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The Impact and Comparison of Venture Capital and R&D Investment on Green Technology Innovation

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Abstract

In the context of double carbon, the development of green technology is one of the key factors affecting the competitiveness of enterprises in the future, and it is also the future development trend of China's economy and society. Yes, and venture capital and R&D investment can provide essential green technology innovation Funds to avoid the shackles brought by the shortage of funds. This project will compare and study the impact of venture capital and R&D investment on green technology innovation, build an ordinary panel model and a spatial panel model to analyze the correlation between venture capital and R&D investment and green technology innovation, and analyze the reasons from multiple perspectives. It analyzes and puts forward suggestions related to the development of green technology, and provides a reference for the progress of green technology in China. The research finds that both venture capital and R&D investment have a positive impact on green technology innovation, but the impact of R&D investment on green technology innovation is higher than that of venture capital.

Keywords

Venture Capital; R&D Investment; Green Technology Innovation; Panel Model.

1. Introduction

In recent years, China has sacrificed its natural environment and over-consumed ecological resources for its rapid economic development. Although my country's GDP has indeed maintained a high-speed growth, the extensive mode of economic development has had an irreversible and adverse impact on China's ecology, which is incompatible with China's sustainable development. Development goes in the opposite direction. Based on this, China's economy has changed the direction of high-speed growth, reversed the pursuit of high-quality development, and adhered to the concept of green development. Since the 18th National Congress of the Communist Party of China, the balance, coordination and sustainability of economic development have been significantly enhanced, and the pursuit of high-quality development is the new direction of China's economic development; the report of the 19th National Congress emphasized that "green mountains are invaluable assets"; At the 75th United Nations General Assembly, President Xi announced that China will strive for the two goals of carbon peaking and carbon neutrality, advocate green, environmentally friendly and low-carbon industrial development, accelerate the pace of reducing carbon emissions, guide enterprises in green technology innovation, and strengthen enterprises. sustainable development capacity and improve the global competitiveness of industries and economies. This series of measures has undoubtedly demonstrated to the world China's firm determination to green development. In an important stage of economic transformation, green technology innovation can effectively reduce energy and environmental pollution and promote high-quality economic development. The development of green technology innovation must avoid the problem of insufficient funds. Venture capital and R&D investment, as the key points of capital inflow, inject capital flow into green technology innovation from different angles. Although the development history of venture capital in China is short, its development scale

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and its role are constantly expanding. In 2021, the scale of venture capital in China will rank second in the world with 393.38 billion yuan (data from London & Partners), second only to the United States . The investment in research and development is also huge, reaching 2,786.4 billion in 2021 (data from the National Bureau of Statistics), maintaining a high level of growth, which fully reflects the government's high emphasis on technological innovation. Venture capital and R&D investment play a significant role in promoting economic growth and technological innovation, their importance is evident, and it is worth paying attention to their role in green technology innovation. This paper will study the impact of venture capital and R&D investment on green technology innovation and compare and analyze the role of the two, and draw conclusions to provide relevant theoretical support for the government to formulate policies.

2. Literature Review and Research Methods

2.1. Literature Review

Undoubtedly, due to its high risk, green technology innovation is inseparable from sufficient funds as support, and venture capital and R&D investment, as an important source of funds for technological innovation, can effectively alleviate the financial predicament of green technology innovation, so it is widely accepted by scholars. their high attention. However, at present, there is no unified conclusion in the academic circle on the impact of venture capital and R&D investment on green technology innovation.

At present, there are generally three views in the academic circle on the role of venture capital in technological innovation. First, most scholars agree that venture capital has a positive impact on technological innovation. Xiang Weimin et al. (2021) [1], Song Jing et al. (2021) [2], Cheng et al. (2019) [3] studied from different perspectives and believed that venture capital is positively correlated with technological innovation. Second, some scholars believe that venture capital is not enough to have a significant impact on technological innovation. Richard Florida (1990) [4] studies the development of high technology in the context of the US economic development, which is less affected by venture capital. Third, some scholars believe that the role of venture capital in technological innovation is uncertain. For example, Xia Qinghua et al. (2021) [5] found through research that venture capital has a dual role in technological innovation. Green technology innovation is an important content of technological innovation, but it is constrained by the conditions of green environmental protection, and whether the impact of venture capital on green technology innovation has a positive impact, the current academic circles have little research on such topics. Wang Xinxin (2021) [6] found that venture capital has a positive effect on green technology innovation, but the force is limited by regions, and there is spatial heterogeneity; Song Xiaona (2022) [7] studied with different types of manufacturing as samples It is found that foreign direct investment provides a strong impetus for the development of green technology innovation.

The role of R&D investment in technological innovation is also valued by the academic community. Most scholars believe that R&D investment has a positive role in promoting technological innovation. For example, Yin Gongli (2020) [8] found that R&D investment has a positive impact on technological innovation in the context of Sino-US economic and trade frictions and the epidemic; Yang Yun (2020) [8] [9] From the perspective of high-end equipment manufacturing enterprises, it is found that there is a one-way Granger relationship between R&D investment and technological innovation, and the impact has a hysteresis. Refining the research scope to the role of R&D investment on green technology innovation also shows a positive impact. Wang Xinxin (2021) [10], Li Xinan (2021) [11] and others also came to the same conclusion. Xu Hong et al. (2020) [12] found that R&D investment has a promoting effect on green technology. Although the progress of green technology shows a marginal

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decreasing trend with the increase of R&D investment, the impact on the development direction of green technology is gradually increasing. In addition, some scholars have studied the relationship between R&D investment and green technology innovation from the perspective of government R&D subsidies. For example, Zhang Wenqing (2022) [13] believes that the government provides a stable financial guarantee for enterprises' green technology innovation through R&D subsidies.

Combining the above literature, it can be seen that most of the academic circles study the role of venture capital and R&D investment on green technology innovation, but few scholars compare and analyze the impact of the two on green technology innovation. In addition, due to the different research methods adopted by many scholars, different regional data, and differences in national environment, it is difficult to form a unified conclusion on the impact and comparison of venture capital and R&D investment on green technology innovation. Therefore, the topic of this paper has research significance. This paper will use the provincial panel data from 2001 to 2019 to construct an ordinary panel model and a spatial panel model to empirically analyze the impact of venture capital and R&D investment on green technology by comparing the impact of venture capital and R&D investment on green technology innovation. At the same time, in order to avoid the limitations of the spatial panel model, this paper adopts the window reduction method for robustness test.

2.2. Mechanism Analysis

Green technology innovation can effectively reduce energy consumption, reduce the production cost of enterprises, improve the economic benefits of enterprises, and promote the long-term development of enterprises by improving production efficiency and reducing pollution. source of funds to provide the necessary capital flow for green technology innovation. For the impact of green technology innovation, this paper will focus on the effects of two main factors, venture capital and R&D investment, on the policy background of carbon peaking. One is that venture capital enters the enterprise, and under the influence of the trend of interests, it guides the enterprise to carry out green technology innovation; the other is that the enterprise realizes the importance of green technology innovation to the competitiveness of enterprises, and invests funds in green technology innovation independently .

Under the influence of the overall environment of the industry, venture capital increases the attention to green technology innovation, thereby increasing the flow of funds in the field of green technology innovation and promoting the development of green technology of enterprises. Venture capital can meet the funds necessary for enterprises to carry out green technology innovation at all stages, share the pressure of innovation and research and development of enterprises, reduce the burden of enterprises to carry out green technology innovation, and also provide necessary value-added services for enterprises, such as through the good reputation of venture capital and gradual progress. The tendency of profit to transmit good information to the outside world and attract more capital investment, and for the enterprise to carry out green technology innovation to attract outstanding talents and improve the transformation efficiency of green technology innovation. [15] In addition, the transformation of an enterprise's R&D investment into an enterprise's green technology innovation is subject to the enterprise's own scale and development plan. R&D investment has an important impact on the innovation performance of enterprises, which is beneficial to reduce the production cost of enterprises, increase the added value of enterprise products, improve the market competitiveness and share ratio of enterprise products, and ultimately improve the market competitiveness of enterprises. [16] Although some scholars believe that the impact of R&D investment on technological innovation has a time lag, R&D investment will bring technological innovation and new knowledge accumulation to enterprises, and the

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accumulation of knowledge and technology will reach a new stage. It will bring new technological innovations to the enterprise. [17]

Based on this, this paper proposes Hypothesis 1 and Hypothesis 2:

H1: Venture capital has a positive impact on green technology innovation.

H2: R&D investment positively affects green technology innovation.

Green technology innovation has positive externalities, but it has the problems of high investment cost and uncertain rate of return. Therefore, enterprises need to take greater risks when injecting R&D investment into the field of green technology innovation, and the expected rate of return needs to be considered. . In addition, green technology innovation involves new technologies and business models, which will increase the cost of technology research and development, and the lack of consensus in the market for the application of new technologies will also have a negative impact on the tendency of venture capital to green technology innovation. [18] Both venture capital and R&D investment have a significant impact on green technology innovation, but the academic community rarely compares the effect of the two. Based on this, the third hypothesis of this paper is proposed:

H3: Venture capital and R&D investment have different influences on green technology innovation.

It is worth noting that venture capital and R&D investment are not completely separated. After entering the enterprise, venture capital may be transformed into R&D investment of the enterprise to promote the green technology innovation of the enterprise. In addition, venture capital and R&D investment promote the technological innovation of enterprises from the inside and outside. However, due to the uncertainty of the results of technological innovation, the high risk of research and development, and the long process of realization, after obtaining the source of funds, the enterprise may not necessarily invest all the funds in green technology research and development due to the influence of risk investment with interests as the first priority. , but tend to achieve the goal of maximizing benefits through other means. Therefore, the impact of green technology innovation by venture capital and R&D investment needs to be further analyzed and discussed using relevant data to establish a model.

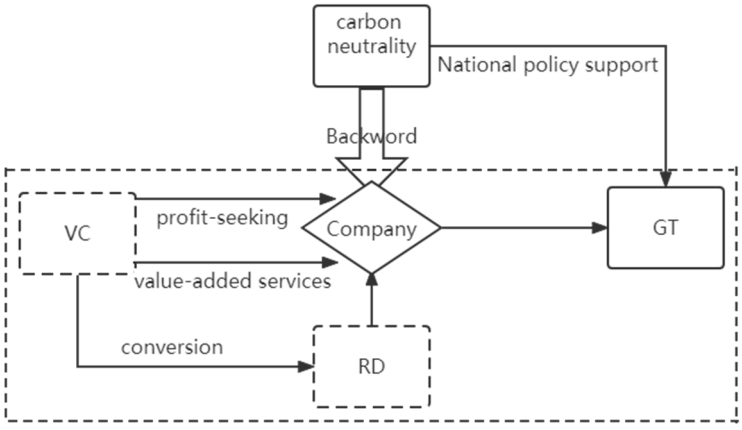

Figure 1. Mechanism analysis diagram

Regarding the mechanism of venture capital and R&D investment on green technology innovation, this paper refers to the research of Yin Gongli and other scholars, which can be summarized as follows: (1) Venture capital provides convertible funds for technological innovation, reduces the pressure of green technology innovation, and improves technological innovation. The willingness to innovate promotes the vigorous development of green technology innovation; (2) venture capital transmits favorable information and attracts more

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capital investment to promote the field of green technology innovation; (3) R&D investment directly injects funds into green technology innovation. (4) The green technology innovation of enterprises is affected by the carbon peak policy; (5) There is a transformation relationship between venture capital and R&D investment. After entering the enterprise, a part of venture capital may be transformed into R&D investment under the leadership of the enterprise's development plan.

2.3. Research Methods

2.3.1. Research on Spatial Agglomeration

Spatial autocorrelation can be understood as similar variable values in areas with similar locations. In order to test whether there is a spatial agglomeration effect in China's venture capital scale and R&D investment level, so as to determine the subsequent measurement model, Moran's I index is used for measurement and calculation. The specific formula is as follows .

$$Moran's\ I = \frac{\sum_{i-1}^{n}\sum_{j-1}^{n} w_{ij}\,(u_i - \bar{u})(u_j - \bar{u})}{S^2 \sum_{i-1}^{n}\sum_{j-1}^{n} w_{ij}}$$

Among them, $S^2 = \frac{\sum_{i=1}^{n}(u_i-\bar{u})^2}{n}$ is the sample variance, and w_{ij} is the spatial weight matrix (i, j) elements, $\sum_{i-1}^{n}\sum_{j-1}^{n} w_{ij}$ is the sum of all weight matrices, $u_i, u_j$are observations, $\bar{u}$ is the mean value.

2.3.2. Research on Econometric Models

From the literature review, it can be seen that the scale of venture capital and the level of R&D investment may have spatial autocorrelation characteristics, and the ordinary panel model cannot measure its lag effect, which easily leads to estimation bias. Therefore, this paper constructs the ordinary panel model and the spatial panel model respectively in order to obtain different estimation effects.

First, the formula for constructing a common panel model is shown in (1).

$$GT_{it} = \beta_0 + \sum_{\varphi=1}^{n} \alpha_\varphi X_{\varphi,it} + \varepsilon_{it} \quad (1)$$

Among them, i represents the region, t represents the year; GT_{it} represents the venture capital scale of the t-th year in the i region; β_0 represents the constant term, $X_{\varphi,it}$ represents the t-th year in the i regionφ Influencing factors, α_φ represents the regression coefficient of the φ influencing factor, and ε_{it} is the random disturbance term.

Secondly, a spatial panel model is constructed, and a spatial Durbin model (SDM) is constructed to analyze the influence of spatial autocorrelation characteristics on venture capital.

$$GT_{it} = \beta_0 + \sum_{\varphi=1}^{n} \beta_\varphi X_{\varphi,it} + \tau w_{ij} * GT_{it} + \mu w_{ij} * \sum_{\varphi=1}^{n} X_{\varphi,it} + \varepsilon_{it} \quad (2)$$

Among them, w_{ij} is the spatial weight matrix, $w_{ij} * GT_{it}$ is the spatial lag variable of the dependent variable, $w_{ij} * X_{it}$ is the spatial lag variable of the explanatory variable, The spatial Durbin model also examines the influence of the scale of venture capital and R&D investment in the neighboring regions on the region, and the influence of neighboring regions or random shocks on the venture capital in the region.

2.3.3. Spatial Weight Matrix

The spatial weight matrix is the premise of spatial econometric analysis. In order to prevent a priori errors caused by the construction of the spatial weight matrix, this paper will construct and analyze the empirical results of two types of spatial weight matrices, namely the geographic

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distance matrix (WD_{ij}) and the economic matrix (WE_{ij}). The following is the specific calculation formula of each matrix:

(1) The geographic distance matrix WD. d_{ij} is the geographic distance between provinces i and j, measured by the shortest railway mileage between the corresponding provincial capitals.

$$WD_{ij} = (1/d_{ij}) / \left[\sum_{j=1}^{N} (1/d_{ij})\right]$$

(2) Economic matrix WE. $\overline{pgrp_j}$ is the average level of economic development in the j region during the sample period.

$$WE_{ij} = (1/|\overline{pgrp_i} - \overline{pgrp_j}|) / \left[\sum_{j=1}^{N} (1/|\overline{pgrp_i} - \overline{pgrp_j}|)\right]$$

In this paper, the spatial autocorrelation analysis will use the WD matrix, and the spatial econometric model will use the WE matrix.

3. Empirical Research

3.1. Variable Selection and Descriptive Statistics

3.1.1. Explained Variable

Green technology innovation (GT), considering the availability of data, this paper refers to the relevant data of the National Bureau of Statistics of China, and uses the ratio of the number of green patents in China to the total number of green patents in the country in that year as a measure. The number of green patents does not consider design patents. .

3.1.2. Explanatory Variables

This paper studies the comparative impact of venture capital and R&D investment on green technology innovation, so the explanatory variables of this paper are venture capital and R&D investment. Taking into account the convenience and reliability of data acquisition, venture capital (VC) refers to the ratio of the regional venture capital investment in China in the current year (100 million yuan) to the total national venture investment in the current year, and R&D investment (RD) refers to the R&D investment in China in the current year in the statistical yearbook. funds.

3.1.3. Control Variables

The selection of control variables should include variables that can influence green technology innovation by influencing venture capital (VC) or R&D investment (RD).Referring to the index system of scholars such as Yang Renfa [17], this paper selects four indicators: the level of opening to the outside world, the level of education development, the level of government intervention, and the intensity of environmental regulation. The level of opening to the outside world (OPEN) is the ratio of foreign direct investment (100 million yuan) and total import and export trade (100 million yuan) to GDP (100 million yuan) in the same period; education development level (EDU) refers to the number of years of education per capita in a region; the degree of government intervention (GOV) is measured by the proportion of government general budget expenditure (100 million yuan) to GDP (100 million yuan) in the same period; environmental regulation intensity (EI) is measured by the ratio of the number of environmental administrative penalty cases accepted in a certain year to the total number of national penalty cases in a certain year.

3.1.4. Descriptive Statistics

Considering the completeness of the data and the difficulty of collection, this paper deletes the data of Hong Kong, Macao, Taiwan and Tibet, and takes the data of 30 provinces in China from 2001 to 2019 as the research object, analyzes the impact of China's venture capital and R&D

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investment on green technology innovation and analyzes it. comparing. The data comes from "China Statistical Yearbook", "China Industrial Statistical Yearbook", Wind terminal database and authoritative data published in various regions. Descriptive statistical analysis of each variable is carried out, see Table 1.

Table 1. Descriptive statistics of variables

Variable	Abbrew	Obs	Mean	Std. Dev.	Min	Max
Green Technology Innovation	GT	570	0.033	0.036	0.000	0.159
Venture capital scale	VC	570	0.006	0.023	0.000	0.234
R&D investment level	RD	570	0.012	0.011	0.000	0.074
level of opening	OPEN	570	0.319	0.433	0.003	1.931
educational development level	EDU	570	9.013	1.596	6.040	15.451
level of government intervention	GOV	570	0.212	0.097	0.030	0.628
The intensity of environmental regulation	EI	570	8.031	5.315	0.909	54.793

3.2. Moran's I Index

Using Moran's I index to measure the global spatial autocorrelation of venture capital scale and R&D investment level, the results are shown in Table 2. It can be seen from Table 2 that the scale of venture capital and the level of R&D investment in the 19 years from 2001 to 2019, the Moran's I index measurement results were 0.290 and 0.577 respectively, and both were significant at the 1% level, indicating the scale of venture capital and the level of R&D investment. Overall, there is a significant global spatial positive correlation.

Table 2. Moran's I index and Geary's c two-sided test probability of venture capital and R&D investment

Moran's I					
Variables	I	E(I)	Sd (I)	z	p-value*
VC	0.290	-0.002	0.013	22.013	0.000
RD	0.577	-0.002	0.014	41.933	0.000
Geary's C					
Variables	c	E(c)	Sd (c)	z	p-value*
VC	0.724	1.000	0.038	-7.363	0.000
RD	0.469	1.000	0.020	-26.008	0.000

3.3. Measurement Model

It can be seen from Table 3 that the fit degree of venture capital and green technology innovation estimated by OLS is 0.331, and the fit degree of R&D investment and green technology innovation is 0.555, which pass the significance test at the 1% level as a whole. In order to further study the impact of venture capital and R&D investment on green technology innovation, this paper uses the construction of spatial Durbin model to analyze it. It is concluded that venture capital and R&D investment have a positive relationship with green technology innovation respectively, so Hypotheses 1 and 2 are established. In OLS and SDM, the fitting degree of R&D investment is higher than that of venture investment. By comparing the Log-L of the two, it can also be concluded that the fitting effect of R&D investment is better. It can be seen that Hypothesis 3 is established, and the relationship between venture capital and venture capital is better. The impact of R&D investment on green technology innovation varies.

In addition, among the control variables, OPEN has no significant impact on green technology innovation, while EDU and EI positively affect green technology innovation, and GOV has a negative impact on green technology innovation.

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Table 3. Model regression results

	OLS	SDM	OLS	SDM
VC	0.417*** (0.000)	0.225*** (0.000)		
RD			1.686*** (0.000)	1.808*** (0.036)
OPEN	0.005 (0.110)	0.002 (0.306)	0.001 (0.547)	0.001 (0.580)
EDU	0.003*** (0.003)	0.003** (0.023)	0.005*** (0.000)	-0.006*** (0.000)
GOV	-0.162*** (0.000)	-0.051*** (0.000)	-0.133*** (0.000)	-0.076*** (0.000)
EI	0.001*** (0.000)	0.001*** (0.001)	0.000** (0.036)	0.000** (0.025)
Constant	0.030*** (0.000)		-0.007 (0.287)	
W*VC		0.403** (0.012)		
W*RD				0.154 (0.616)
W*OPEN		-0.008 (0.233)		-0.005 (0.369)
W*EDU		0.022*** (0.000)		0.028*** (0.000)
W*GOV		-0.182*** (0.000)		-0.187*** (0.000)
W*EI		-0.001* (0.081)		-0.001** (0.043)
rho		0.304*** (0.000)		0.107 (0.130)
sigma2_e		0.001*** (0.000)		0.000*** (0.000)
Observations	570	570	570	570
R-squared	0.331	0.179	0.555	0.578
F-test	55.879		140.594	
Prob > F	0.000		0.000	
Log-likelihood		1327.8213		1446.5153

Remarks: ***p<0.01, **p<0.05, *p<0.1

The impact of OPEN on green technology innovation is not significant. The reason is that my country's level of opening to the outside world has not reached a higher level than that of developed countries, resulting in a less significant impact on green technology innovation. In addition, GOV has a negative impact on green technology innovation. The reasons include the following: 1. Wang Yao (2015) [18] and others believe that green technology innovation is cyclical and depends on the long-term support of relevant green policies. Therefore, GOV is not conducive to the development of green technology innovation in this context; 2. Some scholars believe that the degree of government intervention has a threshold effect on the role of green technology innovation, and when the degree of government intervention does not reach a

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certain level, there is a negative correlation. , such as Yang Renfa (2022) [19] and so on. EI and green technology innovation are both presented as 0 in the OLS and SDM models of R&D investment, indicating that there is no relationship between environmental regulation and green technology innovation, while the Porter hypothesis proposes that appropriate environmental regulation is conducive to technological innovation, indicating that the intensity of environmental regulation is currently Moderate levels are not achieved in the context.

4. Conclusions and Recommendations

The following conclusions can be drawn from the appeal analysis: (1) Venture capital and R&D investment have a positive impact on green technology innovation; (2) R&D investment has a higher impact on green technology innovation than venture capital; (3) External development Level, education development level, and government intervention level will all have a significant impact on green technology innovation, but the level of government intervention will be negatively and linearly related to green technology innovation. Therefore, the government should reasonably consider the implementation of policies when formulating relevant policies.

Based on the above conclusions, this paper proposes suggestions from the perspectives of the government and enterprises:

Government perspective: 1. The government is guided by policies and funds to guide the green technology innovation and development of enterprises: the government focuses on the R&D investment of green technology innovation, which will positively promote the R&D investment of enterprises related to green technology innovation, and encourage enterprises to increase their investment in green technology innovation. The strength of green technology innovation. Local governments should adjust measures according to local conditions, actively promulgate relevant government regulations according to specific conditions, provide corporate policies and financial support to meet green development, attract enterprises to enter the field of green technology innovation, encourage enterprises to increase technological innovation, and promote the greenization of technological innovation of enterprises. 2. Promote carbon tax legislation and force enterprises to transform into green technology: The government can issue relevant industry norms, requiring enterprises to disclose pollution conditions, and provide upper and lower limits for enterprises' production pollution and energy consumption, thereby urging enterprises to enter the field of green technology innovation. Technology iteration to reduce environmental pollution, so as to meet the standards of industry norms. A carbon tax is imposed on companies that do not meet green standards, which forces companies to increase their emphasis on green technology innovation and increase their R&D investment level, thereby promoting the improvement of their green innovation level and reducing their pollution levels. 3. Reasonably tilt the support of venture capital and R&D investment, encourage enterprises to increase R&D investment, and promote the efficient development of green technology innovation: The empirical results of this paper show that the impact of R&D investment on green technology innovation is greater than the impact of venture capital, so the government should Enterprises are encouraged to increase investment in research and development, but the intensity of government regulation has a negative impact. Therefore, the government should reasonably control the implementation of policies and adapt to the actual development of the situation.

Enterprise perspective: Enterprises also need to clarify the potential of green development, understand the importance of green technology innovation to improving the sustainable development of enterprises, actively respond to energy conservation and emission reduction under the background of the government's carbon peak, develop green technology innovation, and reduce production costs and governance. Pollution costs, improve the comprehensive

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competitiveness of enterprises, and reasonably balance the maximization of benefits and the greening of benefits.

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