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Research on Impact of Artificial Intelligence Orientation on Enterprise Green Innovation

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Abstract: As the core technology to lead the digital future and promote the industrial revolution, artificial intelligence (AI) technology can empower the whole chain of manufacturing enterprises, accelerate the fundamental transformation of production mode and enterprise form, guide enterprises to integrate artificial intelligence with green innovative technology, and improve energy efficiency. Based on the background of green transformation faced by the manufacturing industry, we discuss the mechanism of artificial intelligence to realize green innovation of enterprises through dynamic capabilities. AI orientation refers to the tendency and strategy of enterprises in introducing and applying AI technology. Based on the strategic management theory and the resource-based view, a questionnaire survey for manufacturing enterprises was conducted. Using regression analysis method to conduct empirical research on 204 valid questionnaire data, to test the hypothesis. The result shows that AI has a significant positive effect on the green innovation of enterprises. Both strategic sensing capacity and timely decision-making capacity positively affect the green innovation of enterprises. Strategic sensing capacity and timely decision-making capacity play a partial mediating role between AI and green innovation. AI gives the light to enterprise development to clarify the direction of progress of the production technology. Enterprises need to establish AI-orientated strategies in many aspects to realize green innovation and improve environmental performance.

Keywords: AI Orientation, Strategic Sensing Capacity, Timely Decision-Making Capacity, Green Innovation

1. Introduction

With the increasing environmental problems, manufacturing enterprises are incorporating environmental protection into their long-term development strategies and exploring effective paths for green transformation and high-quality development. Innovation drives economic growth. Green innovation introduces ecological ideas into technological innovation activities to reduce environmental pollution through product or process innovation and ensure the sustainability of enterprises' competitive advantages. However, green innovation involves multi-disciplinary fields, as the result of the cooperation and benign interaction between subjects. It is the transformation and reform of the existing technological paradigm and is characterized by investment and complexity [1]. As the demographic dividend gradually weakens, and it is difficult to afford the high cost of green technology, how to promote green innovation has become an important issue for manufacturing enterprises.

Scholars have focused on the influence of external factors such as institutional pressure and market structure on green innovation. However, green innovation belongs to the category of breakthrough innovation, which requires carrying out a comprehensive system layout and strategic planning [2]. Therefore, we need to turn the research perspective to the inside of the enterprise. With the advent of the digital age, artificial intelligence (AI) has changed the development model of traditional industries in all directions and the entire value chain through technological revolution and industrial transformation. AI-oriented development refers to the tendency and strategy of

enterprises to provide a framework for AI-related decision-making, investment, applications, and management practice [3]. Therefore, enterprises pay attention to the strategic choice of AI technology through policy and market analysis and technical research. They eventually form an environmental protection strategy with AI technology to develop themselves and reduce environmental pollution f. While studies have revealed the important role of AI in green innovation, e-waste could exacerbate the pressures on the environment. In addition, other influencing factors in this process need careful discussion to further explore the relationship between AI and enterprise green innovation.

Since entering the era of Industry 4.0, the involvement of artificial intelligence in the manufacturing industry is gradually deepening. The role of artificial intelligence orientation in the ecological and environmental protection of manufacturing enterprises has also attracted the attention of the academic circle [4]. Through the above systematic review of relevant researches at home and abroad, although some scholars have conducted relevant researches on variables such as artificial intelligence orientation, green technology innovation, environmental regulation and carbon emission respectively, and achieved relatively fruitful results, there is still a lack of researches on the relationship between these variables [5, 6]. At present, most studies are still discussing the impact of strategic orientation on economic performance and environmental performance of enterprises, while few literatures focus on the field of artificial intelligence to explore its mechanism for achieving the goal of green innovation, which is worthy of further research. Secondly, the process of artificial intelligence-oriented promoting green innovation is still a "black box". There seems to be a certain relationship between them, but few literatures have thoroughly studied the mechanism of action. Finally, most domestic and foreign literatures regard environmental regulation as the antecedent variable affecting green technology innovation, but ignore its role in the orientation of artificial intelligence, and the conclusions drawn have certain limitations [7].

Although AI provides opportunities and convenience for enterprises to manage and optimize production processes and reduce resource consumption and pollutant emissions, the complex and changeable external environment cannot be ignored to truly achieve green innovation. Dynamic capabilities refer to an enterprise's ability to effectively integrate and allocate resources to cope with changes in the external environment. The deployment of organizational resources and capabilities determines the practical effect of green innovation. In addition, several scholars pointed out that strategic orientation promotes enterprises to carry out environmental innovation under its influence on dynamic capabilities. Therefore, dynamic capabilities are likely to serve as an intermediary bridge between AI and green innovation. To sum up, we explore the mechanism of AI orientation to promote green innovation through dynamic capabilities enhancement.

2. Theoretical Foundations and Hypotheses

2.1. AI and Green Innovation

The primary driving force of green transformation comes from enterprises, while strategic orientation helps enterprises clarify the direction of business activities and find new competitive advantages in the market. On the other hand, Li believes that green intelligent manufacturing has become the general trend of transformation from the traditional manufacturing industry [8]. AI technology manages business processes in enterprise resource planning, intelligent decision-making process, and automatic control technology to enhance the innovation activities of information technology. In the application of AI technology in Brazilian industrial enterprises, digital services and cloud computing are conducive to the application and improvement of product design and manufacturing to improve the efficiency of green innovation [9].

To find the key role of the strategic operation of modern enterprises and industrial upgrading with digital technology, the strategic use of AI technology is considered, which is defined as AI orientation. If enterprises improve the performance of the economy and environment, they need to apply AI such as machine learning and computer vision to empower green innovation. This empowerment process is mainly reflected in the design, production, operation, maintenance, testing, and logistics. In addition, AI orientation enhances the aggregation of innovation resources and the cultivation of environmental awareness. It generates new ideas and effectively reduces innovation risks and costs. Therefore, AI orientation, as a strategic guideline, helps enterprises optimize production by using the new generation of information technology and reshaping the nature of the innovation process. Enterprises' innovation is enabled by the realization of green innovation. Therefore, the following hypothesis is proposed.

H1: AI orientation has a significant positive impact on green innovation.

2.2. Dynamic Capabilities and Green Innovation

Dynamic capabilities are transformation-oriented to help companies redeploy their resources and develop innovative strategies for market demands and competition [10]. There are uncertainties in products for environmental protection such as a lack of technical and complementary knowledge. However, enterprises need to adapt to the uncertain environment with dynamic capabilities. Under the circumstance of environment-friendly products' short life, enterprises need to rely on dynamic capabilities for continuous innovation. Previous studies regarded dynamic capabilities as a multi-dimensional variable. We divide dynamic capabilities into strategic sensing and timely decision-making capability. Strategic sensing capability refers to the ability to acquire market information for new market demands and potential threats. This affects the

enterprise's innovation. Timely decision-making capability refers to the ability to quickly formulate and select strategic directions to cope with changes in the external environment.

The deployment of enterprise resources and capabilities must be based on the competition of the market and stakeholders' expectations, and the technology and knowledge. The strategic decision of green innovation depends on enterprises' comprehensive judgment of potential market opportunities, stakeholders' environmental demands, and the development of existing green technologies. Strong strategic sensing capacity keenly helps capture market information. It changes stakeholders' needs and makes a large amount of investment in green innovative products at an appropriate time. The stronger the strategic sensing capacity is, the more green information enterprises obtain, and the more frequent the green innovation actions of enterprises [11]. This makes the green innovation have a scale effect. Strategic sensing capacity helps enterprises use their resources towards green innovation for green products, green processes, and green technologies.

The resources for enterprise green innovation are distributed in the global market at all levels of the enterprise. In the rapidly changing competitive environment, the success of green innovation depends on the enterprise's ability to acquire new information and timely response to the external environment. Enterprises need strong timely decision-making capability to respond quickly to market demands and handle conflicts in the process of strategy implementation. Enterprises need to integrate internal and external resources, reform the existing organizational structure and production process, reconstruct the dynamic capability, and upgrade or transform green products and processes [12]. Therefore, timely decision-making capability shapes a whole new ecosystem for enterprises and promotes green innovation. Therefore, the following hypotheses are proposed.

H2a: Strategic sensing capacity has a significant positive impact on green innovation.

H2b: Timely decision-making capability has a significant positive impact on green innovation.

2.3. Mediating Role of Dynamic Capabilities

In recent years, the manufacturing industry is developing new technology with fierce competition. Enterprises need to pay attention to the dynamic resource for innovation. AI orientation is for technology choice and plays a key role in dynamic capabilities. AI orientation improves the ability to allocate resources through strategic decision-making. AI orientation is characterized by innovation, advanced action, and risk bearing to actively detect dynamic changes and make timely decisions to seek benefits and avoid disadvantages. Advanced technological innovation opens up new markets ahead of competitors and fully mobilizes the dynamic capabilities for green innovation. Enterprises also need to implement AI orientation into green innovation practices [13].

Enterprises with AI orientation accumulate technical resources, form a corporate culture for technology, and improve technical capabilities. The stronger the AI orientation is, the stronger the strategic sensing capacity in the market. This allows for identifying available green knowledge and technology and defining the direction of green innovation. Moreover, enterprises with high technology and data use efficiently realize the external environment with strategic sensing capacity to reduce the risk of green innovation. The stronger AI orientation contributes to the organization's timely decision-making capability in time. The external and internal knowledge is integrated to optimize the organizational structure and operating system. In the shortest time, AI orientation enables enterprises to have optimal strategic decisions, reduce the hindrance in the innovation process, and secure powerful internal support for enterprises' green innovation and value transformation. Therefore, the following hypotheses are proposed.

H3a: AI orientation has a significant positive impact on strategic sensing capacity.

H3b: AI orientation has a significant positive impact on timely decision-making capability.

H4a: Strategic sensing capacity plays a mediating role between AI orientation and green innovation.

H4b: Timely decision-making capability plays a mediating role between AI orientation and green innovation.

3. Research Design

Data were obtained through a questionnaire survey. For AI orientation, the measurement scale of Li was adopted [8]. For dynamic capabilities and green innovation, the research results of Li [14] and Chang [15] were referred to, respectively. All questions were measured on a 7-point Likert scale, with 1–7 corresponding "strongly disagree" to "strongly agree". The questionnaire results were processed and analyzed by SPSS26.0.

4. Analysis Results

4.1. Descriptive Statistical Analysis

The questionnaire was distributed to the employees of manufacturing enterprises through the questionnaire star platform. A total of 413 questionnaires were sent out, and 289 were recovered with a recovery rate of 69.98%. 204 valid questionnaires were obtained finally. The collected questionnaires were analyzed, and the basic information is shown in Table 1.

Table 1. *Descriptive Statistical Analysis of Samples.*

Characteristic	Category	Frequency	Percentage
Gender	Male	104	51.0%
	Female	100	49.0%
Age	18-24	34	16.7%
	25-30	93	45.6%
	31-40	50	24.5%
	>40	27	13.2%
Ownership	State-owned Enterprise	80	39.2%
	Non-state Owned Enterprise	124	60.8%

Characteristic	Category	Frequency	Percentage
	<300	12	5.9%
	300-499	90	44.1%
Firm Size	500-999	68	33.3%
	1000-1999	26	12.7%
	>2000	8	3.9%
	0-5	36	17.6%
	6-10	68	33.3%
Firm Age	11-15	63	30.9%
	16-20	29	14.2%
	>20	8	3.9%

4.2. Reliability and Validity Test

Cronbach's alpha was used to analyze the reliability scale, and the result is shown in Table 2. The α values of AI orientation, strategic sensing capacity, timely decision-making capability, and green innovation are all higher than 0.7, so the survey ‘s reliability is verified.

Table 2. *Reliability Analysis Results.*

Variables	Cronbach' α	Item
AI Orientation	0.951	8
Strategic Sensing Capacity	0.939	6
Timely Decision-making Capability	0.900	4
Green Innovation	0.938	6

Validity tests are conducted for content validity and structure validity. Before the survey, experts including scholars and enterprise managers were invited to discuss and modify the survey items. The results of the KMO value and Bartlett’s Test of Sphericity are shown in Table 3. The KMO coefficients are greater than 0.6 at the significant level of 0.001. Therefore, the validity of this study is confirmed.

Table 3. *Validity Analysis Results.*

KMO and Bartlett’s Test		
Sample Sufficient Degree of KMO Metric		0.964
Bartlett’s Test of Sphericity	The approximate χ^2	4663.225
	Degree of Freedom	276
	Sig.	0.000

4.3. Hypothesis Testing

Regression analysis was conducted by SPSS 26.0, and the results are shown in Tables 4-8. Model 1 examines the influence of two control variables on green innovation. Model 2 examines the influence of AI orientation on green innovation. Model 3 and Model 4 examine the effectiveness of strategic sensing capacity and timely decision-making capacity on green innovation. Model 5 and Model 6 verify the influence of AI orientation on strategic sensing capacity and timely decision-making capacity. Model 7 and Model 8 test the influence of AI orientation on green innovation after the introduction of strategic sensing capacity and timely decision-making capacity.

4.3.1. Impact of AI Orientation on Green Innovation

Model 1 examines the influence of control variables on green innovation. AI orientation was added to construct Model 2. The regression results show that AI orientation has a significant positive correlation with green innovation (β=0.378, P<0.001), so hypothesis 1 is verified.

Table 4. *Impact of AI Orientation on Green Innovation.*

Variables	Green Innovation	
	Model 1	Model 2
Firm Size	0.989	0.462
Firm Age	-0.259	-0.309
AI Orientation		0.378***
R^2	0.018	0.321
ΔR^2	0.009	0.311
ΔF	1.892	31.565***

*** means significant at 0.001 level, ** means significant at 0.01 level, and * means significant at 0.05 level. The same below.

4.3.2. Impact of Dynamic Capabilities on Green Innovation

As shown in Table 5, from the regression results of models 3 and 4, strategic sensing capacity (β=0.438, P<0.001) and timely decision-making capacity (β=0.679, P<0.001) have a significant positive impact on green innovation. Thus hypothesis 2a and hypothesis 2b are verified.

Table 5. *Impact of Dynamic Capabilities on Green Innovation.*

Variables	Green Innovation	
	Model 3	Model 4
Firm Size	0.614	0.655
Firm Age	-0.564	-0.416
Strategic Sensing Capacity	0.438***	
Timely Decision-making Capability		0.679***
R^2	0.263	0.271
ΔR^2	0.252	0.26
ΔF	23.780***	24.746***

4.3.3. Impact of AI Orientation on Dynamic Capabilities

The regression results of models 5 and 6 show that AI orientation has a significant influence on strategic sensing capacity (β=0.462, P<0.001) and timely decision-making capacity (β=0.302, P<0.001). Thus, hypothesis 3a and hypothesis 3b were verified.

Table 6. *Impact of AI Orientation on Dynamic Capabilities.*

Variables	Strategic Sensing Capacity	Timely Decision-making Capability
	Model 5	Model 6
Firm Size	0.212	0.070
Firm Age	0.635	0.191
AI Orientation	0.462***	0.302***
R^2	0.366	0.359
ΔR^2	0.357	0.350
ΔF	38.550***	37.397***

4.3.4. Mediating Role of Dynamic Capabilities

When AI orientation and strategic sensing capacity influence green innovation at the same time, the regression coefficient of strategic sensing capacity on green innovation is still significant (β=0.228, P<0.001. The regression coefficient of AI orientation on green innovation decreases, but it is still significant (β=0.272, P<0.001). thus, hypothesis 4a has been verified.

Table 7. *Mediating Role of Strategic Sensing Capacity.*

Variables	Green Innovation		
	Model 2	Model 3	Model 7
Firm Size	0.462	0.614	0.413
Firm Age	-0.309	-0.564	-0.454
AI Orientation	0.378***		0.272***
Strategic Sensing Capacity		0.438***	0.228***
R^2	0.321	0.263	0.364
ΔR^2	0.311	0.252	0.352
ΔF	31.565***	23.780***	28.514***

The regression coefficient of timely decision-making capacity to green innovation is significant (β=0.366, P<0.001). The regression coefficient of AI orientation on green innovation decreases, but it is still significant (β=0.267, P<0.001). Thus, hypothesis 4b has been verified.

Table 8. *Mediating Role of Timely Decision-making Capability.*

Variables	Green Innovation		
	Model 2	Model 4	Model 8
Firm Size	0.462	0.655	0.436
Firm Age	-0.309	-0.416	-0.379
AI Orientation	0.378***		0.267***
Timely Decision-making Capability		0.679***	0.366***
R^2	0.321	0.271	0.369
ΔR^2	0.311	0.26	0.356
ΔF	31.565***	24.746***	29.064***

5. Research Conclusions and Discussion

We investigated the effectiveness of AI orientation and the mediating effect of dynamic capabilities on green innovation. The theoretical model was verified through the analysis, and the following conclusions were drawn.

AI orientation positively promoted dynamic capabilities, namely strategic sensing capacity and timely decision-making capability. Strategic sensing capacity and timely decision-making capacity also have a significant positive impact on green innovation. In addition, strategic sensing capacity and timely decision-making capability play a mediating role between AI orientation and green innovation.

For the global digital economy and the deterioration of the environment, AI technology may become critical for manufacturing enterprises to change the competitive landscape. However, at present, many enterprises do not have the overall strategic goals with AI. This results in a low utilization rate of AI technology and data mining. Thus, enterprise green innovation has not been realized to the maximum extent. The research result for development in the transformation of enterprises under a dynamic environment to promote green innovation provides practical reference for further studies.

When integrating AI technology into production and development, AI orientation allows enterprises to apply related technologies to obtain competitiveness with green innovation capabilities. Therefore, in promoting green innovation, enterprises need to strengthen the guiding role of AI orientation on green innovation. Enterprises need to take the cultivation of dynamic capabilities as a long-term strategic goal. By improving strategic sensing capacity and timely decision-making capacity, enterprises obtain the latest information in the market to rapidly reconstruct resources for timely decisions. At the same time, enterprises need to use the influence of AI orientation or dynamic capabilities on green innovation and integrate AI orientation and multi-dimensional dynamic capabilities. Enterprises also need to increase investment in information technology to promote environmental protection, encourage green consumption, and incorporate energy conservation and emission reduction into their strategic planning. Then, it is achievable to improve their green innovation performance and promote the transformation of their production and operation of green development.

6. Limitations and Directions for Future Research

The limitations of this study are mainly reflected in the following three aspects. First, we discuss the mediating role of dynamic capabilities between AI orientation and green innovation. However, the mechanism of AI orientation on green innovation is complex and may be influenced by external factors such as market fluctuations and policy factors. In the future, attempts can be made to explore the influence path between AI orientation and innovation variables from multiple perspectives. Secondly, we conduct empirical analysis based on manufacturing enterprises, and whether the conclusions apply to other industries needs further demonstration. Finally, due to the limited time, the sample size of this paper is not large enough to ensure the stability of the model results, and the sample size can be increased in future studies.

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