

Article

Fiscal Decentralization, Enterprise Digital Transformation and Enterprise Green Innovation—The Case of 11 Years A-Share Listed Companies in China

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Abstract: In the context of accelerating economic transformation and upgrading, and comprehensively promoting the construction of digital China and ecological civilization in China, this paper uses text mining and OLS to quantitatively study the relationship between fiscal decentralization, enterprise digital transformation and green innovation in 31 provinces from 2011 to 2021. This study finds that fiscal decentralization will promote enterprise green innovation and digital transformation, and that digital transformation has a partial mediating effect between fiscal decentralization and enterprise green innovation. Furthermore, this expansive study finds that fiscal decentralization has a positive role in promoting the green innovation of heterogeneous enterprises and enterprises in different regions, among which its promotion effect on state-owned enterprises is higher than that of private enterprises, and its promotion effect on enterprises in the central and western regions is higher than that of enterprises in the eastern region. Moreover, an inverted U-shaped relationship exists between fiscal decentralization and the green innovation of enterprise. In addition, financing constraints have a masking effect between fiscal decentralization and green innovation in enterprise and green innovation significantly promotes enterprise environmental, social and governance (ESG) development.

Keywords: fiscal decentralization; digital transformation; enterprise green innovation; financing constraints; sustainability



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1. Introduction

China's economy has achieved leapfrog development after its reform and opening up, and its total economic volume ranks second in the world. However, behind the rapid economic development, China's economy is also facing many problems such as gradual slowing growth, insufficient development momentum, aggravated environmental pollution and ecological degradation. According to the "2020 Global Environmental Performance Index Report" [1] and the "2021 Global Innovation Index", China's comprehensive score of the environmental performance index is only 37.3 points, ranking last in the world, while China's innovation index only ranks 12th. The original extensive development model of pollution first and treatment later can no longer meet the needs of green and sustainable development in China, and the country's overall innovation capacity needs to be improved. In this context, the report of the 19th National Congress of the Communist Party of China put forward the "innovation-driven development strategy" [2]. In 2020, it further proposed the dual carbon goals, promoting the fundamental improvement of China's ecological environment and the green and sustainable development of economy and society through the dual carbon goals, which shows that transforming the development model and promoting green innovation have become the general direction and inevitable requirement of China's economic and social development in the new era.

As an important part of China's socialist economic system, the green innovation ability and level of enterprises have become an important means for enterprises to maintain their core competitiveness and achieve long-term development. At the same time, enterprises have greatly influenced the green transformation process of the regional economy, and they have become grassroots practitioners of China's economic and ecological civilization construction. However, green innovation has a long cycle and known instability, where relying only on market regulation may lead to unfavorable situations such as insufficient power. Therefore, the government, as the leader of China's economic development and the controller of various resources, uses the "visible hand" to correct market failure and provides various guarantees for microenterprises and high-quality economic and social development, which have become the responsibility of governments at all levels. After the implementation of China's split tax system reform in 1994, fiscal decentralization (including fiscal revenue decentralization and expenditure decentralization), as an important means for the central government to mobilize the enthusiasm of local governments to perform their duties and promote local economic development, has alleviated the financial pressure of local governments to a certain extent, improved the pertinence of government services, made the allocation of government resources more efficient, and played an important role in promoting regional economic and social development. However, although some scholars have studied the relationship between fiscal decentralization and economic development, there is still little research on microenterprises. Therefore, in the context of China's comprehensive implementation of the innovation-driven strategy and the dual carbon goals, it is urgent to discuss whether fiscal decentralization will promote the green innovation activities of enterprises and determine the impact mechanism. In addition, with the development of digital technology, the digital economy has become an important engine for promoting economic growth and enterprise development in China. China pointed out in its "14th Five-Year Plan" that it is necessary to promote the coordinated development of the digital economy and the real economy, and accelerate the construction of a new pattern of "dual circulation" [3]. The report of the 20th National Congress of the Communist Party of China further pointed out that, to build a "digital China" [4], the digital economy has become a new carrier and direction for China's economic transformation and enterprise development. Therefore, under the background of China's comprehensive promotion of green and high-quality development and digital transformation, studying the relationship between fiscal decentralization, enterprise digital transformation and green innovation has important theoretical and practical significance for China's economic development and ecological civilization construction.

Through research, this paper aims to solve the following questions: First, what is the mechanism of fiscal decentralization affecting enterprises' green innovation and digital transformation, and what is the quantitative relationship between the three? Secondly, are there differences in the impact of fiscal decentralization on the green innovation of heterogeneous enterprises and enterprises in different regions? Finally, is the digital transformation of enterprises a specific path for fiscal decentralization in order to affect the green innovation of enterprises? The rest of this article is arranged as follows: Section 2 presents a literature review. Section 3 outlines the theoretical analysis and research hypotheses. Section 4 presents the empirical design and Section 5 presents the empirical results. Section 6 is the discussion and Section 7 concludes this paper.

2. Literature Review

2.1. Research on Fiscal Decentralization

The research on fiscal decentralization is mainly empirical, primarily focusing on two dimensions of economic and environmental governance. In terms of the impact of fiscal decentralization on the economy, Wang et al. [5] found that fiscal decentralization will promote the development of green economy and promote the role of local governments in regional economic development. Yi [6] found that fiscal decentralization has a positive spatial spillover effect on green technology innovation and also promotes the surrounding

areas. Qi et al. [7] used China's provincial panel data to conduct empirical research and found that fiscal decentralization can promote the green transformation of industry. Chen et al. [8] used 26 years of panel data of 31 provinces in China as a sample and found a co-integration relationship between fiscal decentralization, income gap and tourism growth. Liu et al. [9] conducted an empirical study on China's provincial panel data and found that there is a U-shaped relationship between income and expenditure decentralization and green development efficiency. Wang et al. [10] found an inverted U-shaped relationship between fiscal decentralization and high-quality regional development. However, Han [11] and Li and Xu [12] conducted a study on the provincial data of 30 regions in China from 2008 to 2020 and found that fiscal decentralization will suppress the improvement of national green economy efficiency. In terms of the impact of fiscal decentralization on environmental governance, Zhao et al. [13] selected provincial panels in China from 2003 to 2019 as a sample and found that fiscal decentralization, industrial structure upgrading and carbon emissions are negatively correlated. Meng et al. [14] found that fiscal decentralization can significantly reduce carbon emissions only in the middle- and low-emission quantiles. Sun et al. [15] used the augmented mean group method and found that the deployment of green technology and renewable energy improves the environment, while fiscal decentralization and economic growth exacerbate ecological damage. Zhao et al. [16] found that fiscal decentralization significantly promoted environmental pollution, especially in economically underdeveloped areas. Cheng and Zhu [17], Yin et al. [18] and Wang et al. [19] conducted a study of Chinese cities and found that increased fiscal decentralization significantly aggravates smog pollution in and around the studied regions. Guo et al. [20] found that increasing fiscal decentralization would help improve the carbon productivity of the province but would inhibit the carbon productivity of neighboring provinces. Phan et al. [21] used the ARDL model and found that fiscal decentralization has an asymmetric effect on CO₂ emissions.

2.2. Research on Enterprise Digital Transformation

The research on the digital transformation of enterprises is mainly carried out from the two aspects of its influencing factors and economic consequences. In the study of influencing factors, Luo [22] took the data of China's A-share listed companies from 2011 to 2020 as a sample and found that the development of digital finance has a significant role in promoting the digital transformation of enterprises, especially for non-state-owned enterprises. Zhang et al. [23] conducted a multi-case study of three Chinese enterprises from different industries and found that enterprises would innovate in multiple ways simultaneously to achieve digital transformation when facing market and technological changes. Chen and Yang [24] found that there is an inverted U-shaped relationship between executive shareholding and corporate digital transformation. In the study of the economic consequences of enterprise digital transformation, Wu et al. [25] took the listed companies in China from 2007 to 2020 as samples and found that enterprise digital transformation can significantly reduce the risk of stock price collapse. Zhao and Ren [26] found that enterprise digital transformation has a significant impact on improving enterprise capacity utilization. Liu et al. [27] found that digital transformation can improve the innovation ability of enterprises, reduce the operating costs of enterprises, improve customer satisfaction and reduce the dependence of enterprises on key customers. Zhang et al. [28] used the DID model and found that the digital transformation of Chinese manufacturing listed companies will significantly improve green innovation output. Du et al. [29] constructed static and dynamic benchmark regression models and regulatory effect models and found that digital transformation has a positive impact on energy technology innovation. Shang et al. [30] conducted empirical research using a sample of A-share listed companies in Shanghai and Shenzhen from 2012 to 2020 and found that digital transformation of enterprises can reduce their carbon emission intensity by improving their technological innovation capabilities and environmental information disclosure levels.

2.3. Research on Enterprise Green Innovation

The current research on the green innovation of enterprises is mainly carried out from its internal and external influencing factors. In the study of internal influencing factors, Naveed et al. [31] took 3736 annual observations of A-share listed companies in China from 2010 to 2019 as samples and found that the gender diversity of the board of directors promotes enterprise green innovation. Wan et al. [32] indicated that the management vision and investment vision of enterprise managers are the core supporting factors of green innovation performance. Feng et al. [33] built a double-fixed effect model and found that digital transformation significantly improves the green innovation level of enterprises. Roh et al. [34] found that the intellectual property rights of Korean manufacturing enterprises have a significant impact on green product innovation. Liu [35] found that the short-sighted behavior of management will inhibit the green innovation behavior of enterprises. In a study of external influencing factors, Wang and Chen [36] and Zhu et al. [37] found that national green development strategies and policies have a positive role in promoting regional green innovation. Shen and He [38] built a DID model for Chinese manufacturing enterprises and found that the government's deleveraging policy can play a positive role in promoting the green innovation of enterprises. Xu et al. [39] tested the data of 655 companies in Shanghai and Shenzhen A-shares from 2010 to 2020 and found that the overall level of green innovation of listed companies is low and that there is a U-shaped characteristic between environmental regulations and enterprise green innovation. Chai et al. [40] indicated that low carbon plans have an inhibitory effect on innovation of heavily polluting enterprises. In addition, Fiorillo et al. [41] found that the number of stock analysts tracking companies was positively correlated with enterprise green innovation. Al-Swidi et al. [42] found that consumer pressure is positively related to the green innovation of enterprises. Zheng and Ye [43] used A-share listed companies in China's heavy pollution industry from 2010 to 2021 as a sample to test and found that green innovation has a strategic behavior of direct imitation, and it also modifies its own decisions based on environmental information disclosed by peers. Zhang and Wang [44] found that there is an inverted U-shaped relationship between enterprises' political connections and green innovation.

To sum up, the existing literature on fiscal decentralization mainly focuses on the impact on macroeconomic and environmental governance, among which there is still some debate on the view that fiscal decentralization is not completely positively correlated with economic and social development. Moreover, the research on fiscal decentralization rarely involves microenterprises, and although some scholars have discussed digital transformation and enterprise green innovation, they have not carried out systematic research from the perspective of fiscal decentralization. In view of this, this paper uses panel data from 31 provinces in China from 2011 to 2021 as a sample for empirical research, and this paper has the following contributions: First, this paper unifies the analysis of fiscal decentralization, enterprise digital transformation and green innovation, and systematically analyzes the impact mechanism and quantitative relationship among the three; expands the research perspective of fiscal decentralization and enterprise digital transformation; and further enriches the research on the influencing factors and economic consequences of enterprise green innovation, making up for the shortcomings of existing research. Second, this paper reveals the mediating effect of enterprise digital transformation and financing constraints between fiscal decentralization and enterprise green innovation, and further expands the research on the path of fiscal decentralization in promoting enterprise green innovation. Third, by revealing the linear and nonlinear relationships between fiscal decentralization and enterprise green innovation, as well as the differences in the impact of fiscal decentralization on green innovation in different regions and heterogeneous enterprises, this paper provides corresponding references for China's fiscal decentralization system reform, enterprise digital transformation and green development decision making, which have certain practical significance.

3. Theoretical Analysis and Research Hypothesis

3.1. Impact of Fiscal Decentralization on the Green Innovation of Enterprises

Green innovation plays an important role in the development of enterprises and the transformation and development of the national economy, which is not only the key for enterprises to maintain their core competitiveness and achieve their long-term development, but also an important carrier for the country to achieve green development. The theory of technological innovation believes that innovation is actually a new combination of production factors and production conditions, which is not only the independent behavior of enterprises, but is also promoted by the country's overall innovation system. Therefore, enterprise green innovation is not only affected by the enterprises' own factors, but also greatly affected by the support and policy guidance of government departments. Since the reform of China's tax-sharing system in 1994, the fiscal decentralization system, as an important part of China's socialist market economy system, enhances the governance enthusiasm of governments at all levels. With the improvement of fiscal decentralization, it means that local governments have more abundant funds and higher financial freedom. Based on the rational person hypothesis, with the improvement of financial freedom, local government leaders are more willing to increase infrastructure construction, expand the supply of public goods, and provide various public support for the green transformation of the regional economy and the development of enterprises in order to realize regional economic and social development and further improve personal value. Then, with the construction of regional infrastructure and the improvement of government support for enterprises, the external operating costs of enterprises will be reduced to a certain extent, and more resource support will be provided for enterprises' green innovation. At the same time, with the increase of the country's attention to environmental protection, enterprises will increase green innovation in order to obtain more national funds and policy support to enhance their competitiveness, so the improvement of fiscal decentralization level will promote the green innovation of enterprises. Therefore, this paper proposes the following assumption:

H1. *Fiscal decentralization plays a positive role in promoting the green innovation of enterprises.*

3.2. Impact of Fiscal Decentralization on Enterprise Digital Transformation

The report of the 20th National Congress of the CPC proposed to accelerate the construction of "digital China"; hence, accelerating the deep integration of digital technology and traditional economy has become the key to deepening reform and improving economic efficiency in China. For the government, the improvement of the local digital level can promote the transformation and upgrading of regional industrial structure, eliminate backward production capacity, reduce the economic and environmental costs of regions and enterprises, further optimize the allocation of resources in the region, improve production efficiency, and promote regional economic development and the implementation of the dual carbon goal. In addition, with the improvement of the level of regional digitalization, it can virtually shorten the time and space constraints, increase the attraction of regions and enterprises, and then attract more external high-quality resources to enter, and ultimately provide various support for local and enterprise development. Therefore, with the increase of the level of fiscal decentralization, local governments will increase their investment in the transformation of the digital economy, providing various early guarantees for the promotion of the construction level of the digital economy and the development of economic transformation. At the same time, the theory of resource dependence states that the development of enterprises cannot be separated from the environment on which they depend, and the resources of the region where the enterprises are located will become indispensable factors for the development of the enterprises. For enterprises, digitalization, as an important manifestation of modern enterprise competitiveness, has a significant impact on enterprise development. With the improvement of the construction level of regional digital infrastructure, it will provide various conveniences for enterprise digital transformation, reduce the cost of enterprise digital transformation to a certain extent,

and then promote the process of enterprise digital transformation. Therefore, this paper proposes the following assumption:

H2. Fiscal decentralization plays a positive role in promoting the digital transformation of enterprises.

3.3. Mechanism Analysis Based on Enterprise Digital Transformation

With the proposal of the dual carbon goal and the acceleration of the construction of a green China, promoting the green transformation and development of industry enterprises has become the focus of attention of all sectors of society, in which digital transformation plays an irreplaceable role in promoting the green innovation of enterprises. The improvement of the level of enterprise digital transformation can further reduce the asymmetry of internal and external information of enterprises, break the information island of green innovation, and improve the level of internal and external cooperative research and development (R&D), so that enterprises can concentrate their advantageous resources to seek development and then help improve the level of green innovation of enterprises. In addition, the improvement of enterprises' digital economy will force enterprises to carry out green innovation. With the improvement of the degree of digital transformation of enterprises, there are gradually no secrets among enterprises, and the competition between them is more intense. Therefore, technological innovation will become the key to the smooth development of enterprises. Among them, the digital transformation of enterprises will accelerate the elimination of backward production capacity of enterprises, promote green R&D, and improve their green innovation output and production and operation efficiency; hence, digital transformation has a positive role in promoting the green innovation of enterprises. In addition, fiscal decentralization promotes both enterprise digital transformation and green innovation, so enterprise digital transformation of enterprises may be a specific mechanism for fiscal decentralization to affect the green innovation of enterprises. Therefore, this paper proposes the following assumptions:

H3. The digital transformation of enterprises plays a positive role in promoting the green innovation of enterprises.

H4. The digital transformation of enterprises has a mediating effect between fiscal decentralization and enterprise green innovation.

Through the above analysis, the logical framework diagram of this paper is obtained, as shown in Figure 1:

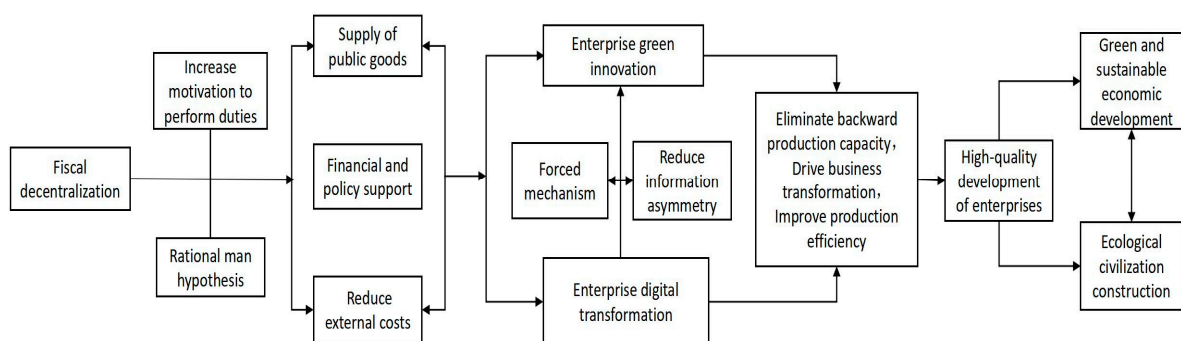


Figure 1. Theoretical framework of fiscal decentralization, enterprise Digital transformation and enterprise green innovation.

4. Research Design

4.1. Variable Definition and Sample Selection

4.1.1. Dependent Variable

Enterprise Green Innovation (EGI). The green innovation in this paper is technological innovation. From the perspective of innovation output, this paper divides the green innovation of enterprises into three dimensions: total output of enterprise green patent [45]

(TOEGP), substantive green innovation output (SGIO₁) and strategic green innovation output (SGIO₂) [46], which are measured by adding 1 to the number of enterprise green patent applications, green invention patent applications and green utility model patent applications, respectively, and then taking the natural logarithm.

4.1.2. Explanatory Variables

Fiscal decentralization (FD). Fiscal decentralization is a system in which the central government grants local governments a certain degree of autonomy in the scope of fiscal revenue and expenditure on the basis of government functions, so as to handle the relationship between the central and local governments at all levels. This paper uses the proportion of fiscal revenue in the region where the enterprise is located to the central fiscal revenue to measure the degree of fiscal decentralization in the region [47]. The larger the index, the higher the level of fiscal decentralization in the region.

4.1.3. Mediating Variables

Enterprise Digital Transformation (EDT). Digital transformation is a high-level transformation that combines with the company's core business on the basis of digital transformation and upgrading, and then realizes the new business model. Referring to the research of Wu et al. [48], this paper uses Python's crawler technology to collect and sort out the annual reports of all A-share listed companies in the Shanghai and Shenzhen Stock Exchanges, and then this paper extracts all text information through the Java PDFbox library and uses it as a data pool. On this basis, this paper searches, matches and counts 76 key feature words at five levels, including AI, blockchain, cloud computing, big data and digital technology applications. Considering the "right bias" of the data, this paper takes the natural logarithm of the number of keyword occurrences plus 1 as the proxy indicator of digital transformation of enterprises. The larger the EDT, the higher the degree of enterprise digital transformation.

The financing constraint is represented by the SA index (SA). This paper selects the SA index built by Hadlock and Pierce [49] to reflect the financial pressure of the enterprise. This indicator is composed of the age and size of the enterprises. The larger the absolute value of the SA index, and the larger its absolute value, the more obvious the financing constraints of the enterprise are. This is as shown in Formula (1), where $Size_{i,t}$ is the natural logarithm of the total assets of the enterprise, $Age_{i,t}$ is the year of establishment of the enterprise, and i and t represent the enterprise and year, respectively.

$$SA_{i,t} = -0.737 \times Size_{i,t} + 0.043 \times Size_{i,t}^2 - 0.04 \times Age_{i,t} \quad (1)$$

4.1.4. Control Variables

Considering that the green innovation of enterprises is affected not only by the level of regional fiscal decentralization and the degree of digital transformation of enterprises themselves, but also by many other factors, this paper takes enterprise size (ES) and executive compensation (EC) and other variables as control variables [50] to control in the empirical process, as shown in Table 1.

Table 1. Definition of the main variables.

Variable Type	Variable Name	Variable Code	Definitions
Explained variable	Enterprise green innovation	TOEGP _{i,t}	Add 1 to the number of green patent applications of Listed Companies in year t , and take the natural logarithm
		SGIO1 _{i,t}	Add 1 to the number of green invention patent applications of Listed Companies in year t , and take the natural logarithm
		SGIO2 _{i,t}	Add 1 to the number of green utility model patent applications of Listed Companies in year t , and take the natural logarithm

Table 1. Cont.

Variable Type	Variable Name	Variable Code	Definitions
Explanatory variable	Fiscal decentralization	FDi,t	Provincial fiscal revenue/central fiscal revenue in year t
Mediating variable	Enterprise digital transformation	EDTi,t	According to the proxy indicators of the digital transformation of Listed Companies in year t
	Financing con-straints	SAi,t	SA index of Listed Companies in year t
Control variable	Enterprise scale	ESi,t	Natural logarithm of the total assets of the listed company at the beginning of the year in year t
	Asset liability ratio	ALRi,t	Debt/total assets of Listed Companies in year t
	Return on assets	ROAi,t	Net profit/total assets of Listed Companies in year t
	Management Expense Rate	MERi,t	Management expenses/main business income of Listed Companies in the year t
	Cash holdings	CHi,t	Monetary funds/total assets of Listed Companies in year t
	Enterprise growth	EGi,t	Growth rate of operating income of Listed Companies in year t
	Executive compensation	ECi,t	Natural logarithm of the compensation of the top three executives of Listed Companies in year t
	Equity incentive	Eli,t	Natural logarithm of the number of shares held by executives of Listed Companies in year t
	Company age	CAi,t	Add 1 to the Listed Company's age, and take the natural logarithm
	Year	YEAR	Dummy variable
Industry	IND	Dummy variable	

4.1.5. Data Source

The distribution of fiscal decentralization, financial data, and innovation data involved in this paper comes from the National Bureau of Statistics, China Guotai'an Database (CSMAR), and China Research Data Service Platform (CNRDS). This paper selected the data of A-share listed companies in Shanghai and Shenzhen from 2011 to 2021. In order to ensure the representativeness of the sample data, this paper systematically screened the initial sample data, among which this paper excluded the samples of financial and insurance companies, ST companies, PT companies and companies with major problems in their operating conditions, as well as the samples with serious lack of data. At the same time, this paper also Winsorized all continuous variables by 1% up and down. Then, this paper matched regional fiscal decentralization with corporate finance and green innovation data according to the registered place of listed companies. Finally, a non-balanced panel data composed of 24,411 sample observations was obtained, and the observed values from 2011 to 2021 were 2017, 2137, 2139, 2220, 2351, 2484, 2718, 2770, 1767, 1990 and 1818, respectively. All data were cross-checked and state15 statistical software was used for descriptive statistics and multiple regression analysis. The definitions of specific variables are shown in Table 1.

4.2. Model Construction

This paper uses the ordinary least squares (OLS) method to empirically study the relationship between fiscal decentralization, digital transformation and enterprise green innovation. To test hypotheses H1–H4, the specific model is as follows:

$$EGlit = \alpha_0 + \alpha_1FDit + \alpha_2Controlit + \epsilon it \quad (2)$$

$$EDTit = \beta_0 + \beta_1FDit + \beta_2Controlit + \epsilon it \quad (3)$$

$$EGlit = \gamma_0 + \gamma_1EDTit + \gamma_2Controlit + \epsilon it \quad (4)$$

$$EGlit = \omega_0 + \omega_1FDit + \omega_2EDTit + \omega_3Controlit + \epsilon it \quad (5)$$

$$EGlit = \eta_0 + \eta_1FDit + \eta_2FD^2 + \eta_3Controlit + \epsilon it \quad (6)$$

Among them, *EGI* represents enterprise green innovation, *FD* represents fiscal decentralization and *EDT* represents enterprise digital transformation; FD^2 is the square term of *FD*; Control represents the control variable; ε_{it} is a random disturbance term; and i and t indicate the enterprise and year, respectively.

In the regression process, when α_1 and β_1 are significantly positive, this indicates that fiscal decentralization has a positive impact on green innovation and digital transformation of enterprises; when γ_1 is significantly positive, this indicates that the digital transformation of enterprises can promote green innovation; when η_1 is significantly positive, η_2 is significantly negative, which indicates a nonlinear relationship between fiscal decentralization and green innovation in enterprises.

4.3. Data Description

Table 2 shows that the maximum and standard deviation of green innovation for listed enterprises in China are above 6.4313 and 1.0116, respectively, indicating that there are large differences between the green innovation of Chinese enterprises. The standard deviation of fiscal decentralization is 0.0341, which indicates that the level of fiscal decentralization in different regions of China is not much different, and the financial freedom is generally low. The standard deviation of digital transformation of enterprises is 1.6501, which indicates that the digital transformation of Chinese enterprises is quite different, which is consistent with the actual situation. The standard deviation of the asset–liability ratio and cash holding level of enterprises is 0.3597 and 0.1351, respectively, indicating that the overall capital risk of Chinese enterprises is low; the average return on assets is only 0.0392, indicating that the asset operation status of enterprises needs to be improved. The standard deviations of the growth and management expense ratio of enterprises are 22.9431 and 13.5449, respectively, and the standard deviations of enterprise scale, executive compensation and equity incentives are all above 1, indicating that there are great differences in the development trend and management level of various enterprises.

Table 2. Descriptive statistics.

	N	Minimum	Maximum	Mean	Standard Deviation
TOEGP	24,411	0	7.3639	1.043014	1.251971
SGIO1	24,411	0	7.2313	0.714524	1.060011
SGIO2	24,411	0	6.4313	0.698274	1.011657
FD	24,411	0.001	0.1291	0.06031	0.034178
EDT	24,411	0	6.993	1.647012	1.650166
ES	24,411	14.9416	28.6365	22.25324	1.392868
ALR	24,411	−0.1947	28.5477	0.440931	0.359771
ROA	24,411	−29.6088	108.3657	0.039224	0.747406
MER	24,411	−0.1108	2114.999	0.189472	13.54491
CH	24,411	0.0002	1	0.183977	0.135192
EG	24,411	−3414.72	1	−0.36886	22.94315
EC	24,411	0	18.1966	14.3595	1.020096
EI	24,411	0	21.4756	10.27947	7.458386
CA	24,411	0	3.4657	2.174747	0.861641

5. Regression Results

5.1. Multiple Regression Analysis of Fiscal Decentralization on Enterprise Digital Transformation and Green Innovation

Table 3 shows that fiscal decentralization promotes green innovation and digital transformation of enterprises, and both have passed the 1% significance test. Among them, its impact coefficient on the total output of green innovation is 1.0696, and the promotion effect on the substantive green innovation of enterprises is greater than that of strategic green innovation. Enterprise digital transformation actively promotes enterprise green innovation, which plays the smallest role in enterprise strategic green innovation. With the improvement of the level of regional fiscal decentralization, local governments will have

greater financial freedom, focus more on long-term development, and then increase support for green innovation, digital transformation and development of enterprises, promote green R&D and digital transformation of enterprises, and promote green transformation and development of economy and society. With the improvement of the digital transformation level of enterprises, it will reduce the asymmetry of internal and external information of enterprises, improve the resource allocation ability and operation efficiency of enterprises, and accelerate the green innovation of enterprises. Because the strategic green innovation of enterprises is mostly an improvement in appearance or form, not a real green technology upgrade and cannot bring real economic and environmental benefits, fiscal decentralization and digital transformation have the least impact on the strategic green innovation of enterprises. Through an empirical test, this paper verifies hypotheses H1, H2 and H3.

Table 3. Test results of the relationship between fiscal decentralization, enterprise digital transformation and green innovation.

	(1) toegp	(2) sgio1	(3) sgio2	(4) edt	(5) toegp	(6) sgio1	(7) sgio2
fd	1.0696 *** (0.1923)	0.9831 *** (0.1711)	0.7741 *** (0.1612)	1.2855 *** (0.2417)			
edt					0.0552 *** (0.0051)	0.0640 *** (0.0045)	0.0100 ** (0.0043)
es	0.4522 *** (0.0057)	0.3826 *** (0.0051)	0.3345 *** (0.0048)	0.1441 *** (0.0072)	0.4431 *** (0.0058)	0.3724 *** (0.0051)	0.3322 *** (0.0048)
alr	0.0988 *** (0.0185)	0.0748 *** (0.0164)	0.0946 *** (0.0155)	−0.0041 (0.0232)	0.0991 *** (0.0184)	0.0752 *** (0.0164)	0.0946 *** (0.0155)
roa	0.0165 ** (0.0082)	0.0134 * (0.0073)	0.0151 ** (0.0069)	−0.0112 (0.0103)	0.0174 ** (0.0082)	0.0144 ** (0.0072)	0.0155 ** (0.0069)
mer	0.0016 (0.0015)	0.0014 (0.0013)	0.0009 (0.0012)	0.0051 *** (0.0018)	0.0014 (0.0015)	0.0012 (0.0013)	0.0009 (0.0012)
ch	0.2688 *** (0.0507)	0.3727 *** (0.0451)	0.0897 ** (0.0425)	0.3680 *** (0.0637)	0.2492 *** (0.0506)	0.3498 *** (0.0449)	0.0866 ** (0.0425)
eg	0.0005 (0.0009)	0.0004 (0.0008)	0.0002 (0.0007)	0.0028 *** (0.0011)	0.0004 (0.0009)	0.0003 (0.0008)	0.0002 (0.0007)
ec	0.0247 *** (0.0067)	0.0182 *** (0.0060)	0.0168 *** (0.0056)	0.0306 *** (0.0084)	0.0273 *** (0.0067)	0.0202 *** (0.0059)	0.0198 *** (0.0056)
ei	0.0042 *** (0.0010)	0.0031 *** (0.0008)	0.0021 *** (0.0008)	0.0160 *** (0.0012)	0.0038 *** (0.0010)	0.0025 *** (0.0008)	0.0023 *** (0.0008)
ca	0.0316 *** (0.0091)	0.0363 *** (0.0081)	0.0006 (0.0076)	0.0541 *** (0.0115)	0.0239 *** (0.0091)	0.0285 *** (0.0081)	−0.0036 (0.0076)
_cons	−10.0628 *** (0.1486)	−8.4909 *** (0.1322)	−7.5778 *** (0.1246)	−3.4238 *** (0.1868)	−9.8758 *** (0.1494)	−8.2735 *** (0.1327)	−7.5451 *** (0.1255)
N	24,411	24,411	24,411	24,411	24,411	24,411	24,411
r2	0.4421	0.3842	0.3996	0.4925	0.4441	0.3884	0.3992
r2_a	0.4399	0.3817	0.3972	0.4905	0.4418	0.3859	0.3968
F	196.5969	154.7481	165.1262	240.7800	198.1781	157.5197	164.8266

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In terms of control variables, the enterprise size, cash holding level, executive compensation and equity incentive have a significant role in promoting enterprise digital transformation and green innovation. The larger the enterprise size and the higher the level of cash holding mean that the enterprise has more sufficient resources, the enterprise development is positive, and it has better future expectations, so it is more inclined to long-term investment, thus promoting the green innovation and digital transformation development of the enterprise. With the improvement of executive compensation and equity incentives, it will enhance the enthusiasm of the management, urge them to increase enterprise research and development, accelerate innovation output, and achieve further improvement of enterprise profits and personal income. However, the age of enterprises

suppresses strategic enterprise green innovation. The enterprise's management mode and thinking become more mature and the management will pay more attention to the long-term development of the enterprise after the age of the enterprise gradually increases, thus reducing inefficient strategic innovation.

5.2. Path Inspection

Through the mediation effect test [51], this paper discusses whether the digital transformation of enterprises is the specific path of fiscal decentralization affecting the green innovation of enterprises. As shown in Table 4, columns 1–3 show that fiscal decentralization promotes the three dimensions of the green innovation of enterprises. The fourth column shows that the coefficient of fiscal decentralization is significantly positive, indicating that it can improve the level of digital transformation of enterprises. Columns 5–7 show that the coefficient of enterprise digital transformation is significantly positive, and the coefficient of fiscal decentralization is significantly positive, which is significantly smaller than columns 1–3, indicating that fiscal decentralization affects the green innovation of enterprises by improving the level of enterprise digital transformation. Through Sobel and Bootstrap tests, it is found that the digital transformation of enterprises has a partial intermediary effect between fiscal decentralization and enterprises' green innovation, with effect values of 0.2432, 0.3044 and 0.102, respectively. Among them, digital transformation has the lowest intermediary effect between fiscal decentralization and the strategic green innovation of enterprises. This verifies hypothesis H4, indicating that the digital transformation of enterprises is the specific path for fiscal decentralization to affect the green innovation of enterprises.

Table 4. Path analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	toegp	sgio1	sgio2	edt	toegp	sgio1	sgio2
fd	2.6373 *** (0.2148)	2.1165 *** (0.1834)	1.8894 *** (0.1772)	5.6373 *** (0.3043)	1.9959 *** (0.2134)	1.4722 *** (0.1813)	1.6965 *** (0.1781)
edt					0.1137 *** (0.0044)	0.1142 *** (0.0037)	0.0342 *** (0.0037)
_cons	−9.2294 *** (0.1362)	−7.8524 *** (0.1163)	−6.7755 *** (0.1124)	−3.9982 *** (0.1931)	−8.7745 *** (0.1356)	−7.3955 *** (0.1152)	−6.6387 *** (0.1132)
N	24,411	24,411	24,411	24,411	24,411	24,411	24,411
r2	0.2302	0.2171	0.1973	0.1103	0.2502	0.2453	0.2001
r2_a	0.2299	0.2168	0.197	0.11	0.2499	0.2449	0.1997
F	729.79	676.7	599.78	302.63	740.32	720.89	554.8
Sobel		0.6414 *** (Z = 14.99)		0.6443 *** (Z = 15.78)		0.1929 *** (Z = 8.236)	
Goodman-1		0.6414 *** (Z = 14.98)		0.6443 *** (Z = 15.78)		0.1929 *** (Z = 8.236)	
Goodman-2		0.6414 *** (Z = 15)		0.6443 *** (Z = 15.79)		0.1929 *** (Z = 8.245)	
Mediation effect coefficient		0.6414 *** (Z = 14.98)		0.6443 *** (Z = 15.78)		0.1929 *** (Z = 8.2358)	
Direct effect coefficient		1.9959 *** (Z = 9.3491)		1.4722 *** (Z = 8.1181)		1.6965 *** (Z = 9.521)	
Overall effect coefficient		2.6373 *** (Z = 12.2776)		2.1165 *** (Z = 11.5396)		1.8894 *** (Z = 10.6597)	
Mediation effect ratio		0.2432		0.3044		0.102	
Bootstrap test		95% confidence interval [0.5564, 0.7263]		[0.5635, 0.725]		[0.1475, 0.2383]	

Standard errors in parentheses *** $p < 0.01$.

5.3. Expansibility Analysis

5.3.1. Influence of Fiscal Decentralization on the Green Innovation of Heterogeneous Enterprises

Table 5 shows that, after dividing enterprises into state-owned and private enterprises according to the nature of controlling shareholders, fiscal decentralization has a positive promoting effect on green innovation in state-owned and private enterprises and has

passed the significance tests of 1% and 10%, respectively. For state-owned enterprises, their scale is generally large. With the improvement of the level of fiscal decentralization of local governments, they may increase the financial support for state-owned enterprises to further stabilize economic development. At the same time, in order to seek higher political promotion and reduce the risk of being held accountable by higher authorities, state-owned enterprise managers may further respond to the call of the state, increase green research and development, and promote enterprise transformation and development. However, private enterprises often have smaller scales and more obstacles to development. With the improvement of the level of local fiscal decentralization, local governments may increase the financial or other support for private enterprises, thus accelerating the green innovation of enterprises.

Table 5. Heterogeneity test results.

	State-Owned Enterprise			Private Enterprise		
	(1)	(2)	(3)	(4)	(5)	(6)
	toegp	sgio1	sgio2	toegp	sgio1	sgio2
fd	2.3859 *** (0.3437)	2.3569 *** (0.3133)	1.5441 *** (0.2926)	0.6459 *** (0.2327)	0.6177 *** (0.2021)	0.3755 * (0.1942)
_cons	−10.919 *** (0.2364)	−9.3546 *** (0.2154)	−8.2805 *** (0.2012)	−8.5859 *** (0.2055)	−6.9438 *** (0.1785)	−6.5701 *** (0.1715)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes	Yes	Yes	Yes
N	9546	9546	9546	14,865	14,865	14,865
r2	0.5292	0.4788	0.4766	0.3870	0.3220	0.3484
r2_a	0.5246	0.4738	0.4715	0.3830	0.3176	0.3442
F	115.4768	94.4098	93.5763	97.1101	73.0744	82.2528

Standard errors in parentheses * $p < 0.1$, *** $p < 0.01$.

5.3.2. Influence of Fiscal Decentralization on the Green Innovation of Enterprises in Different Regions

This paper divides China into three regions: eastern, central and western regions on the basis of China's administrative divisions in combination with China's actual situation to test the impact of fiscal decentralization on enterprises in different regions of China. As shown in Table 6, fiscal decentralization promotes the green innovation of enterprises in three regions in China, among which the promotion effect on enterprises in the central region is the highest, followed by the western region and the lowest in the east. For the eastern region, the level of economic development and people's awareness of environmental protection are relatively high, coupled with the improvement of environmental protection requirements and corresponding punishment levels. Enterprises have achieved green transformation or cross-regional development to seek long-term development, so the improvement of local fiscal decentralization level has generally a low effect on the promotion of the green innovation of enterprises in the eastern region. The economic development level in the central and western regions is relatively slow, the traditional production experience mode has not been effectively changed, and there is a shortage of talents and funds in the development of enterprises. Therefore, with the improvement of regional fiscal decentralization, resource support for the green transformation and development of enterprises will be increased, and then the green innovation of enterprises will be promoted.

Table 6. Analysis of enterprises in different regions.

	Eastern Region			Central Region			Western Region		
	(1) toegp	(2) sgio1	(3) sgio2	(4) toegp	(5) sgio1	(6) sgio2	(7) toegp	(8) sgio1	(9) sgio2
fd	0.4705 * (0.2614)	0.3906 * (0.2332)	0.3798 * (0.2192)	17.7367 *** (1.9605)	14.7723 *** (1.7350)	11.1348 *** (1.6383)	9.9480 *** (1.4543)	9.2941 *** (1.2554)	5.1347 *** (1.2316)
_cons	−10.4720 *** (0.2027)	−9.1130 *** (0.1808)	−7.8785 *** (0.1700)	−9.1923 *** (0.3444)	−6.9814 *** (0.3048)	−7.1686 *** (0.2878)	−9.0815 *** (0.3537)	−7.2578 *** (0.3053)	−6.7637 *** (0.2995)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yearfixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	16,849	16,849	16,849	4604	4604	4604	2958	2958	2958
r2	0.4658	0.4180	0.4263	0.4396	0.3619	0.3881	0.4407	0.3713	0.3964
r2_a	0.4627	0.4146	0.4229	0.4297	0.3506	0.3773	0.4248	0.3533	0.3792
F	149.0307	122.7514	126.9839	44.3447	32.0633	35.8577	27.6308	20.7035	23.0275

Standard errors in parentheses * $p < 0.1$, *** $p < 0.01$.

5.3.3. Nonlinear Relation Test

In order to further test whether there is a nonlinear relationship between fiscal decentralization and the green innovation of enterprises, this paper uses the square term fd^2 of fiscal decentralization. Table 7 shows that the primary coefficient of fiscal decentralization is significantly positive, while the secondary coefficient is significantly negative, indicating that there is an inverted U-shaped relationship between fiscal decentralization and enterprise green innovation. The value range of fiscal decentralization is [0.001, 0.1290], and there are three threshold points. That is, when the level of fiscal decentralization rises from a lower level, it will have a positive role in promoting the green innovation behavior of enterprises. However, when it exceeds the threshold, it will inhibit the green innovation behavior of enterprises in a certain dimension. The maximum threshold of fiscal decentralization is 0.0928. When the level of fiscal decentralization is higher than 0.0928, it will inhibit the three dimensions of the green innovation of enterprises. With the improvement of fiscal decentralization, local governments will have more free capital allocation rights and will thus increase investment in environmental protection, support the construction of environmental protection projects, and promote the green innovation of enterprises. However, when the level of fiscal decentralization exceeds a reasonable range, there may be problems such as capital redundancy, multiple investment directions and reduced utilization efficiency, which is not conducive to the green innovation of enterprises.

Table 7. Nonlinear relationship analysis.

	(1)	(2)	(3)
	toegp	sgio1	sgio2
fd	5.7050 *** (0.7697)	5.8534 *** (0.6845)	2.9422 *** (0.6456)
fd ²	−33.8853 *** (5.4483)	−35.6017 *** (4.8451)	−15.8485 *** (4.5696)
_cons	−10.1128 *** (0.1487)	−8.5435 *** (0.1322)	−7.6011 *** (0.1247)
Control	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes
N	24,411	24,411	24,411
r2	0.4430	0.3855	0.3999
r2_a	0.4407	0.3830	0.3975
F	195.3034	154.0642	163.6539
Extreme points of fiscal decentralization	0.0841	0.0822	0.0928
Value range of fiscal decentralization		[0.001, 0.1290]	

Standard errors in parentheses *** $p < 0.01$.

5.3.4. Path Analysis of Financing Constraints

In order to test whether the financing constraint is the path in which fiscal decentralization affects the green innovation of enterprises, this paper further tests the intermediary effect. Table 8 shows that financing constraints have a masking effect between fiscal decentralization and enterprise green innovation, with effect values of 0.0532, 0.0796 and 0.0816, respectively, which proves that financing constraints are the specific path of fiscal decentralization affecting enterprise green innovation. With the improvement of regional fiscal decentralization, the financing constraints of enterprises will be eased to a certain extent, and green innovation will be accelerated.

Table 8. Financing Constraint Path Test.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	toegp	sgio1	sgio2	sa	toegp	sgio1	sgio2
fd	2.6373 *** (0.2148)	2.1165 *** (0.1834)	1.8894 *** (0.1772)	−0.4535 *** (0.0453)	2.7777 *** (0.2147)	2.285 *** (0.183)	2.0437 *** (0.1769)
sa					0.3095 *** (0.0302)	0.3715 *** (0.0257)	0.3402 *** (0.0249)
_cons	−9.2294 *** (0.1362)	−7.8524 *** (0.1163)	−6.7755 *** (0.1124)	−4.0294 *** (0.0287)	−7.9819 *** (0.1825)	−6.3551 *** (0.1555)	−5.4047 *** (0.1503)
N	24,411	24,411	24,411	24,411	24,411	24,411	24,411
r2	0.2302	0.2171	0.1973	0.2576	0.2335	0.2237	0.2034
r2_a	0.2299	0.2168	0.197	0.2573	0.2332	0.2234	0.203
F	729.79	676.7	599.78	846.77	675.81	639.33	566.36
Sobel		−0.1404 *** (Z = −7.152)		−0.1685 *** (Z = −8.214)		−0.1543 *** (Z = −8.065)	
Goodman-1 (Aroian)		−0.1404 *** (Z = −7.134)		−0.1685 *** (Z = −8.201)		−0.1543 *** (Z = −8.051)	
Goodman-2		−0.1404 *** (Z = −7.169)		−0.1685 *** (Z = −8.227)		−0.1543 *** (Z = −8.079)	
Mediation effect coefficient		−0.1404 *** (Z = −7.1517)		−0.1685 *** (Z = −8.2139)		−0.1543 *** (Z = −8.0648)	
Direct effect coefficient		2.7777 *** (Z = 12.9324)		2.285 *** (Z = 12.4858)		2.0437 *** (Z = 11.5505)	
Overall effect coefficient		2.6373 *** (Z = 12.2776)		2.1165 *** (Z = 11.5396)		1.8894 *** (Z = 10.6597)	
Mediation effect ratio		−0.0532 = 0.0532		−0.0796 = 0.0796		−0.0816 = 0.0816	
Bootstrap test		95% confidence interval [−0.1821, −0.0986]		[−0.2107, −0.1263]		[−0.1966, −0.1119]	

Standard errors in parentheses *** $p < 0.01$.

5.3.5. Influence of Green Innovation on Sustainable Development of Enterprises

Based on the systematic analysis of the impact of fiscal decentralization on the green innovation of heterogeneous enterprises and its path, this paper further examines the impact of green innovation on the sustainable development ability of enterprises. This paper uses the ESG index to measure the sustainable development ability of enterprises. As shown in Table 9, enterprise green innovation has a positive role in promoting enterprise ESG and has passed the significance test of 1%, and the promotion level of enterprise substantive green innovation on enterprise ESG is higher than that of strategic green innovation. With the improvement of the green innovation level of enterprises, it will further transform the production and operation mode of enterprises, reduce the pollution emissions of enterprises, improve the social, environmental and governance performance of enterprises, promote the long-term development of enterprises, and enhance the ability of sustainable development. However, strategic green innovation is mostly the patent of a utility model, not the real invention, so its promotion effect on the ESG of enterprises is obviously lower than that of the substantive green innovation of enterprises.

Table 9. Analysis of the impact of enterprise green innovation on ESG.

	(1) esg	(2) esg	(3) esg
toegp	0.7639 *** (0.0741)		
sgio1		1.0958 *** (0.0832)	
sgio2			0.5813 *** (0.0885)
_cons	-1.4×10^2 *** (1.8724)	-1.4×10^2 *** (1.8549)	-1.4×10^2 *** (1.8460)
Control	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes
N	24,411	24,411	24,411
r2	0.4573	0.4588	0.4559
r2_a	0.4551	0.4566	0.4537
F	209.0351	210.2952	207.8522

Standard errors in parentheses *** $p < 0.01$.

5.4. Robustness Test

To conduct the robustness test, we performed the following steps: (1) Rebuild the subsample. In order to reduce the impact of sample selection bias on the research results, this paper deletes seven classifications such as retail, wholesale, other financial industry, and sports to form a new sample according to the classification guidelines of China's "Listed Company Industry" for robustness testing. As shown in Table 10, the regression results support hypotheses H1, H2 and H3, indicating that the conclusions of this paper are still robust. (2) Perform the instrumental variable method. Considering that regions with higher levels of green innovation and digital transformation of enterprises tend to have higher levels of fiscal decentralization, this mutual causal relationship may lead to endogenous problems, which may lead to deviation in the regression results. Therefore, this paper uses the instrumental variable method to alleviate the endogenous problems that may exist in the model. This paper selects the regional economic scale (res) as the instrumental variable of fiscal decentralization. As shown in Table 11, after addressing potential endogeneity issues, the conclusion of the article remains robust.

Table 10. Robustness test: reconstruct the subsample.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	toegp	sgio1	sgio2	edt	toegp	sgio1	sgio2
fd	1.0856 *** (0.1989)	1.0020 *** (0.1775)	0.7401 *** (0.1671)	1.3498 *** (0.2468)			
edt					0.0608 *** (0.0053)	0.0702 *** (0.0047)	0.0127 *** (0.0045)
_cons	-10.5627 *** (0.1532)	-8.9317 *** (0.1367)	-7.9797 *** (0.1287)	-3.3114 *** (0.1901)	-10.3650 *** (0.1539)	-8.7025 *** (0.1370)	-7.9405 *** (0.1296)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	23,036	23,036	23,036	23,036	23,036	23,036	23,036
r2	0.4444	0.3881	0.4034	0.5026	0.4469	0.3931	0.4031
r2_a	0.4422	0.3857	0.4010	0.5006	0.4446	0.3907	0.4007
F	199.4738	158.1948	168.6222	251.9739	201.4591	161.5482	168.4111

Standard errors in parentheses *** $p < 0.01$.

Table 11. Endogenous test: instrumental variable method.

	(1)	(2)	(3)	(4)	(5)
	fd	toegp	sgio1	sgio2	edt
res	0.0364 *** (0.0002)				
fd		1.7741 *** (0.2314)	1.5142 *** (0.2058)	1.1353 *** (0.1939)	0.7241 ** (0.2908)
_cons	−0.3212 *** (0.0017)	−10.0615 *** (0.1484)	−8.4899 *** (0.1320)	−7.5771 *** (0.1243)	−3.4248 *** (0.1865)
Control	Yes	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes	Yes
Ind fixed	Yes	Yes	Yes	Yes	Yes
N	24,411	24,411	24,411	24,411	24,411
r2	0.6756	0.4418	0.3839	0.3995	0.4924
r2_a	0.6756	0.4396	0.3814	0.3971	0.4904

Standard errors in parentheses ** $p < 0.05$, *** $p < 0.01$.

6. Discussion

As the largest developing country in the world, although China has achieved great success in reform and development, there are still many problems such as slow economic growth, prominent ecological problems, insufficient innovation motivation and significant regional development differences. Therefore, under the background that the Chinese government fully implements the “dual carbon” goal, speeds up the construction of “digital China”, and promotes green and high-quality development, this paper systematically analyzes the logical relationship between fiscal decentralization, enterprise digital transformation and green innovation based on the existing literature combined with fiscal decentralization theory, technological innovation theory and resource dependence theory. This paper measures the level of fiscal decentralization and the degree of digital transformation of enterprises in various regions and uses OLS and other measurement methods to empirically test the panel data of 31 provinces in China from 2011 to 2021, revealing the quantitative relationship between the three items. This research finds that fiscal decentralization has a positive role in promoting enterprise digital transformation and green innovation, and enterprise digital transformation and financing constraints have a partial mediating effect between fiscal decentralization and enterprise green innovation. Further research finds that there are differences in the impact of fiscal decentralization on green innovation among heterogeneous enterprises and enterprises in different regions, an inverted U-shaped relationship exists between fiscal decentralization and green innovation, and green innovation has a significant promoting effect on enterprise ESG.

As an important indicator of regional financial freedom, fiscal decentralization plays a positive role in promoting regional economic and enterprise development. Based on the rational person hypothesis, both government officials and entrepreneurs have a propensity for profit. Therefore, in the context of the country’s comprehensive strict party management, digital transformation and green innovation development, in order to seek political stability and further improvement, government officials use their power to increase fiscal investment, accelerate green innovation and achieve high-quality economic and social development. For enterprises, with increasing competition, maintaining advantages in the fierce competitive environment and achieving long-term development have become the focus. Among them, digital transformation and green innovation, as a new direction of economic development in the new era, have become an important means for enterprises to attract the attention of the government and the public. Then, with the improvement of local fiscal decentralization, the government will increase support for infrastructure, digitalization and green innovation projects, thereby creating a good social environment for economic development, and also providing various supports and guarantees for enterprise development. Moreover, the improvement of digital transformation and green innovation level of enterprises will

attract more external funds and attention, thereby enhancing the core competitiveness of enterprises and ultimately promoting the high-quality development of enterprises and regional economies and societies. Therefore, the improvement of fiscal decentralization will promote the digital transformation process and green innovation level of enterprises, and ultimately achieve sustainable economic and social development.

In addition, this paper takes into account China's vast territory and significant differences among regions, with the economic development level in the central and western regions generally being relatively low compared to the eastern region with a relatively high level of economic development; thus, the improvement of fiscal decentralization can better alleviate the financial constraints of enterprises and accelerate their green innovation. Moreover, in the current situation where public ownership is the mainstay of China's economy and multiple forms of ownership are developing together, state-owned enterprises are generally larger in scale and have more mature development models. The government may have more preferences in providing policies and funds. Therefore, fiscal decentralization has a higher promoting effect on green innovation in state-owned enterprises than in private enterprises. In addition, although fiscal decentralization can enhance the governance enthusiasm of local governments, excessive fiscal freedom may breed problems such as corruption, inefficient use of funds, and vicious economic competition among regions. Therefore, this article analyzes the nonlinear relationship between fiscal decentralization and green innovation in enterprises and finds an inverted U-shaped relationship between the two. When the level of fiscal decentralization is higher than 9.28%, it will inhibit green innovation in enterprises. At the same time, in the context of China's implementation of the dual carbon goal and comprehensive promotion of ecological civilization construction, with the improvement of enterprises' green innovation level and the elimination of outdated production capacity, the production and operation mode of enterprises will be improved to a certain extent, thereby enhancing their social, environmental and governance performance, as well as their sustainable development ability. This paper also verifies this idea through empirical testing.

The existing research do not directly incorporate fiscal decentralization, enterprise digital transformation and enterprise green innovation into a unified framework. Moreover, the existing research conclusions on the relationship between digital transformation and enterprise green innovation are consistent with this paper. Therefore, this paper has a certain originality in the linear and nonlinear conclusions of fiscal decentralization on enterprise digital transformation and enterprise green innovation. Moreover, this paper reveals the logical and quantitative relationship between fiscal decentralization, enterprise digital transformation and green innovation, which makes up for the lack of existing literature, expands the research perspective of fiscal decentralization, and enriches the relevant research on the influencing factors and economic consequences of enterprise green innovation. Furthermore, this paper provides corresponding ideas and references for the reform of the fiscal decentralization system, regional policy formulation, allocation of fiscal funds, digital transformation of enterprises and green innovation strategy selection in China and other developing countries, and has certain enlightenment for the green and sustainable development of China's economy and the construction of ecological civilization.

7. Conclusions

7.1. Conclusions

Based on the panel data of 31 provinces in China from 2011 to 2021, this paper firstly integrates fiscal decentralization, enterprise digital transformation and green innovation into a unified framework, studies the quantitative relationship and transmission path among the three using OLS and other measurement methods, and draws the following conclusions: Fiscal decentralization has a positive role in promoting enterprise green innovation and digital transformation and promotes the total output of green innovation and substantive green innovation greater than strategic green innovation. Further research shows that there is an inverted U-shaped relationship between fiscal decentralization

and the green innovation of enterprises. When the proportion of fiscal decentralization exceeds 9.28%, fiscal decentralization will inhibit the green innovation of enterprises. Fiscal decentralization promotes green innovation in the three dimensions of heterogeneous enterprises and enterprises in different regions. Moreover, the promotion effect on state-owned and central and western region enterprises is higher than that on private and eastern region enterprises, respectively. In addition, enterprise green innovation has a significant role in promoting enterprise ESG. In addition, the digital transformation of enterprises has a positive role in promoting the green innovation of enterprises, and its role in the strategic green innovation of enterprises is the lowest. Through the intermediary effect test, this paper finds that the digital transformation of enterprises has a partial mediating effect between fiscal decentralization and enterprise green innovation. Further research finds that financing constraints have a masking effect between fiscal decentralization and enterprise green innovation.

7.2. Recommendations

Based on the above conclusions, this paper proposes the following suggestions:

(1) Deepen the reform of the fiscal decentralization system and enhance the fiscal freedom of local governments. First of all, in the post-pandemic era, the central government should further improve the level of fiscal decentralization of local governments, increase their fiscal freedom, and give them more sufficient funds to support various work in the region. Second, when expanding the level of local fiscal decentralization, the central government should fully consider its reasonable range so as to avoid problems such as redundant funds and inefficient use caused by the improvement of local governments' fiscal freedom. Third, the central government should take into account the overall situation; refine the development direction of each region; increase financial support for central and western regions, state-owned enterprises, digital transformation and green innovation projects; and further improve the budget and final account system of local governments and the performance evaluation system of their own financial funds to ensure the investment direction and use efficiency of local government financial funds. Finally, local governments should further increase infrastructure construction and provide more public goods to provide sufficient resource support for regional development, so as to promote regional economic transformation and upgrading and enterprise development.

(2) Further refine the institutional reform to support green innovation and promote the green innovation of enterprises. First of all, governments at all levels should establish a reward and punishment system for green development of enterprises, so as to create a good external environment for green development. Second, government departments should increase tax incentives for the green innovation of enterprises through tax reform, further stimulate enterprises' enthusiasm for green innovation, and improve their green innovation level. Third, government departments should increase policy guidance and financial support for private enterprises and ease their financing constraints by providing interest-free loans, increasing R&D subsidies and extending the repayment period of bank loans so as to promote their green innovation. Finally, relevant government departments should formulate an evaluation system for the green innovation of state-owned enterprises, increase the assessment of the direction and efficiency of the use of green R&D funds of state-owned enterprises, and improve the efficiency and quality of the green innovation of state-owned enterprises.

(3) Accelerate digital transformation and promote the main role of enterprise green innovation. First of all, government departments should further develop support policies and systems for traditional industries and projects combining industry with digital technology to enhance the enthusiasm of enterprises for digital transformation. At the same time, the government should encourage high-quality talents to actively participate in digital transformation and green innovation projects, so as to provide intellectual support for enterprise digital transformation and enterprise green innovation. Second, enterprise managers should combine the actual situation of the enterprise and make scientific layout,

accelerate the process of enterprise digital transformation, reduce the production and operation costs of the enterprise, make full use of the role of enterprise digital transformation, and promote enterprise green innovation. Third, enterprises should improve their budget system, enhance the efficiency of using innovation funds, and thereby enhance the efficiency of green innovation in enterprises. Finally, enterprises should further improve the salary incentive system, such as increasing the salary and equity ratio of corporate executives, so that the personal interests of managers can be combined with the actual development of enterprises so as to reduce managers' short-sighted behavior and promote digital transformation and green innovation.

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