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Digital Transformation and Green Investment: The Mediating Role of Green Technological Innovation and Environmental Uncertainty

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ABSTRACT

With the continuous advancement of digitization in traditional industries, digital transformation has become one of the key elements for enterprises to enhance their competitiveness and achieve sustainable development. This study aims to explore how digital transformation affects corporate green investment through green technological innovation and environmental uncertainty, and to validate whether corporate ESG performance and CSR can play a moderating role between digital transformation and green technological innovation. Based on the construction of the theoretical model, further empirical analysis is conducted using unbalanced panel data from 2010 to 2021. The results show that: (1) Digital transformation significantly increases the scale of green investment in enterprises. This conclusion remains valid after using multiple instrumental variables for causal identification. (2) Digital transformation can increase the scale of green investment in enterprises through two paths: improving the level of internal green technological innovation and reducing external micro-environmental uncertainty. (3) Good ESG performance and a high level of CSR in enterprises can positively moderate digital transformation, affecting green investment through technological innovation levels and environmental uncertainty. This study not only enriches the research on digital transformation but also provides policy recommendations for policymakers in promoting green investment and addressing environmental uncertainty.

KEYWORDS

Digital Transformation; Green Investment; Green Technological Innovation; Environmental Uncertainty; ESG; CSR

1. INTRODUCTION

As global climate change and environmental degradation become increasingly severe, investments made by enterprises in green, environmental protection, and sustainable development have become particularly important. From the "carbon reduction" target to the "dual carbon" target, the government's awareness of environmental protection and green development is also constantly increasing. Green investment, also known as sustainable and responsible investment, refers to investment activities that aim to reduce pollution and carbon emissions, protect the environment, and safeguard natural resources [1]. Through green investment, enterprises can reduce their reliance on resources, minimize negative impacts on the environment, actively participate in environmental protection undertakings, and achieve sustainable development. Against this backdrop, the digital transformation of enterprises, as an emerging innovative force, has exerted a profound impact on enterprises' green investment behaviors. Especially for heavily polluting enterprises, digital transformation will affect the efficiency of their green investment through financing constraints,

information asymmetry, and other aspects [2]. Digital transformation can not only provide certain financial support [3], market opportunities, and policy environments [4] for enterprises' green investment, but also help enterprises better communicate with stakeholders to discuss their green investment strategies. It also improves the transparency and traceability of green investment through digital tools [5], which is an important way to promote the green development of enterprises and help them better address the challenges brought by climate change and environmental changes. Although combining digital transformation and enterprise green investment-related content is a hot topic in current academic research, there are still certain theoretical gaps in its research content. Currently, foreign research on green investment mainly focuses on green finance, openness to the outside world, and other aspects. Domestic research on green investment started relatively late, mainly focusing on environmental regulation, and most studies are conducted at the national or provincial macro level, supplemented by research on the impact mechanisms of external environments such as media regulation and government environmental regulation on green investment [6]. There are already studies on digital transformation and green investment efficiency of heavily polluting enterprises [2], as well as enterprise green innovation [7]. However, the mechanism of action between digital transformation and corporate green investment, as well as the roles played by internal green technology innovation, external environmental uncertainty, corporate ESG (Environment, Social, and Governance) performance, and CSR (Corporate Social Responsibility) in this process, have not yet received sufficient academic attention.

Given this, the article aims to investigate how digital transformation can effectively drive enterprises to engage in green investment through which channels? What factors can further promote green investment in enterprises? Thereby helping enterprises achieve sustainable development? To address the above questions, this study adopts a quantitative research method by manually collecting annual reports and announcements of listed companies, obtaining data on corporate green investment and digital transformation through text mining, and conducting empirical research using statistical analysis methods. It conducts an in-depth analysis of the mechanism between digital transformation and corporate green investment at the micro level. The study selects the level of internal green technology innovation and the uncertainty of the external microenvironment as bridges connecting corporate digital transformation and green investment, which not only fills the research gap regarding the impact of internal factors on green investment, but also broadens the understanding of the impact of external factors on corporate green investment. The article further examines the moderating role of corporate ESG performance and CSR to verify whether they can strengthen the relationship between digital transformation and corporate green investment through green technology innovation and external environmental uncertainty. After considering the heterogeneity of enterprises, the study conducts grouped regressions based on whether they are state-owned or the proportion of research and development expenditures. The study found that digital transformation has a more significant effect on promoting green investment in state-owned enterprises and enterprises with a relatively low proportion of R&D expenditures. This indicates that for different types of enterprises, management should consider the unique characteristics of the enterprise when formulating corporate strategies, tailored to the specific conditions of the enterprise, and develop exclusive development strategies. The research results of this article can not only provide references for enterprises' digital transformation and green investment decisions, but also provide strategic suggestions for policymakers in promoting green and sustainable development of enterprises.

2. THEORETICAL ANALYSIS AND HYPOTHESES

2.1. Digital Transformation and Green Investment

In the era of digital economy, digital transformation has gradually become a key strategy for enterprises to achieve sustainable development goals. Digital transformation enables enterprises to effectively utilize government incentive policies, capture market dynamics through digital means,

and launch innovative green products or services, thus gaining a favorable position in the green market. At the same time, digital transformation helps enterprises more accurately assess investment risks and improve the quality of green investment decisions by enhancing information transparency. Moreover, digital transformation promotes information sharing and collaborative innovation among enterprises, driving the green development of the entire industrial chain and achieving the co-creation of resources and value. The relationship between digital transformation and green investment is specifically manifested in the following aspects. Firstly, enterprise digital transformation not only grasps market opportunities but also gains government support, providing a favorable market environment for enterprises to carry out green investment. With the emphasis on sustainable development, the green market is also expanding rapidly. Digital transformation can help enterprises seize these market opportunities and take the lead in capturing the market through innovative green products or services. Facing the changes in the general environment, the government has also introduced corresponding policies to encourage the digital transformation of traditional industries. Therefore, while responding to the policy orientation of digital transformation by government departments, enterprises are also conducive to obtaining more government resources and policy support [8]. These government incentives are specifically reflected in providing financial support for enterprises' green investment or facilitating enterprises' green investment. Secondly, enterprise digital transformation can enhance the accuracy of green investment. The process of enterprise investment is an extremely complex one, facing challenges and risks from various sources. Compared to traditional investments, green investments have higher risks, but enterprises can utilize digital tools to provide more accurate external micro-environment data for the enterprise. These precise and detailed data can effectively help enterprises understand their own environment in a more comprehensive manner, provide more comprehensive and accurate risk assessment reports, provide more scientific decision-making basis for management, optimize green investment decisions, and thus ensure the sustainability of green investment. Thirdly, digital transformation can promote information sharing among enterprises, integration and improvement of internal and external information [9], and facilitate cooperation between enterprises and stakeholders. This collaborative cooperation helps to promote the green development of the entire industrial chain, achieve resource sharing and value co-creation, and further promote enterprises' green investment. In summary, digital transformation not only aligns with the policy direction of the government but also can guide enterprises to make green investments in a more scientific manner, effectively reducing unpredictable risks in the investment environment, and promoting cooperation among stakeholders. Based on the above analysis, the following hypothesis is proposed:

H1: Digital transformation can increase the scale of enterprises' green investment.

2.2. Digital Transformation, Environmental Uncertainty, and Green Investment

The digital transformation of enterprises involves all aspects of their operations. In the process of transformation, the uncertainty of the microenvironment, such as fluctuations in policy environment, industry trends, market demand, and competition patterns, may have an impact on the green investment of enterprises. Firstly, digital transformation enables enterprises to respond more quickly to changes in industry and market demand, providing them with a more stable operating environment. The uncertainty of the industry may lead enterprises to delay or reduce investment in green technologies to avoid potential risks. Through digital transformation, enterprises can collect, analyze and utilize various information more efficiently, enabling them to have more complete and valuable information resources [10]. In addition, enterprises can use digital tools to help them more accurately assess the impact of the operation process on the environment, reduce the uncertainty of the industry, and provide a more reliable basis for long-term strategic planning and investment decisions. In such a stable environment, enterprises are more likely to consider and carry out green investments. Secondly, digital transformation enhances the competitiveness of enterprises, enabling them to occupy a favorable position in the green market and form a competitive landscape conducive to their

development. In digital transformation, data is regarded as an enterprise resource that can provide enterprises with lasting competitive advantages [11]. If an enterprise undergoes digital transformation and makes significant progress in the green field, it needs to continuously increase green investments to further enhance or maintain its market competitiveness, thus accelerating the pace of green investments. Finally, digital transformation enables enterprises to respond faster to policy changes by improving the transparency and real-time nature of their information [12]. Digital transformation brings immediate information feedback to enterprises, which helps them respond quickly to changes in the external environment and predict future trends more accurately. This allows enterprises to prepare in advance, ensuring that their green investment strategies are in line with the latest industry trends, market demands, and policy directions. Consequently, enterprises can more effectively cope with changes in the micro-environment and reduce uncertainty risks. Based on the above analysis, the following hypothesis is proposed:

H2a: Digital transformation can increase the scale of enterprises' green investment by reducing the uncertainty of the external environment.

2.3. Digital Transformation, Green Technological Innovation, and Green Investment

In the context of digital transformation, enterprises are able to carry out green technological innovation activities more flexibly, largely benefiting from the application of digital technologies. Digital transformation not only drives the improvement of enterprises' digital technologies but also generates technological spillover effects, promoting enterprises to engage in green technological innovation activities [13]. By collecting vast amounts of data through digital platforms and conducting intelligent analysis of big data, enterprises can gain a deeper understanding of resource utilization and environmental impact, which in turn helps them discover green market potential and innovation opportunities, thus promoting the research, development, and promotion of green products or services. In terms of investment capital, investors are paying increasing attention to the environmental and social responsibilities of enterprises. The green technological innovations achieved through digitalization have become a powerful testament to their sustainability, enhancing the trust of external investors and alleviating financing constraints for enterprises [14]. This allows enterprises to obtain more capital to engage in green investments that require significant upfront investment and have high demands on the sustainability of the capital chain. In terms of enterprise competitiveness, green technological innovations reduce production costs, improve resource utilization, reduce resource and energy consumption, and enhance the corporate image, thus strengthening the enterprise's competitive advantage in the field of environmental protection [15]. In summary, after digital transformation, enterprises can effectively utilize various digital technologies to assist in the efficient analysis of data, discover opportunities for green technological innovation, reduce the waste of resources and energy, alleviate financing constraints, and enhance their competitiveness. Therefore, enterprise digitization not only directly promotes internal green technological innovation, but also indirectly promotes green investment through green technological innovation, laying a solid foundation for the enterprise to achieve long-term sustainable development. Based on the above analysis, the following hypothesis is proposed:

H2b: Digital transformation can increase the scale of enterprises' green investment by enhancing their internal green technological innovation capabilities.

2.4. The Moderating Role of Enterprises' ESG Performance and CSR

The research and development process for green technological innovation products is relatively lengthy, requiring significant upfront capital investment and a long return period, with high demands on the continuity of the enterprise's capital chain. A company's ESG performance can significantly enhance its level of green technological innovation [16]. On one hand, excellent ESG performance demonstrates the company's strong sustainability, attracting the attention of investors and

stakeholders. On the other hand, outstanding ESG performance can further strengthen trust with investors and stakeholders, reducing the company's financial risks and providing sufficient financial support for its green technological innovation [17], which can be utilized in the development of green technological innovation projects. These innovative projects may include the development of environmentally friendly technologies, promoting the adoption of renewable energy, producing environmentally-friendly products, and improving the negative impact on the environment during the enterprise's operational processes. Through these green technological innovation activities, enterprises can also enhance their environmental image, further increasing the opportunities and attractiveness of green investment. Additionally, a company's ESG performance is an important indicator of its performance in sustainable development. By improving ESG performance, enterprises can reduce the uncertainty of the external environment on multiple levels. The better a company's ESG performance, the higher its transparency [18], which can help stakeholders gain a more comprehensive understanding of the company and reduce investors' and the market's uncertainty about the company's future development direction. At the same time, compliance with relevant industry laws, regulations, and standards is an essential part of corporate governance. By strengthening internal control and compliance management, companies can reduce legal and reputational risks arising from violations. Based on the above analysis, the following hypothesis is proposed:

H3a: A company's ESG performance can enhance the scale of its green investment through green technological innovation and environmental uncertainty.

With the increasing concern of stakeholders for corporate environmental protection and social responsibility, companies are actively fulfilling their social responsibilities in response to this trend. On one hand, they produce environmentally friendly products or services through green technological innovation to meet market demands, enhancing their awareness of green innovation. On the other hand, by fulfilling CSR, companies satisfy stakeholders while also gaining their trust, reducing the uncertainty of the industry environment. Corporate green technological innovation emphasizes the harmonious coexistence between the enterprise and the social environment, reducing pollution emissions and energy consumption through technological innovation, and mitigating the negative impact of the enterprise's production practices on the environment [19]. In this way, engaging in green technological innovation not only fulfills a company's environmental responsibility, but also enhances its capabilities in green technological innovation. Furthermore, this driving force for green technological innovation helps companies gain a competitive advantage in the environmental protection field, increasing the stability of their market environment. From the perspective of sustainable development, companies that are committed to green technological innovation and pay attention to environmental issues tend to perform better in terms of profitability compared to ordinary companies [20]. Moreover, investors tend to prefer investing in companies with better CSR performance and encourage them to engage in more green technological innovation activities [21], which is conducive to the sustainable development of these companies. To a certain extent, green investment is also a manifestation of a company actively fulfilling its social responsibilities. Green investment not only enhances a company's reputation in environmental protection, but also creates new market opportunities for the company, playing a positive role in enhancing its corporate image and achieving sustainable development goals. Therefore, fulfilling CSR can not only promote a company's green technological innovation and reduce the uncertainty of its external micro-environment, but also give the company more momentum in green investment. This sustainable business model also contributes to the coordinated development of the economy, society, and the environment, laying a solid foundation for the company's long-term development. Based on the above analysis, the following hypothesis is proposed:

H3b: CSR can enhance the scale of green investment through green technological innovation and environmental uncertainty.

3. METHOD

3.1. Data Source

The article uses unbalanced panel data from A-share listed companies that made green investments between 2010 and 2021 as the sample for this empirical study. To eliminate the impact of extreme values and outliers on the empirical results, the variables were trimmed at the 1% and 99% levels, and ST data were excluded. The data on digital transformation in the article comes from the CSMAR database. The data on corporate green investment comes from the annual reports and announcements of listed companies. The data on corporate green technology innovation comes from the National Intellectual Property Administration. ESG data comes from the Huazheng ESG rating. Corporate CSR data comes from Hexun.com. All other control variables are sourced from the CSMAR database.

3.2. Variable Description

Explanatory Variable: Digital Transformation. Currently, the primary measurement method for assessing the digital transformation of enterprises is through textual analysis. By constructing a digital keyword database encompassing five aspects - AI technology, blockchain technology, cloud computing technology, big data technology, and digital technology application - Python is utilized to capture relevant digital keywords from the annual reports of listed companies. Subsequently, the frequency of these keywords is classified and counted, and ultimately, the arithmetic mean of these five dimensions is used as a measure to evaluate the extent of digital transformation [22].

Explained variable: green investment scale. Referring to the approach of Zhao and Wang (2021) [23], this article manually collects the annual reports and announcement data of listed companies, sums up the investment expenditures related to the enterprises' ecological environment governance, green production, pollution prevention and control, etc., to obtain the data of enterprises' green investment in the current year, and conducts research from the perspective of investment scale. The total green investment of enterprise i in year t is used as a proxy variable for the scale of corporate green investment.

Mediator variables: (1) Green technological innovation. At present, the number of patents is often used as a proxy variable to measure corporate innovation. However, compared to the sheer number of patents, the number of patent applications can more accurately reflect a company's true level of innovation [24]. Therefore, this article follows the approach of Liu and Dong (2023) by taking the logarithm of the number of green patent applications plus one to measure the quantity of internal green technological innovation [25]. (2) Environmental uncertainty. The environmental uncertainty referred to in this article is at the micro-level. Drawing on the research of Shen et al. (2012), we adopt the standard deviation of sales revenue over the past five years for listed companies as a measure of the degree of environmental uncertainty they face [26].

Moderator variables: (1) ESG. The Huazheng ESG rating system provides a quantitative analysis and comprehensive evaluation of listed companies' performance in environmental, social, and governance aspects. It is widely recognized for its rating and ranking of companies' overall ESG performance [27]. Therefore, this article also uses the Huazheng ESG rating data as a proxy variable for corporate ESG. (2) Corporate social responsibility. For the measurement of CSR, the article draws on most scholars' measurements of CSR and uses a third-party CSR rating index, i.e., the overall CSR score assigned to listed companies by Hexun.com [28]. Drawing from relevant literature, the article selects control variables that include total debt ratio, enterprise value, and tangible asset-to-liability ratio.

4. RESULTS

4.1. Descriptive Statistical Analysis

As shown in the descriptive statistics in Table 1, the maximum and minimum values of digital transformation are 172 and 0, respectively, with a relatively large variance, indicating a significant gap in the degree of digital transformation among listed companies. Similarly, the large variances in the total green investment and CSR of listed companies also suggest a significant difference in the level of attention paid to green investment and CSR among these companies. The variances of environmental uncertainty, green technology innovation, and ESG performance of listed companies are all around 1, indicating relatively small differences in these areas among listed companies.

Table 1. Descriptive statistics of main variables

Variable	N	Mean	p50	SD	Min	Max
Digital	2811	22.29	12	29.21	0	172
Ginvest	2811	7.720	0.229	28.46	0	217.5
EU	2205	1.236	0.986	1.001	0.158	6.010
GI	2811	1.056	0.693	1.242	0	4.466
CSR	2223	23.91	21.25	16.31	-3.300	73.82
ESG	2739	6.520	6	1.161	3	9

(Note: Digital= Digital Transformation, Ginvest= green investment scale, EU= Environmental uncertainty, GI= Green technological innovation)

4.2. Main Effect Test

To reduce the interference of omitted variables on the regression results, the article further applies year fixed effects and industry fixed effects on the basis of including control variables. As shown in column (3) of table 2 the regression results, the regression coefficient is 0.04, which is significant at the 5% significance level. This regression result indicates a significant positive correlation between corporate digitalization and corporate green investment.

Table 2. Main effect test

	(1)	(2)	(3)
	Ginvest	Ginvest	Ginvest
Digital	0.049***	0.041**	0.040**
	(2.69)	(2.25)	(1.98)
_cons	6.618***	0.894	-5.126
	(9.81)	(0.45)	(-0.70)
Control variables	No	Yes	Yes
Two-way fixed effect	No	No	Yes
N	2811	2744	2744
Adjusted R2	0.002	0.052	0.197
F	7.242	38.900	9.745

(Note: Digital= Digital Transformation, Ginvest= green investment scale; t statistics in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

4.3. Mediation Effect Test

The article uses the three-step mediation method to test the mediation effect, and the specific test results are shown in Table 3. There is a significant negative correlation between the external environment uncertainty of enterprises and enterprise digitalization. In column (2) of table 3, the regression coefficient of the external environment uncertainty of enterprises is -2.317, which is significant at the 1% significance level. There is a significant positive correlation between internal green innovation and enterprise digitalization. The regression coefficient of the level of green innovation in enterprises in column (3) is 3.145, which is significant at the 1% significance level. The empirical results show that enterprise digitalization can affect the scale of green investment by reducing the external environment uncertainty and improving the level of internal green innovation.

Table 3. mediation effect test

	(1)	(2)	(3)	(4)
	EU	Ginvest	GI	Ginvest
Digital	-0.002***	0.036	0.006***	0.019
	(-2.65)	(1.53)	(8.19)	(0.95)
EU		-2.317***		
		(-3.89)		
GI				3.145***
				(6.44)
Control variables	Yes	Yes	Yes	Yes
Two-way fixed effect	Yes	Yes	Yes	Yes
N	2164	2164	2744	2744
Adjusted R2	0.055	0.212	0.367	0.209
F	2.687	8.669	21.652	10.304

(Note: Digital= Digital Transformation, Ginvest= green investment scale, EU= Environmental uncertainty, GI= Green technological innovation; t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

4.4. Moderating Effect Test of Enterprise ESG Performance and Corporate Social Responsibility

To better highlight the relationships among variables, the moderating variables were centered. As shown in columns (1) and (2) of table 4, the coefficients of the interaction terms between the enterprise's ESG performance and environmental uncertainty, and between ESG performance and green innovation are -1.499 and 1.723, respectively, both significant at the 1% significance level. This empirical result indicates that the better the enterprise's ESG performance, the lower the uncertainty of external environment, which in turn promotes green investment. Similarly, the better the ESG performance, the higher the level of internal green innovation, which further enhances the scale of green investment. Columns (3) and (4) of table 4 present the moderating effect tests of CSR. The regression coefficient of the interaction term between CSR and external environmental uncertainty is -0.107, significant at the 1% level. The regression coefficient of the interaction term between CSR and internal green innovation is 0.066, significant at the 5% significance level. The empirical results suggest that the better the CSR performance of an enterprise, the lower the uncertainty of the external environment, which promotes green investment. Likewise, the better the CSR performance, the higher the level of internal green innovation, which enhances the scale of green investment.

Table 4. Moderating effect analysis

	(1)	(2)	(3)	(4)
	Ginvest	Ginvest	Ginvest	Ginvest
EUxESG_c	-1.499***			
	(-2.84)			
GIxESG_c		1.723***		
		(5.47)		
EUxCSR_c			-0.107***	
			(-2.67)	
GIxCSR_c				0.066**
				(2.57)
EU	-2.588***		-2.483***	
	(-4.24)		(-4.33)	
GI		2.473***		2.794***
		(5.02)		(5.93)
Control variables	Yes	Yes	Yes	Yes
Two-way fixed effect	Yes	Yes	Yes	Yes
N	2142	2700	1788	2165
Adjusted R2	0.218	0.220	0.190	0.191
F	8.952	10.858	6.682	7.803

(Note: Digital= Digital Transformation, Ginvest= green investment scale, EU= Environmental uncertainty, GI= Green technological innovation; t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Table 5. Endogeneity test

	IV=inter	IV=inter	IV=IPR	IV=IPR
	the first stage	the second stage	the first stage	the second stage
	Digital	Ginvest	Digital	Ginvest
Digital		0.407**		0.247***
		(3.8)		(3.13)
inter	2.368***			
	(9.76)			
IPR			0.622***	
			(12.78)	
Control variables	Yes	Yes	Yes	Yes
N	2562	2562	2562	2562
Adjusted R2	0.0351		0.0593	

(Note: Digital= Digital Transformation, Ginvest= green investment scale, inter= internet penetration rate, IPR= internet broadband users; t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; the t-value is within the parentheses in the first stage, and the z-value is within the parentheses in the second stage.)

5. ENDOGENEITY ISSUE

To further determine the causal relationship between enterprise digitalization and green investment, we employed instrumental variables for further analysis. Drawing on the research by Ma et al. (2023) and Wang et al. (2023), we used the internet penetration rate and the number of broadband internet users at the prefecture-level city as instrumental variables for two-stage regression [29, 30]. The regression results of the first stage are shown in table 5, where the regression coefficients between the instrumental variables and digitalization are 2.368 and 0.622, both significant at the 1% level. In the second stage, the regression coefficients for digital transformation are 0.407 and 0.247, significant at the 5% and 1% levels respectively. The regression coefficients in the second stage show minimal changes compared to the benchmark regression coefficients, indicating a good causal identification in this model.

6. CONCLUSION AND DISCUSSION

Based on the construction of a theoretical model, this article conducts an empirical study on the relationship between digitalization and corporate green investment using unbalanced panel data from 2010 to 2021. The results indicate that digital transformation in enterprises can increase the scale of corporate green investment. This conclusion remains valid after using instrumental variables for causal identification. In the mechanism analysis, digital transformation promotes corporate green investment by enhancing the level of corporate green innovation and reducing external environmental uncertainty. Furthermore, good ESG performance and high levels of CSR in enterprises can positively moderate digital transformation, affecting corporate green investment through technological innovation and environmental uncertainty. While enriching research on digital transformation, this study also provides policy recommendations for policymakers in promoting green investment and addressing environmental uncertainty.

Based on the above research conclusions, the following research recommendations are proposed: 1. Accelerate the digitalization process. Enterprises should adopt cutting-edge digital technologies and information systems to accelerate their digital transformation. This will not only provide data support for business operations but also enhance the capabilities of risk identification and seizing green investment opportunities, thereby expanding the scale of green investment, improving operational efficiency, and enhancing market competitiveness. 2. Internal and external strategic synergy. Enterprises need to develop integrated internal and external strategies, leveraging internal green technological innovation and sharing digital resources with external partners to jointly address micro-environmental uncertainties and promote green investment. 3. Strengthen ESG and CSR management. Enterprises should prioritize and optimize ESG and CSR practices to strengthen the connection between digital transformation and green investment, enhance corporate image and trustworthiness, and drive sustainable development.

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