresponding to Formula (1). The impact coefficient of the digital economy on the green development of the provinces is 0.4108. The significance test at the 5% confidence level shows that the digital economy can effectively promote the green development level of the provinces. For every unit of the digital economy increased, the green development level of the provinces can be increased by 41.08%. This is because the digital economy relies on digital infrastructure to realize industrial digitalization, digital industrialization, and digital governance through a technological revolution, which in turn improves the market transaction efficiency, promotes the evolution of division of labour, optimizes the allocation of market resources, and, thus, promotes green development.

As for the other control variables, the influence coefficient of traffic level (lnTRAFFIC) is −0.0694, and it passes the significance test under the 1% confidence level, which indicates that the current traffic level has a significant negative effect on the green development of the province, and the improvement of traffic level inhibits the green development of the province to a certain extent. This is mainly because with the improvement of traffic level, the number of vehicles on the highway will increase, and the emission of vehicle exhaust will also increase significantly. The large amounts of harmful substances in vehicle exhaust cause serious pollution to the ecological environment, thus inhibiting the local green development to a certain extent; the parameters of the lnPGDP, lnIND, and lnFDI are insignificant. The results show that the current economic development level, industrial structure, and foreign direct investment have no significant impact on green development.

Model (2) is the panel regression result for the effect of the digital economy on intermediate variable technological innovation, reflecting the impact of the digital economy on intermediate variable technological innovation, corresponding to Formula (2). The influence coefficient of the digital economy on technological innovation is 0.5866, and it passes the significance test at the 10% confidence level, indicating that the digital economy can effectively promote the improvement of provincial technological innovation levels. For every unit of digital economy level increased, the provincial technological innovation level can be increased by 58.66%. The influence coefficients of lnTRAFFIC, lnPGDP, and lnIND are 0.3902, 1.3654, and 1.0979, respectively, all of which pass the significance test under the confidence level of 1%, indicating that the current traffic level, economic development level, and industrial structure have a certain positive role in promoting technological innovation. The impact coefficient of lnFDI is 0.0170 and fails to pass the significance test, indicating that the current foreign direct investment has no significant impact on technological innovation.

Model (3) is the panel regression result for the effect of the digital economy on the green development of the provinces when the intermediate variable technological innovation is used as the control variable, corresponding to Formula (3). The estimated coefficient of the digital economy is significantly positive at the 5% confidence level, indicating that the digital economy has a positive role in promoting green development. However, if the estimated coefficient of technological innovation is not significant, it is still uncertain whether technological innovation has an intermediary effect. To further determine whether the digital economy has an intermediary effect on green development through technological innovation, the Sobel test is required. The result of the Sobel test, Z = −1.941 (p = 0.052), is significant at the 10% confidence level. Technological innovation has an obvious intermediary effect at the 10% confidence level. The digital economy has an indirect impact on the green development of the provinces through technological innovation. The digital economy can improve the green development level of the provinces by promoting technological innovation.

4.2. Empirical Results and Analysis of Threshold Effect

For the panel threshold regression model, it is necessary to confirm the existence and number of thresholds. Therefore, we employed the Bootstrap "self-sampling" method by referring to Hansen (1999) and used Stata15.0 software for the threshold effect test. The results are shown in Table 6. In addition, the inflection point of the threshold value in the LR diagram was observed, and the results in Figure 2 reveal the inflection point at the threshold value of 6.6399.

From Table 6, the digital economy passed the single threshold test of a 10% significance level under the conditions of 300 and 500 self-sampling, respectively, and the corresponding F value is 33.07, and the corresponding P value is 0.0867 and 0.0860, respectively, while the double threshold is not significant under the conditions of 300 and 500 self-sampling, respectively. This shows that under the premise that technological innovation is taken as the threshold variable, the digital economy has a single threshold effect on the green development of the provinces, with a single threshold of 6.6399 and a 95% confidence interval of [6.5709, 6.7238].

Table 6. The threshold effect test results.

Threshold Variable	Threshold Type	Threshold Value	F Value	*p* Value	Bootstrap Times	Critical Value of Different Significance Levels		
						10%	5%	1%
$lnTECH_{300}$	Single threshold	6.6399 *	33.07	0.0867	300	31.2895	40.2171	70.2037
	Double-threshold	5.6699	28.93	0.1067	300	29.1818	31.9994	45.7323
$lnTECH_{500}$	Single threshold	6.6399 *	33.07	0.0860	500	32.2092	38.5844	67.3958
	Double-threshold	5.6699	28.93	0.1100	500	29.5944	36.4451	56.3869

Note: * indicate significance at the levels of 10%.

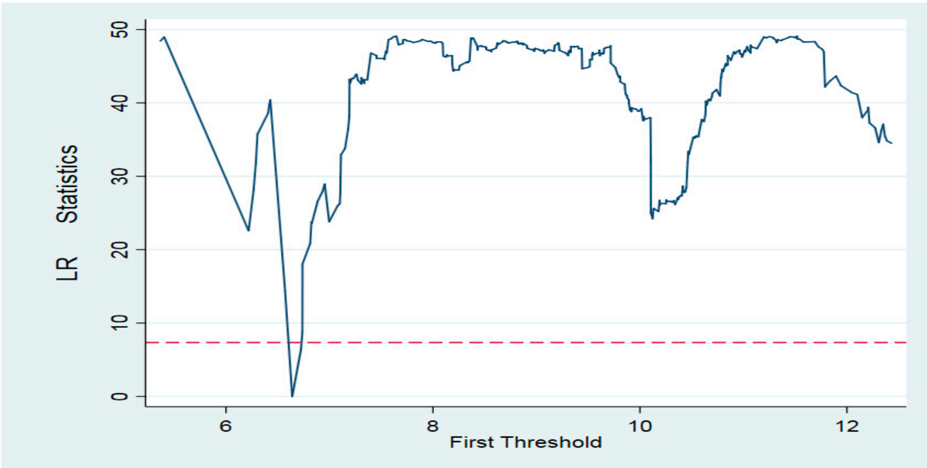

Figure 2. LR diagram of the threshold effect. Note: The red dotted line is the critical value of 5%.

The threshold variable of technological innovation is divided into two types: low-level technological innovation (lntech ≤ 6.6399) and high-level technological innovation (lntech > 6.6399). Table 7 shows the specific relationship between the digital economy and green development under different levels of the threshold variable of technological innovation. The estimation results show that when the level of technological innovation is at a low level, the impact coefficient of the digital economy on green development is 10.7976. The significance test at the 1% confidence level shows that under this condition, the digital economy significantly promotes the green development of the provinces. For each unit of increase in the level of the digital economy, the level of green development of the provinces will increase by 10.7976 units; when the level of technological innovation is at a high level, the impact coefficient of the digital economy on green development is 0.3916. Through the significance test at the 1% confidence level, it shows that under this condition, the digital economy still significantly promotes the green development of the provinces, but the promotion effect is significantly weakened. For each unit of increase in the level of the digital economy, the level of green development of the provinces will be increased by 0.3916 units. This means that the impact of the digital economy on green development under different levels of the threshold variable of technological innovation is positive, but it does not increase linearly. Instead, there is an inflection point or threshold in the shape of a broken line. The broken line changes from steep to flat, and the marginal effect changes from strong to weak.

From the regression results of the other control variables, in the two threshold intervals of technological innovation, the regression coefficients of the traffic level are −0.0511 and −0.0695, respectively, and both passed the significance test at the 1% confidence level, which indicates that the current traffic level has a negatively inhibitory effect on the green development of the province, mainly due to the increase of road traffic vehicle exhaust emissions. The regression coefficients of foreign direct investment were 0.0161 and 0.0115, respectively, which passed the significance test at the confidence level of 5% and 10%.

It indicates that foreign direct investment has a positive role in promoting the green development of the provinces. This shows that free trade and free investment improve economic efficiency and productivity to improve the input–output level of resources and the environment. After being affected by economies of scale, the environmental quality will also be gradually improved, and the green development level of the provinces will be improved. When technological innovation is at a low level, the regression coefficient of the economic development level is 0.0331, and it passes the significance test at a 5% confidence level, which indicates that the economic development level has a positive role in promoting green development. The regression coefficient of the industrial structure is 0.1831, and it passed the significance test at the 1% confidence level, which indicates that the industrial structure has a positive role in promoting the green development of the province. When technological innovation is at a high level, the level of economic development and industrial structure fails to pass the significance test, which indicates that the level of economic development and industrial structure has no significant impact on green development.

Table 7. Estimation results of the threshold effect model.

Variable Name	(lnTECH ≤ 6.6399) Gd	(lnTECH > 6.6399) Gd
De	10.7976 *** (1.5690)	0.3916 *** (0.0713)
lnTRAFFIC	−0.0511 *** (0.0146)	−0.0695 *** (0.0139)
lnPGDP	0.0331 ** (0.0132)	0.0193 (0.0137)
lnIND	0.1831 *** (0.0402)	0.0641 (0.0424)
lnFDI	0.0161 ** (0.0065)	0.0115 * (0.0065)
_cons	−0.3434 * (0.1808)	0.4816 ** (0.2078)
R^2	0.5738	0.6721

Note: ***, **, and *, respectively, represent mean significance at the levels of 1%, 5%, and 10%, and the standard error is in brackets.

5. Robustness Test

Considering that there may be hysteresis in the promotion effect of the digital economy on green development, hybrid OLS regression tests were carried out for the digital economy with hysteresis phase I and hysteresis phase II, respectively, within the division range of the original technological innovation threshold to verify further the robustness of the above results of a threshold effect. From the robustness test results in Table 8, no matter whether the digital economy was in lag phase I or phase II, the influence coefficient for the digital economy in the corresponding threshold interval did not change considerably, and the sign direction of the coefficient did not change. It indicates that the regression results are robust, and the trajectory result of the original threshold model has high reliability.

Table 8. Robustness test results considering the hysteresis of explanatory variables.

Variable	Hysteresis Phase I		Hysteresis Phase II	
	(lnTECH ≤ 6.6399)	(lnTECH > 6.6399)	(lnTECH ≤ 6.6399)	(lnTECH > 6.6399)
	Gd	Gd	Gd	Gd
De	9.8314 *** (1.5814)	0.5191 *** (0.0843)	5.2791 *** (1.6545)	0.6662 *** (0.0983)
lnTRAFFIC	−0.0714 *** (0.0172)	−0.0930 *** (0.0160)	−0.0874 *** (0.0180)	−0.1058 *** (0.0166)
lnPGDP	0.0270 * (0.0140)	0.0037 (0.0147)	0.0221 (0.0165)	−0.0129 (0.0167)
lnIND	0.1794 *** (0.0417)	0.0712 * (0.0432)	0.1559 *** (0.0452)	0.0621 (0.0445)
lnFDI	0.0178 *** (0.0068)	0.0107 (0.0067)	0.0190 *** (0.0072)	0.0091 (0.0069)
_cons	−0.0495 (0.2126)	0.8974 *** (0.2373)	0.2658 (0.2261)	1.2715 *** (0.2498)
R^2	0.5647	0.6773	0.5667	0.6803

Note: *** and *, respectively, represent mean significance at the levels of 1% and 10%, and the standard error is in brackets.

6. Discussion

It can be seen from the above research that the digital economy has a positive role in promoting green development at different levels of technological innovation of threshold variables. Among them, the digital economy can promote regional green development, which is basically consistent with the research conclusion of Liu et al. (2021) [38]; the role of technological innovation in promoting green development is consistent with the research conclusion of Hu et al. (2021) [39]. On the basis of previous research, this study adds the digital economy as a research object and uses Chinese provincial data to measure it. From another perspective, the intermediary effect of technological innovation is studied.

This paper used provincial data as a regional research object to explore the intermediary effect of technological innovation, which had certain limitations. In future research, it can be considered to expand the research to cities or urban agglomerations.

7. Conclusions and Policy Recommendations

In this study, 30 provinces in China from 2005 to 2019 were selected to reach the objectives of the study where we have constructed an index system of the digital economy development level and green development level, and an empirical test was first conducted to assess the impact of the digital economy on green development at the provincial level, and an intermediary effect model was built to analyze whether the digital economy affects the green development through the intermediary effect of technological innovation, and technological innovation was finally used as the threshold variable to examine the differential impact of the digital economy on green development under different levels of technological innovation. The technological innovations were divided into different levels to analyze the heterogeneity of the threshold effect of technological innovation at different levels. In general, technological innovation has played an intermediary role in the process of the digital economy driving regional green development. Furthermore, technological innovation has a single threshold effect. With the increase in the technological innovation level, the marginal effect of the digital economy on green development turns from strong to weak, without linear increase, but there is an inflection point in the shape of a broken line, which is steep first and then turns flat. In addition, China's current traffic level has an inhibitory effect on the green development of the provinces, while the economic development level, industrial structure, and foreign direct investment all play a positive role in improving the green development level of the provinces.

In consideration of the aforesaid research conclusions, we put forward the following countermeasures and suggestions to promote green development.

Firstly, China shall vigorously develop a digital economy to facilitate green development. On the one hand, China should strengthen the innovative application of key digital technologies and cultivate and expand energy conservation and environmental protection industries, cleaner production industries, and clean energy industries. On the other hand, China should continue to improve its digital governance system and improve its digital service level for green industries.

Secondly, actively encouraging technological innovation and facilitating green development can be a good choice. China should continue to promote innovation and development-driven strategy. While increasing the technology subsidies and investment and rewarding green innovation, China must actively develop renewable energy and promote a green and low-carbon transformation of energy consumption. This proposal is also beneficial for developing countries, such as China.

Thirdly, it is recommended to transform the mode of economic development to facilitate green development. China should integrate digital technologies such as big data, cloud computing, artificial intelligence, and the Internet of Things into the traditional industries so as to promote the transformation and upgrading of traditional industries and high-quality economic development. By cultivating green industries, China can form a new economic growth point.

In addition, the government should improve the level of green transportation, accelerate the optimization and upgrade of industrial structure, appropriately expand the degree of opening to the outside world, and improve the level of economic development to further promote green development.

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