IMPACT MECHANISM OF DIGITAL TRANSFORMATION ABOUT TECHNOLOGY-BASED SMALL AND MEDIUM-SIZED ENTERPRISES ON GREEN INNOVATION

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Abstract: With the development of the digital economy, the digital transformation of enterprises has become a focus of academic attention. This article takes technology-based small and medium-sized enterprises as an example, based on resource allocation theory, collects data from 360 enterprises, and uses hierarchical regression to verify the impact mechanism of digital transformation of technology-based small and medium-sized enterprises on green innovation. Research has found that the digital transformation of technology-based small and medium-sized enterprises has a significant positive impact on green innovation; The ability to integrate resources and information transparency both play a mediating role between digital transformation and green innovation; The positive regulation of executive green cognition is indirectly related to the impact of resource integration on green innovation in the digital transformation of technology-based small and medium-sized enterprises.

Keywords: Technology-Based Small And Medium-Sized Enterprises, Digital Transformation, Green Innovation, Resource Integration, Information Transparency, Executive Green Awareness

Introduction

Digitalization empowers greenlization, which is a new engine and driving force for enterprises to control pollution and transform to low-carbon in the digital economy era. It has received numerous policies supports and innovative practice feedback. In this context, many enterprises actively design

and construct projects such as digital green supply chain management platforms, civil aircraft manufacturing green park management platforms, 5G+ cloud tin industry smart smelting factories, and digital technology to promote green logistics full chain emission reduction. They have created a number of successful cases of digital transformation synchronously integrated into enterprise business operations and green development processes, comprehensively enhancing enterprise competitiveness.

Against the backdrop of strong policy support and active practice by enterprises, the primary objective of this study is to analyze the positive role of digital transformation in promoting green innovation in enterprises from a theoretical perspective. Digital economy innovation has the characteristics of high innovation efficiency, wide impact coverage, and high penetration rate, and is the main direction for the transformation of new and old driving forces in economic development. For the green development of enterprises, these advantages can promote more rational allocation of enterprise resources and improve green production efficiency, supporting the transformation of enterprises from traditional development methods to low-carbon and green development. Existing literature has conducted in-depth discussions on digital transformation and green innovation. Most studies support that digital transformation of enterprises can promote green technology innovation, and propose that the impact of digital transformation on green innovation of enterprises is mainly achieved through mechanisms such as improving innovation efficiency, optimizing internal control processes, alleviating financing constraints, accelerating information transmission, and improving environmental, social, and governance (ESG) performance. Another series of studies focuses on the impact of digital transformation on internal organizational dynamics and external institutional environmental factors in the process of green innovation, such as dynamic capabilities, financing models, information disclosure, board characteristics, as well as external factors such as market competition, policy uncertainty, and environmental regulation.

Although there is increasing discussion in academia about the digital transformation of enterprises, there are still several research gaps and shortcomings, such as a lack of attention to the important role of green innovation motivation in enterprises. The green innovation motivation of enterprises is closely related to the external environmental regulatory pressure and the main business of enterprises. The greater the regulatory pressure faced by enterprises, the closer the relationship between the main business and pollution reduction and carbon reduction, and the stronger the green innovation motivation of enterprises. Similarly, the strengthening of external supervision and the high potential pollution hazards in business scope are the core factors driving the dual transformation of enterprises. However, existing literature on enterprise digital transformation and green innovation has not paid attention to the heterogeneity of enterprise decision-making behind the differences in motivation for green innovation, and has overlooked the possibility that the green development motivation of enterprises may blur the differences in mechanisms for enterprise digital transformation. Only a few scholars have classified green innovation into substantive green innovation and strategic green

innovation based on the motivation of green innovation, and has demonstrated that the positive impact of digital transformation on green innovation is limited to substantive green innovation. However, the motivation analysis for green innovation still starts from the perspective of general enterprises and does not consider the differences in motivation between different types of enterprises. Based on this, this article focuses on the perspective of the differences in the degree of environmental regulatory pressure faced by technology-based small and medium-sized enterprises, with digital transformation as the independent variable, green innovation as the dependent variable, resource integration and information transparency as mediating variables, and executive green cognition as moderating variables, to explore the impact mechanism of digital transformation on green innovation in technology-based small and medium-sized enterprises.

Literature Review

1. Digital Transformation and Green Innovation

Digital transformation is the process in which enterprises use digital technology as a core production factor to drive comprehensive changes in strategy, organizational structure, business model, product and service processes, build new value systems, achieve close connections with stakeholders and value co creation, and enhance competitiveness and innovation performance. It can help enterprises identify, acquire, and accumulate valuable resources from within and outside the organization through the application of digital technology. At the same time, data itself is also an important core element in the innovation process of enterprises, enriching the existing innovation resources of enterprises. The research from the perspective of enterprises focuses on the green innovation effect of digital transformation of enterprises. The digital transformation of enterprises promotes green innovation by improving production efficiency, reducing internal control costs, optimizing human capital structure, increasing research and development investment, and promoting business model innovation. Some scholars also believe that the digital transformation of enterprises relies on rapidly developing digital technologies, which have a double-edged sword effect on the environment. While promoting energy-saving and emission reducing technological innovation through technology diffusion, the expansion of digital technology application scale will also increase energy consumption (Dhar, 2020), diluting the green innovation effect of enterprise digital transformation. The impact of digital transformation of enterprises on green innovation under the combined effect of increase and decrease is not clear. Research from the perspectives of industrial organization and industrial structure shows that digital transformation of enterprises reduces transaction costs, promotes industry university research cooperation, and improves the level of green technology innovation; Scholars have also explored the evolution of division of labor triggered by digital transformation of enterprises based on specific cases, such as the emergence and evolution of new industrial organizational characteristics such as digital platforms and intelligent cluster ecosystems, and their impact process and mechanism on green

innovation. The digital transformation of enterprises will also generate spillover effects, promoting industrial structure upgrading through knowledge spillover in the supply chain, stimulating the integration and innovation of digital technology and green technology, and forming new models and formats. The literature from a macro perspective mainly focuses on the path dependence and path change of technological innovation. Starting from the path dependence theory, it is believed that due to the influence of existing funding and technological path dependence, the motivation for digital transformation of enterprises is weaker, and they are more inclined to continue using existing technologies and production methods, or to ride on the positive externalities of digital transformation of other enterprises (Acemoglu et al., 2016). Under the guidance of this behavior, industrial digitization will also remain at a relatively low level. Correspondingly, the incremental green innovation created through enterprise digital transformation is also relatively small. There are also literature that starts from the relationship between digital technology and data elements and the quality of economic growth, and regards green technology innovation as one of the key mechanisms for promoting high-quality development in the digital economy (Ma & Zhu, 2022), that is, the creative destructive power of digital technology has triggered green biased technological progress, which will change the innovation path dependence of enterprises and transform innovation towards green.

2. Information Transparency

In existing research literature, information transparency has been widely defined and is related to the meanings contained in other words, such as information sharing, information exchange, information disclosure, information openness, as well as the meanings of comprehensibility, usefulness, specificity, visibility, clarity, and so on. Former SEC Chairman Levitt was the first to apply information transparency to the field of accounting information for research, which sparked strong reactions. Since then, the SEC has repeatedly used accounting information transparency as a core concept, interpreting it as comparable, transparent, and fully disclosed, sparking a wave of academic research on information transparency. The Basel Committee on Banking Supervision defined the connotation of information transparency in September 1988 as follows that if banks can release real and trustworthy information in real time, allowing customers to have a clear understanding of the bank's economic strength, sales amount, and planned operations, thereby timely and effectively grasping and preventing risks, it will increase consumers' goodwill and even trust in banks. This is the role of information transparency. This definition mainly emphasizes the reliability and timeliness of information, and is given for the information itself. In the preliminary research, the study on information transparency mainly focused on the stage of information disclosure, emphasizing the accuracy, timeliness, and reliability of information disclosure. With the continuous research and expansion of information transparency in academia, it is gradually being applied to information dissemination, supply chain, and other aspects. The definition of information transparency varies due to differences in academic fields, corporate social environments, social systems, and other aspects. Information transparency is a constantly evolving

process. However, regardless of how information transparency is defined, its importance is already evident. Information transparency has become an important influencing factor for enterprises to ensure product and service quality.

3. Resource Integration

Scarcity, irreplaceability, and difficult to imitate heterogeneous resources are key sources of a company's core competitiveness. Organizations can reduce collaboration costs and improve quality performance by collaborating with external partners to manage internal and external quality related processes and relationships at the operational or strategic level. Based on this, resource integration can be defined as the process in which an organization collaborates with partners in the supply chain who have strategic complementarity and heterogeneous resources to dynamically coordinate and allocate internal and external resources in order to improve performance or maintain competitive advantage, in accordance with strategic goals and changes in the external environment. Research has shown that resource integration is essentially a process of resource transfer and restructuring. Enterprises achieve optimal resource allocation by dynamically adjusting the combination of internal and external resources (such as technology, knowledge, and channels), and their competitiveness stems from the iterative ability of continuous optimization and integration of resources. Efficient collaboration can break resource boundaries, accelerate cross organizational resource flow and integration, enhance environmental adaptability, and the degree of collaboration directly affects the depth and breadth of resource sharing between organizations. The study further empirically verified the value of resource integration: based on the resource-based theory, scholars constructed a theoretical model of resource integration level, enterprise performance, and logistics integration capability in the omnichannel retail scenario. Through structural equation testing, it was found that resource integration has a significant positive impact on both operational and financial performance, and logistics integration capability and organizational synergy capability are the core drivers for improving supply chain integration efficiency. This conclusion not only quantifies the contribution mechanism of resource integration to competitiveness, but also provides theoretical support for resource collaboration practices in the omni channel model. The ability to dynamically restructure resources has become a key mechanism for enterprises to adapt to complex environments and build sustainable competitive advantages.

4. Executive Green Awareness

In recent years, executive green cognition has gradually been linked to green dynamic capabilities, green innovation, and green behavior. The concept of executive green cognition is not unified, but is based on the understanding of green concepts combined with executive cognition. Li et al.(2023) defined executive green cognition as the recognition and understanding of resource and environmental issues by senior management of a company, which includes the knowledge framework and understanding of resource and environmental issues, as well as the psychological feelings and experiences in the process of assuming responsibility for resource conservation and environmental

protection. At the same time, some scholars have expanded the restrictions on breaking away from executives and linked green awareness with farmer behavior, environmental regulations, and other factors. Zhang et al.(2022) studied the impact of the chairman's green cognition on the green entrepreneurial behavior of cooperatives in the context of environmental regulations. He believes that when the chairman's green cognition reaches a certain level, it will to some extent drive the green entrepreneurial behavior of cooperatives. At the same time, the richer the green awareness of executives, the easier it is to identify the risks and benefits of environmental protection, and companies will pay more attention to corporate performance.

In the past few decades, with the increasingly severe global environmental problems, the green awareness of executives has developed rapidly. In the early days, companies mainly viewed environmental issues from the perspectives of cost, regulations, and social pressure. But over time, more and more executives have come to realize that green and sustainable business models can not only meet social and environmental requirements, but also bring economic benefits. This shift can be seen from the increasing adoption of green and sustainable strategies by many businesses. Some studies have explored the basic classification of environmental issues by managers, which view them as opportunities or threats, highlighting the binary thinking of executives when viewing environmental issues. Some studies have refined executives' green awareness into general environmental awareness and cost-benefit environmental awareness, indicating that executives not only view environmental issues from an ethical or moral perspective, but also weigh them from an economic perspective. Our research divides executive green cognition into executive opportunity based green cognition and executive responsibility based green cognition.

Executive opportunity based green cognition is based on a company actively seeking unique environmental strategies with the aim of achieving differentiated competitive advantages. Enterprises believe that environmental sustainability is an opportunity to gain market advantages and customer loyalty through green products, green production processes, and other sustainable practices. The idea behind this motivation is that environmental innovation and practice are not only moral and "correct" practices, but also economically beneficial in the long run. The strategy of executive responsibility green cognition is based on the need of enterprises to comply with environmental regulations, mainly to meet regulatory requirements and avoid potential legal disputes or fines. The implementation of environmental protection behavior by enterprises is to fulfill the basic environmental responsibilities and obligations required in a larger social ecosystem. This motivation is usually based on the need for risk management, aimed at ensuring that businesses do not suffer economic or reputational damage due to violations of environmental regulations or environmental damage.

Theoretical Basis and Research Hypotheses

1. Resource orchestration theory

The resource orchestration theory is a strategic management theory formed by the complementary optimization of resource-based view, dynamic capability theory, and entrepreneurial piecing together theory. This theory points out that the dynamic management of resources by enterprises is the basis for forming key capabilities to gain competitive advantages. The resource orchestration theory is based on resource construction, resource bundling, and resource leverage to build a bridge between resources and performance. It explains how enterprises can dynamically adjust their digital resource combinations and green innovation content to achieve the optimal match between internal development characteristics and external environment. It provides an analytical framework for exploring the relationship between enterprise digital transformation and green innovation. From the perspective of internal capabilities of enterprises, the promotion of green transformation and development through digital transformation first went through the process of green structuring. Enterprises build digital foundations and use their "fully aware" and "fully connected" digital features to achieve green structuring. By optimizing resource allocation and breaking down resource barriers, enterprises can comprehensively improve their operational capabilities. Mainly reflected in: gradually accumulating data resources in various aspects of enterprise operation through digital infrastructure construction such as the construction of digital platforms, the introduction of digital devices, and the layout of digital technology, achieving the improvement of resource utilization efficiency in each aspect, and thereby achieving the separation of ineffective and inefficient resources and improving operational capabilities, such as the separation of redundant business processes and the elimination of inefficient equipment. This indicates that in the non advanced stage of digital transformation, enterprises flexibly and effectively arrange basic digital resources to achieve the construction and improvement of digital infrastructure. Firstly, green structured transformation is achieved at the operational management level, which is mainly reflected in creating competitive advantages and realizing value by promoting green innovation in business management and design.

2. The impact of digital transformation on green innovation

The key to enterprise digital transformation involves integrating digital elements into production and operation. By promoting intelligent manufacturing, applying new digital technologies, and adopting modern networked information systems, it significantly changes the traditional production methods, organizational forms, marketing management models, and business strategies of enterprises. In response to green innovation, full participation of digitalization in enterprise green financing, environmental information acquisition, green research and development, internal resource acquisition and other technological application links and business processes can promote the internal integration and external expansion of new and old resources and capabilities, improve process redundancy, optimize and enhance the efficiency of enterprise green innovation, create more green research and development achievements, and ensure the long-term sustainable competitiveness of enterprises. The role of digital transformation can be summarized into the following three aspects: firstly, digitalization

can improve the efficiency of enterprise information utilization, reduce information asymmetry, and enhance the accuracy of pollution risk assessment through the collection, organization, analysis, flow, and sharing of environmental information resources. This helps enterprises adopt more accurate measures to cope with risks and improve the precision of choosing green innovation goals. Secondly, digitization can optimize the allocation of enterprise resources, and digital transformation of enterprises can help them better utilize existing resources, improve resource integration efficiency through data interconnection platforms, digital resource management, and other methods, reduce resource redundancy, and provide more financial support for the green development of enterprises. In addition, the data resources of enterprises can also help them obtain external financial support, alleviate financial pressure, and further support their participation in green innovation. Thirdly, digitization can also directly participate in the green research and development process of enterprises, integrating innovation functions through diverse forms such as AI modeling and data production management, improving the ability of enterprises to integrate knowledge and absorb external knowledge, thereby providing technical support for green innovation of enterprises. Therefore, based on this theoretical discourse, hypothesis 1 is proposed:

H1: The digital transformation of technology-based small and medium-sized enterprises promotes the improvement of green innovation level.

3. The mediating role of resource integration capability

Resource integration can be divided into two stages: resource search and resource allocation. Digital transformation can promote enterprise resource search. Firstly, digital transformation can effectively identify external resources through digital means such as big data analysis, quickly screen out valuable knowledge resources for the organization, and improve the accuracy of resource search. Secondly, digital transformation relies on digital platforms to build a bridge between organizations and external communication, which is beneficial for enterprises to break through the limitations of time and space, extend the boundaries of resource search, shorten the distance between knowledge, and reduce the cost of enterprise search. Once again, digital transformation promotes internal business process transformation, which is beneficial for enterprises to break down internal communication barriers, make communication and coordination between departments more convenient, and promote efficient flow and effective integration of internal and external knowledge resources between departments. According to the theory of resource allocation, resources serve as the foundation for enterprises to gain competitive advantage. Only through a series of combinations, bundling, and utilization can potential be truly tapped and transformed into sustainable competitive advantages. Enterprises conducting resource searches can obtain diverse and heterogeneous resources, which not only increase the quantity and types of enterprise resources, but also improve the efficiency of resource utilization through the integration of knowledge and optimization of resource allocation. This can effectively solve the contradictions and conflicts that arise in the process of green innovation due to limited resources, maintain dynamic balance and circular

development between developing in existing fields and exploring in unknown fields according to market demand, improve the balance and complementarities of green innovation, and promote the coordinated development of green innovation. Therefore, based on this theoretical discourse, hypothesis 2 is proposed:

H2: Technology oriented small and medium-sized enterprises enhance their resource integration capabilities through digital transformation, thereby promoting green innovation in the enterprise.

4. The mediating role of information transparency

According to the theory of information asymmetry, there are information differences among market participants. Digital transformation processes inefficient information through digital technology and creates open information sharing platforms to improve information transparency and prevent decision-making errors caused by information mismatch. Firstly, digital transformation enhances information transparency, accelerates the flow of information in the supply chain, improves the decision-making efficiency and accuracy of external investors, reduces the cost of market participants obtaining information, effectively reduces the supervision and governance costs of external stakeholders, and encourages enterprises to actively enhance their green innovation to meet the needs of stakeholders, enhance corporate reputation, and achieve long-term sustainable development. Secondly, digital transformation not only enhances the transparency of enterprise information, but also improves the quality and supervision efficiency of internal control, reduces the moral hazard and adverse selection behavior of controlling shareholders and executives, and reduces the behavior of decision-makers that harms stakeholders under the constraints of governance mechanisms, promoting green innovation in enterprises. Based on this theoretical discourse, hypotheses are proposed:

H3: Enterprises enhance information transparency through digital transformation, thereby promoting their green innovation capabilities.

5. The moderating effect of executive green cognition

As the makers of corporate environmental strategy, senior managers' interpretation and understanding of environmental issues will deeply influence the company's green innovation strategy. This provides fundamental theoretical support for subsequent research. When enterprise managers have a stronger understanding and awareness of environmental issues, they are more likely to adopt forward-looking green supply chain strategies. When executives hold strong environmental awareness and cognition, companies are more likely to adopt green practices and thus gain a better competitive advantage. In this context, with the gradual popularization of green innovation in various enterprises, the strategic decision-making and cognition of senior management have become the key to the successful implementation of this management model. In short, when corporate executives have a deep understanding of green ecological issues and can accurately interpret relevant policy provisions, companies are more likely to achieve profitability as soon as possible under the green innovation model.

Some scholars have also refined the green cognition of executives. This provides a new research direction for other researchers. The values and cognitive paradigms of executives often determine the strategic choices of companies in green innovation. More deeply, these values and cognitive paradigms of executives not only determine how companies respond to external environmental challenges, but also affect the rational allocation of internal resources and capabilities. From the perspective of resource-based management, internal resources of enterprises, especially those related to green management, can serve as a source of competitive advantage. This means that if executives have a strong green awareness, it may become a key resource for driving green innovation and improving corporate performance. At the same time, in the B2B market, the support of senior management and the trust relationship between suppliers significantly increase the adoption rate of green innovation practices. Therefore, based on this theoretical discourse, hypothesis 4 is proposed:

H4: Executive green cognition plays a moderating role between resource integration and green innovation. The higher the executive green cognition, the more inclined they are to integrate and utilize resources for green innovation.

As shown in Figure 1, the conceptual model constructed reveals the dual effects of technology-based small and medium-sized enterprises on the path of digital transformation: on the one hand, digital transformation can directly promote green innovation in technology-based small and medium-sized enterprises; On the other hand, digital transformation can indirectly promote green innovation in technology-based small and medium-sized enterprises by enhancing resource integration capabilities and information transparency, and improving executives' green awareness. This discovery provides a new perspective and theoretical basis for studying the sustainable development of technology-based small and medium-sized enterprises.

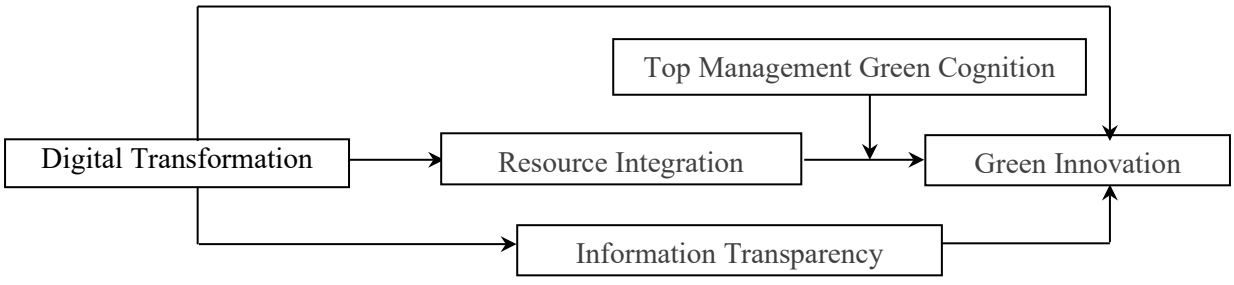

Figure 1: The Conceptual Model Diagram of Technology-Based Small and Medium-Sized Enterprises

Research Design

1. Questionnaire Design and Data Collection

After reviewing a large number of literatures related to the research topic, this article designs relevant questions based on the characteristics of technology-based small and medium-sized enterprises,

optimizes and improves them based on the original questionnaire, and uses the Likert five-point scale for measurement.

This article uses a questionnaire survey method to collect data, selecting technology-based small and medium-sized enterprises as the survey subjects, covering regions such as Guangxi and Guangdong. The questionnaire is distributed on-site and filled out online. The questionnaire consists of four parts: the title of the questionnaire, the description of the questionnaire, the measurement of the main variables, and the basic information of the respondents. Before the formal distribution of the questionnaire, in order to ensure its reliability, a pre survey was conducted to test the reliability and validity of the questionnaire. A total of 100 questionnaires were distributed, and 73 valid questionnaires were collected. Based on the results of the pre survey, any ambiguous or poorly designed items in the questionnaire were modified and improved.

2. Variable measurement

2.1 Measurement of Digital Transformation

The digital transformation of enterprises helps promote green innovation. Based on a large number of literature searches, this article mainly refers to the measurement scale developed by Zhu and Li (2023). After modification and improvement according to the characteristics of the research object, eight items including "Our enterprise has a mature digital transformation plan" were designed to measure digital transformation in questionnaires Q1-Q8, as shown in Table 1.

Table 1: Digital Transformation Scale

Variable	ID	Measurement Items
Digital Transformation	Q1	Our company has a mature digital transformation plan
	Q2	Our company adjusts organizational structure based on digital transformation tasks
	Q3	Our company uses digital technologies to optimize and reshape business processes
	Q4	Our company utilizes large amounts of internal and external data for intelligent decision-making
	Q5	Our company uses digital technologies to optimize and transform existing products/services
	Q6	Our company can develop and provide new digital products/services
	Q7	Our company uses data to identify market changes and user needs and responds promptly
	Q8	Our company co-creates value with stakeholders based on resource sharing and technological interconnectivity

2.2 Measurement of Green Innovation

Based on the measurement methods proposed by Chan (2005), Cao and Chen (2017), Song and Yu (2018), semantic adjustments were made and experts were invited to evaluate and revise. Seven items were designed, including "Our company attempts to reduce negative impacts on animal species and natural habitats in commercial activities". Green innovation was measured in questionnaires Q9-Q15, as shown in Table 2.

Table 2: Green Innovation Scale

Variable	ID	Measurement Items
Green Innovation	Q9	Our company seeks to reduce negative impacts on animal species and natural habitats in business activities
	Q10	Our company voluntarily invests effort and action in environmental restoration
	Q11	Our company aims to reduce waste generation and emissions in production and sales activities
	Q12	Our company reduces traditional fuel usage and adopts clean energy
	Q13	Our company selects more environmentally friendly materials in production and operations
	Q14	Our company improves production methods to recycle waste, raw materials, and components
	Q15	Our company makes changes in production and operations to reduce the environmental impact of products

2.3 Measurement of Resource Integration

This research refers to Sirmon et al. (2007) on measuring resource integration to measure the variable of resource integration. Six items were designed, including "the enterprise gradually changes the existing resource combination". Resource integration was measured in questionnaires Q16-Q21, as shown in Table 3.

Table 3: Measurement Indicators for Resource Integration

Variable	ID	Measurement Items
Resource Integration	Q16	Our company makes incremental changes to existing resource combinations
	Q17	Our company expands its current resource portfolio
	Q18	Our company maintains foundational resources (e.g., personnel, technology, management processes) without significant changes
	Q19	Our company combines new resources (e.g., technology, capital, employees)
	Q20	Our company y creatively recombines existing resources using innovative methods
	Q21	Our company innovatively integrates new resources with existing ones

2.4 Measurement of Information Transparency

On the basis of reviewing a large number of literatures related to corporate information transparency, this article draws on Lin et al. (2017) on information transparency and designs four questions, including "Our company clearly explains to stakeholders (employees, customers, etc.) how to control emissions that may harm the environment caused by production processes". Information transparency is measured in questionnaires Q22-Q25, as shown in Table 4.

Table 4: Measurement Indicators of Information Transparency

Variable	ID	Measurement Items
Information Transparency	Q22	Our company clearly explains to stakeholders (employees, customers, etc.) how it controls emissions that may harm the environment during production
	Q23	Our company provides stakeholders with the necessary information to understand the environmental impact of its production processes
	Q24	Our company shares relevant information with stakeholders about environmental issues related to its production processes
	Q25	Our company's environmental policies and practices are communicated to stakeholders in a clear and comprehensive manner

2.5 Measurement of executive green cognition

Based on the study of executive green cognition by Xing Liyun and Yu Huixin (2020), this research designed seven items, including "Our company's executives are very familiar with the role of environmental laws and regulations in the enterprise". The green cognition of executives was measured in questionnaires Q26-Q32, as shown in Table 5.

Table 5: Measurement Indicators of Executive Green Cognition

Variable	ID	Measurement Items
Top Management Green Cognition	Q26	Senior executives in our company are well aware of the impact of environmental regulations on the business
	Q27	Senior executives highly prioritize the adverse environmental effects of our company's operations
	Q28	Senior executives have a clear understanding of the strengths and weaknesses of production processes in our industry
	Q29	Senior executives place high importance on environmental protection
	Q30	Senior executives believe green practices enhance corporate image
	Q31	Senior executives believe green practices improve organizational productivity
	Q32	Senior executives believe green practices boost economic performance

Sample screening and descriptive statistics

This article collected questionnaires and conducted statistical and screening on the collected samples, ultimately selecting 360 valid questionnaires. The basic information of the respondents is shown in Table 6.

Table 6: Sample Descriptive Statistics

	Classification indicators	Number of people	Ratio (%)
Gender	Male	215	59.7
	Female	145	40.3
Age	Under 30 years old	66	18.3
	31-40 years old	110	30.6
	41-50 years old	128	35.5
	51 years old and above	56	15.6
Educational level	Technical secondary school and below	81	22.6
	undergraduate	145	40.3
	Master degree or above	134	37.1
Scale	Less than 50 people	84	23.3
	51~100 people	167	46.3
	101~200 people	41	11.4
	More than 201 people	68	19
Rank	Employee	53	14.7
	First-line manager	127	35.3
	Middle managers	136	37.8
	Senior management	44	12.2

Empirical Result Analysis

1. Reliability and Validity Testing

SPSS27.0 software is used to analysis software to conduct reliability and validity analysis on the collected data, the main factors were measured in the form of scales. Therefore, testing the data quality of the measurement results is an important prerequisite for ensuring the significance of subsequent analysis. Firstly, the internal consistency of each dimension is analyzed using the Cronbach's alpha reliability test method. The Cronbach's reliability coefficients of each dimension in this table are above 0.9, indicating that the reliability quality of this data is high and the questionnaire design is reasonable, which can be used for further research and analysis.

In the convergence validity test, standardized loadings, composite reliability (CR), and average variance extracted (AVE) are selected. The CR of each variable is greater than 0.8, indicating that the reliability of each item in the questionnaire is high; The AVE values of the measured variables are all above 0.5, indicating that the model has good convergent validity. Therefore, the correlation coefficient

between the variables suggests that further regression analysis is suitable. The analysis of variable reliability and validity is shown in the Table 8.

Table 8: Results of Variable Reliability and Validity Indicators

Variable	Number of Items	Minimum Factor Load	Maximum Factor Load	CR	Cronbach's Alpha	AVE
Digital Transformation	8	0.804	0.87	0.9496	0.949	0.702
Green Innovation	7	0.75	0.784	0.9063	0.942	0.5801
Resource Integration	6	0.734	0.791	0.8953	0.937	0.5878
Information Transparency	4	0.823	0.853	0.9063	0.906	0.7074
Top Management Green Cognition	7	0.813	0.858	0.9422	0.942	0.6998

2. Descriptive statistics and Normality Testing

According to the descriptive statistical analysis results, it was found that each variable had a score between 3-4, and the scoring method of the scale was 1-5 positive scoring. Therefore, it can be seen that the research variables are all above the moderate level. The normality test of each measurement item is conducted using sleekness and kurtosis. According to Kline's (1998) standard, if the absolute value of sleekness coefficient is within 3 and the absolute value of degree coefficient is within 8, the data can be considered to meet the requirements of approximate normal distribution. According to the data in Table 9.

Table 9: Results of Normality Test

Dimension	Question Items	Average Value	Standard Deviation	Variance	Skewness	Kurtosis	Overall M	Overall SD
Digital Transformation	Q1	3.16	1.398	1.954	-0.307	-1.1	3.154	1.202
	Q2	3.19	1.373	1.884	-0.339	-1.024		
	Q3	3.22	1.41	1.989	-0.298	-1.133		
	Q4	3.16	1.339	1.794	-0.215	-0.986		
	Q5	3.08	1.449	2.1	-0.258	-1.237		
	Q6	3.2	1.424	2.028	-0.269	-1.161		
	Q7	3.06	1.393	1.941	-0.253	-1.14		
	Q8	3.16	1.397	1.952	-0.321	-1.099		
Green Innovation	Q9	3.12	1.383	1.914	-0.242	-1.087	3.135	1.201
	Q10	3.13	1.376	1.894	-0.219	-1.072		
	Q11	3.16	1.408	1.981	-0.269	-1.145		
	Q12	3.15	1.388	1.927	-0.258	-1.096		
	Q13	3.17	1.398	1.955	-0.251	-1.113		
	Q14	3.12	1.401	1.963	-0.268	-1.132		
	Q15	3.1	1.412	1.993	-0.191	-1.145		
Resource Integration	Q16	3.17	1.426	2.033	-0.267	-1.168	3.151	1.238
	Q17	3.11	1.4	1.96	-0.242	-1.128		
	Q18	3.14	1.385	1.919	-0.282	-1.099		

Dimension	Question Items	Average Value	Standard Deviation	Variance	Skewness	Kurtosis	Overall M	Overall SD
	Q19	3.21	1.448	2.096	-0.334	-1.195		
	Q20	3.12	1.45	2.102	-0.259	-1.232		
	Q21	3.15	1.403	1.968	-0.225	-1.107		
Information	Q22	3.06	1.328	1.765	-0.211	-0.969	3.132	1.232
Transparency	Q23	3.17	1.432	2.05	-0.221	-1.183		
	Q23	3.13	1.415	2.002	-0.28	-1.172		
	Q25	3.17	1.4	1.961	-0.287	-1.122		
Top Management	Q26	3.09	1.393	1.941	-0.207	-1.117	3.141	1.214
Green Cognition	Q27	3.1	1.422	2.023	-0.201	-1.165		
	Q28	3.15	1.436	2.061	-0.26	-1.179		
	Q29	3.09	1.411	1.991	-0.222	-1.15		
	Q30	3.12	1.392	1.938	-0.252	-1.115		
	Q31	3.24	1.395	1.946	-0.295	-1.083		
	Q32	3.19	1.411	1.99	-0.22	-1.13		

3. Correlation analysis

In this analysis, Pearson correlation analysis was used to explore the correlation between variables. According to the analysis results in Table 10, it can be seen that there is a significant correlation between variables in this analysis. And they are all significant at the 99% level of significance. According to the correlation coefficient results, it can be seen that the correlation coefficients between all variables are greater than 0. Therefore, it can be concluded that in this analysis, there is a significant positive correlation between all variables.

Table 10: Pearson Correlation Analysis Results

Dimension	Digital Transformation	Green Innovation	Resource Integration	Information Transparency	Top Management Green Cognition
Digital Transformation	1				
Green Innovation	0.945**	1			
Resource Integration	0.943**	0.942**	1		
Information Transparency	0.930**	0.930**	0.917**	1	
Top Management Green Cognition	0.948**	0.938**	0.937**	0.924**	1

**At the 0.01 level (double tailed), the correlation is significant.

4. Model Adaptation Test

According to the suggestions of Mathieu and Farr, the mean of the items containing multiple dimensions of service quality should be used to represent each dimension, in order to reduce the number

of parameters to be estimated, enhance the reliability of measurement indicators, and improve the stability of parameter estimation. Confirmatory factor analysis is mainly used to test the relationship between a factor and its associated measurement items. Build a model using AMOS 28.0 pieces and conduct confirmatory factor analysis using maximum likelihood method. The analysis results are shown in Table 11, and all fitting indices have reached the ideal values, indicating that the model is well adapted and has a good fit, making it an acceptable model.

Table 11: Model Adaptation Test

Index	Reference Standards	Actual Measurement Results
CMIN/DF	1-3 is excellent, 3-5 is good	3.113
RMSEA	<0.05 is excellent,<0.08 is good	0.077
IFI	>0.9 is excellent,>0.8 is good	0.923
TLI	>0.9 is excellent,>0.8 is good	0.916
CFI	>0.9 is excellent,>0.8 is good	0.923

5. Hypothesis Testing

5.1 Main effect test

This article uses the process stepwise regression method to test the influence path (see Table 12). Model 1 indicates that the digital transformation of technology-based small and medium-sized enterprises has a significant positive impact on green innovation (β=0.89, $p<0.01$), supporting hypothesis 1.

5.2 Intermediary effect test

In Model 4, with resource integration capability as the dependent variable and digital transformation degree as the independent variable, the results show that digital transformation of technology-based small and medium-sized enterprises has a significant positive impact on resource integration capability (β=0.87, $p<0.01$). Taking green innovation as the dependent variable, Model 2 adds resource integration capability to Model 1. The results show that the resource integration capability of technology-based small and medium-sized enterprises has a significant positive impact on green innovation (β=0.85, $p<0.01$), supporting Hypothesis 2.

In Model 5, with information transparency as the dependent variable and the degree of digital transformation as the independent variable, the results show that the digital transformation of technology-based small and medium-sized enterprises has a significant positive impact on information transparency (β=0.71, $p<0.01$). Taking green innovation as the dependent variable, Model 3 adds information transparency to Model 1. The results show that the information transparency of technology-based small and medium-sized enterprises has a significant positive impact on green innovation (β=0.46, $p<0.01$), supporting Hypothesis 3.

Table 12: Process Stepwise Regression Analysis Results

Variable Type	Green Innovation						Resource Integration		Information Transparency	
Model	Model1		Model2		Model3		Model4		Mode5	
	β	t	β	t	β	t	β	t	β	t
Digital Transformation	0.89	54.79***	0.25	4.84***	0.56	14.02***	0.87	53.42***	0.71	47.74***
Resource Integration			0.85	7.36***						
Information Transparency					0.46	8.88***				
Top Management Green Cognition			0.71	6.41***						
Resource integration * executive green awareness			0.08	4.57***						
R^2	0.89		0.92		0.91		0.89		0.86	
F	3001.66***		1129.76***		1866.68***		2853.29***		2279.34***	

6. Moderated mediation effect test

Our study used the three-step method proposed by Wen et al. (2023) to test the moderated mediation effect. According to Model 2 in Table 12, the interaction term between resource integration and executive green cognition in technology-based small and medium-sized enterprises has a significant positive impact on green innovation (β=-0.08, p<0.01), supporting Hypothesis 4.

Conclusions and Discussion

1. Conclusion

This study constructs a multi-path model of "digitalization resource/information green innovation" by integrating resource orchestration, information asymmetry, and higher-order theory, revealing the interactive mechanism between technological change, organizational capacity, and manager cognition, providing a cross perspective theoretical framework for green innovation research. The specific conclusions are as follows:

(1) The digital transformation of technology-based small and medium-sized enterprises will significantly enhance their level of green innovation, manifested in an increase in the number of green patents, improved efficiency in environmental technology applications, and shortened development cycles for green products. Additionally, there may be a non-linear correlation between digital intensity and innovation effectiveness, such as threshold effects.

(2) Its digital transformation will indirectly promote green innovation by enhancing resource integration capabilities, especially resource search efficiency and cross departmental collaboration, revealing the key intermediary role of resource orchestration in the "technology innovation" chain.

(3) The improvement of information transparency is another important path for digitalization to promote green innovation, especially in reducing supply chain information asymmetry and

optimizing the external financing environment. The effect of this path may vary depending on the degree of industry pollution or policy regulatory intensity.

(4) The green cognition of executives will strengthen the promotion effect of resource integration on green innovation, indicating that managers' environmental awareness has a regulatory function in the implementation of corporate green strategies, and this role is more prominent in enterprises with centralized decision-making power, such as state-owned enterprises.

2. Research Implications

The main research insights from analyzing the impact of digital transformation of technology-based small and medium-sized enterprises on green innovation are as follows:

(1) Technology oriented small and medium-sized enterprises can promote digitalization in stages (such as prioritizing the construction of data platforms and optimizing resource search processes), improve resource integration efficiency and information transparency, and supplement with executive green awareness training to maximize green innovation benefits.

(2) Policy makers can design a dual track incentive policy of "digitalization + greening" based on this (such as tax incentives tilted towards enterprises that adopt both AI environmental protection technology and blockchain traceability), or establish regional green information sharing platforms to reduce the cost of green transformation for small and medium-sized enterprises.

(3) Financial institutions can develop green credit assessment tools based on the digitalization level and information transparency of enterprises. Investors can incorporate the above indicators into their ESG rating system to promote capital market support for sustainable innovation.

3. Insufficient research

Based on the theory of resource allocation, although the hierarchical regression method is used to verify the impact mechanism of digital transformation of technology-based small and medium-sized enterprises on green innovation, there are still some research shortcomings that can be further expanded in future studies:

(1) Sample limitation: Technology oriented small and medium-sized enterprises are scattered and small in scale, and the sampling frame may be incomplete, resulting in insufficient sample representativeness; Meanwhile, the questionnaire needs to be filled out by senior executives or core employees of the company, and the limited time of the respondents may result in low response rates or uneven data quality.

(2) Time constraints: The questionnaire design, pre survey, formal distribution, and collection process take a long time and may conflict with the company's operational cycle (such as peak production season); In addition, the lagging effects of digital transformation and green innovation are difficult to capture dynamic causal relationships through cross-sectional data.

(3) Funding limitations: Large scale sampling requires high costs (such as travel expenses for offline interviews and online platform service fees), and questionnaire incentives for executives of small

and medium-sized enterprises (such as gifts) may also increase budget pressure, limiting the breadth of sample coverage.

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