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Study on the Impact of Enterprise Digital Transformation on Green Innovation Performance -- The Mediating Role Based on Financing Constraints

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Abstract: As digital technology advances rapidly, digital transformation has emerged as a crucial strategy for enterprises to bolster their competitiveness and pursue green development. Nevertheless, enterprises frequently encounter hurdles such as financing constraints during this transformation, which can hinder the enhancement of green innovation performance. This paper intends to explore the influence of corporate digital transformation on green innovation performance, emphasizing the mediating role of financing constraints in this relationship. This research reveals that digital transformation notably enhances a company's innovative capabilities and market competitiveness, with green innovation performance serving as a pivotal indicator of sustainable development.Funding constraints play an intermediate role between digital transformation and green innovation performance, but it is a role often overlooked in existing studies.By easing financing constraints, digital transformation provides greater financial backing for green innovation projects, fostering green development and improving green innovation performance. These findings not only contribute to the theoretical understanding of the connection between digital transformation and green innovation performance but also offer practical insights for governments formulating policies and enterprises implementing digital transformation strategies.

Keywords: Digital transformation, green innovation performance, financing constraints

1. Introduction

Amidst concerns over global warming and dwindling resources, green development has gained substantial attention in the international arena. Recently, the Chinese government has emphasized environmental protection and sustainable development, introducing the "dual carbon" strategic goals. These goals seek to harmonize economic growth with environmental conservation through measures such as adjusting industrial structures, optimizing energy use, and encouraging green innovations. With the swift progression of digital technology, digital transformation has proven crucial for businesses to enhance their competitiveness and advance green development. However, enterprises often encounter hurdles like financing limitations during this transformation, potentially impeding their efforts to improve green innovation performance. Therefore, examining the effect of corporate digital transformation on green innovation performance, especially focusing on the mediating role of financing constraints, is of great theoretical and practical value.

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This research concentrates on the green innovation performance of enterprises within the framework of the digital economy.As an important modern economic paradigm, digital economy is greatly changing the production, operation and management models of enterprises. Financing constraints, a critical determinant in corporate investment decisions, necessitate thorough examination of their intermediary role between digital transformation and green innovation performance.

Previous studies have extensively covered digital transformation, green innovation performance, and financing constraints. Digital transformation is perceived to bolster a firm's innovative capabilities and market competitiveness, whereas green innovation performance serves as a vital indicator of a firm's sustainable development prospects. Financing constraints, as a notable influence on corporate investment decisions, are widely acknowledged to hinder innovative endeavors. However, existing research frequently overlooks the mediating effect. But existing studies often ignore the media effects of funding constraints when assessing the impact of digital solutions on the outcomes of green technological innovations, hindering a comprehensive grasp of their relationship.

Acknowledging the deficiencies in prior research, this study endeavors to explore the influence of corporate digital transformation on green innovation performance and uncover the mediating effect of financing constraints in this process. It specifically intends to analyze how digital transformation mitigates financing constraints, thus enhancing corporate green innovation performance, offering theoretical insights and practical advice for governmental policymaking and corporate digital transformation endeavors.

2. Literature review and research hypothesis

As information technology advances rapidly, digital transformation has emerged as a pivotal upgrade and transformation path for enterprises worldwide. Concurrently, environmental challenges have gained prominence, prompting widespread focus on green innovation as a vital approach to sustainable development. More recently, it has been supported as an academic research center to study the impact of corporate digital transformation on green innovation performance. Scholars widely acknowledge that digital transformation offers fresh impetus to green innovation by bolstering production efficiency and refining resource allocation [1].

2.1. Digital transformation

The development of the concept of digital transformation has evolved from initial informatization and automation to today’s intelligence and datafication. Some researchers argue that digital transformation is a process where companies use modern information technology to comprehensively innovate business processes, organizational structures, and management models, thereby enhancing efficiency and competitiveness [2]. Other researchers emphasize that the core of digital transformation lies in data collection, analysis, and application, driving decision-making through data to achieve precise operations and intelligent management [3]. This paper, however, views digital transformation as a comprehensive concept that encompasses not only the application of technological means but also changes in corporate strategy, culture, and organizational structure, aiming to significantly enhance the company’s innovation capabilities and competitiveness.

2.2. The relationship between enterprise digital transformation and green innovation performance

Green innovation performance serves as a pivotal index for evaluating the out comes of green initiatives within enterprises. It encompasses diverse aspects such as the development of eco-friendly

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technologies, the introduction of green products, and the implementation of sustainable management practices. The existing body of research can be broadly classified into two categories:

Firstly, digital transformation exerts a direct influence on a company's green innovation performance. This influence is manifested in two primary ways. One viewpoint contends that digital transformation enhances production processes and resource utilization efficiency, thereby fostering the advancement and application of green technologies. Conversely, another perspective argues that digital transformation propels the innovation and marketing of green products by revolutionizing business models and market strategies [4]. Clearly, digital transformation plays a crucial role in augmenting green innovation performance, a notion that has gained widespread acceptance in academic circles.

Secondly, digital transformation indirectly impacts the green innovation performance of enterprises. This perspective highlights the mediatory factors through which digital transformation influences green innovation. It can be further delineated into several viewpoints. One perspective posits that digital transformation elevates the informatization level of enterprises, facilitating internal information sharing and collaboration, and consequently promoting the progression of green innovation activities. Another perspective asserts that digital transformation ameliorates the external business environment by strengthening collaborations with suppliers and customers, fostering the establishment of green supply chains, and ultimately boosting green innovation performance [5]. Furthermore, some scholars have analyzed this from the lenses of organizational structure and corporate culture, suggesting that digital transformation transforms the internal environment of enterprises, kindling employees' awareness towards green innovation and encouraging green innovation practices.

In light of these insights, the following hypothesis is formulated:

H1: Digital transformation in enterprises exerts a positive impact on green innovation performance.

2.3. The mediating role of financing constraints

Financing constraints refer to the limitations and difficulties enterprises encounter when securing external financing. These obstacles may stem from factors such as information asymmetry, agency issues, and imperfect markets.

Researchers have noted that financing constraints can hinder companies' R&D investments, thus affecting the enhancement of green innovation performance [6]. The presence of financing constraints curtails a company's investment capacity, particularly for green innovation projects that demand substantial capital inputs. When companies are subject to financing constraints, they may struggle to secure adequate funds for the research, development, production, and promotion of green technologies, ultimately impacting their green innovation performance.

On the other hand, some scholars argue that while financing constraints may initially dampen green innovation, they can encourage companies to pursue more efficient and environmentally friendly innovation pathways in the long run [7]. Digital transformation mitigates financing constraints by reducing information asymmetry, enhancing operational efficiency, and expanding financing channels. The alleviation of financing constraints not only provides companies with increased financial support but also bolsters their confidence and commitment to green transitions. When companies recognize that digital transformation can ease financing difficulties, they are likely to invest in green innovation projects that are more profitable for the long term.thereby enhancing their green innovation performance.

In summary, digital transformation of enterprises alleviates financing constraints through reducing information asymmetry and improving operational efficiency, which in turn promotes green innovation. Consequently, this study proposes the following hypothesis:

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H2: Financing constraints mediate the relationship between digital transformation and green innovation performance.

3. Research design

3.1. Sample selection and data sources

This study employs data from A-share listed companies spanning the years 2007 to 2022 for empirical analysis. Given that the green innovation performance indicator utilizes future period data, the actual sample period for green innovation performance extends from 2015 to 2022, while other variables cover the period from 2007 to 2014. The data processing involves several steps: (1) excluding ST-class company samples, (2) removing financial company samples, and (3) discarding samples with missing data. Ultimately, this study utilizes 20 annual observation values of companies as the sample data for testing.

3.2. Variable selection

3.2.1. Independent variable: level of digital transformation (digital)

To assess the degree of corporate digital transformation, this paper adopts the frequency of digital-related terms in annual reports as the primary indicator. Following rigorous text analysis methods, key terms related to digital transformation are identified, and their frequency of occurrence is calculated to construct a "text intensity" metric, serving as a proxy for measuring digital transformation.

3.2.2. Dependent variable: green innovation performance (gpat1)

Green innovation performance is evaluated based on the innovation output dimension. Given that companies do not always disclose detailed R&D investments in green innovation, this study uses the total number of green invention patents and green utility model patents independently applied for by listed companies within the same fiscal year as the key indicator.

3.2.3. Mediating variables: financing constraints (SA)

This paper uses SA index to measure the financing constraint of enterprises. The larger the absolute value of SA index, the higher the financing constraint degree of enterprises. To measure the financing constraint degree of enterprises, the specific calculation formula is as follows:

$$\mathrm{SA} = -0.737\mathrm{Size} + 0.043\mathrm{Size}\text{^}2 - 0.04\mathrm{Aage} \quad (1)$$

Among them, Size represents the size of the company, that is, the natural logarithm of the total assets of the enterprise; Age represents the age of the company.

3.3. Control variables

3.3.1. Business size (size)

Business size is measured using the logarithm of total assets. Larger companies tend to have more abundant capital, technological resources, and stronger innovation capabilities, positively correlating with green innovation performance.

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3.3.2. Age of the enterprise (age)

The age of the enterprise is represented by the natural logarithm of the difference between the current year and the year of registration plus one. Older companies often accumulate richer human, technological, and knowledge resources, facilitating improved green innovation performance.

4. Empirical analysis

4.1. Descriptive statistics

Descriptive statistics for independent (numerical conversion) and dependent (green innovation performance) variables are presented in Table 1.

Table 1: Descriptive statistics results

Digital transformation		Green innovation performance	
average	43.94737	average	732.8421
standard error	11.28822	standard error	48.36873
median	20	median	736
standard error	49.20419	standard deviation	210.8344
variance	2421.053	variance	44451.14
kurtosis	0.77987	kurtosis	-0.56576
skewness	1.57814	skewness	0.241504
region	142	region	726
least value	11	least value	440
crest value	153	crest value	1166
sue for peace	835	sue for peace	13924
Observations	19	Observations	19

4.2. Regression analysis and P test

The regression results (Table 2) show that the regression coefficients of digital transformation degree and green innovation performance are positive, and the P-test coefficient is 0.033 <0.05, which verifies the validity of Hypothesis 1 within the 95% confidence interval. That is, Hypothesis 1: The positive impact of digital transformation on green innovation performance is established.

Table 2: P-test for regression coefficients

	Coefficients	t Stat	P-value
Intercept	640.5727476	10.87824	4.45E-09
X Variable 1	2.099542271	2.317545	0.033202
Multiple R		0.48998782	
R Square		0.240088064	
Adjusted R Square		0.195387362	
standard error		189.1188761	
observed value		19	

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4.3. ANOVA

The F value of the sample data is large, which verifies that the sample can reflect the real situation more truly (Table 3).

Table 3: ANOVA results

	df	SS	MS	F
regression analysis	1	192099.4	192099.4	5.371013
residual	17	608021.1	35765.95	
amount to	18	800120.5		

4.3.1. Test of mediation effect

The testing of intermediary models often employs Wen Zhonglin's three-step method for mediation analysis [8]. However, as the integration of statistics and economics becomes increasingly prevalent, scholars have pointed out that this traditional three-step mediation analysis method has certain limitations. Specifically, the statistical test results often fail to objectively and truly reflect the practical significance in economics [9]. Therefore, this paper combines this cutting-edge approach by conducting a regression analysis on financing constraints and digital transformation. As shown in Table 4, the regression coefficients are negative, confirming the negative impact of financing constraints on digital transformation.

Table 4: The role of financing constraints in digital transformation

variance analysis				
	df	SS	MS	F
regression analysis	1	20.55917	20.55917	17.31577
residual	17	20.18425	1.187309	
amount to	18	40.74342		
	Coefficients	standard error	t Stat	P-value
Intercept	12.64911341	0.339279	37.28234	9.57E-18
X Variable 1	-0.02172023	0.00522	-4.16122	0.000654

Studies have shown that financing constraints are one of the significant obstacles for companies engaging in innovation activities [10]. For green innovation, due to its high investment, high risk, and long-term nature, companies often require more financial support. However, when companies face financing constraints, their liquidity is limited, which can result in insufficient funding for green innovation projects. This not only affects the progress and outcomes of the project but may also reduce the company's willingness and enthusiasm to invest in green innovation, thereby negatively impacting the performance of green innovation [11].

While digital solutions directly affect the outcomes of environmental innovation, their mechanisms depend on alleviating funding constraints [12]. In other words, digital transformation indirectly promotes the improvement of green innovation performance by reducing the degree of financing constraints of enterprises.

In summary, the independent variable of digital transformation has great influence on the performance of green transformation. Financing constraints, acting as a mediating variable, play a crucial role in this process. By enhancing digital transformation, companies can not only improve their information technology levels and data processing capabilities but also alleviate financing

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constraints, providing more financial support and security for green innovation projects, thereby promoting the improvement of green innovation performance.

5. Conclusion

This study examines the impact of corporate digital transformation on the performance of green innovation, with particular focus on the intermediary role of funding constraints. This findings highlight two important points. Firstly, digital transformation significantly boosts green innovation performance. This underscores that digital transformation not only elevates operational and production efficiency but also propels green innovation by integrating novel technologies and models, which often feature energy conservation, cost reduction, and enhanced efficiency. These advancements facilitate corporate growth while mitigating adverse environmental impacts, thus offering new impetus for sustainable development.

Secondly, this research reveals that financing constraints act as a critical intermediary between digital transformation and green innovation performance. We observe that digital transformation alleviates corporate financing constraints, thereby fostering improved green innovation performance. By increasing transparency and reducing information asymmetry, digital transformation lowers financing costs and attracts more governmental subsidies and external investments. This financial support fortifies corporate endeavors in green innovation, driving continuous enhancement in their green innovation performance.

Essentially, this research highlights the positive impact of digital transformation on green innovation performance, with financing constraints playing a pivotal intermediary role. These insights offer valuable guidance for both corporate digital transformation strategies and governmental policymaking. Firms should proactively embrace digital transformation, strengthen internal organizational and technological capabilities, and innovate business models to enhance digital proficiency and secure sustained market competitiveness. Additionally, governments should refine relevant policies, accelerate digital infrastructure construction, and provide robust support for corporate digital transformation initiatives, collectively driving the continuous advancement of corporate green innovation performance.

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