Original Research Article

Research on the Influence Mechanism of Artificial Intelligence Application on Corporate Green Innovation

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Abstract: This paper explores the influence mechanism of artificial intelligence application on corporate green innovation with a sample of A-share listed companies in Shanghai and Shenzhen from 2010 to 2023. It is found that artificial intelligence application is significantly positively related to corporate green innovation. After robustness tests such as replacing core variables, excluding new crown epidemics, and excluding green innovation outliers, the finding remains unchanged, indicating that AI application significantly promote corporate green innovation. Further analysis reveals that the promotion effect of AI application on corporate green innovation is more obvious in high management shareholding ratio and non-heavily polluted enterprises, while it does not show a significant difference in the nature of ownership and industry attributes. The findings of this paper not only enrich the existing literature on AI application, but also provide empirical evidence on how governments can promote corporate green innovation.

Keywords: Artificial Intelligence Application, Corporate Green Innovation, Management Shareholding Ratio, Heavily Polluted Enterprises.

1. INTRODUCTION

Green innovation, as an important way to reduce carbon emissions and improve the efficiency of resource utilization, has become a crucial issue in the strategy of realizing green, low-carbon and sustainable development, and is a powerful hand in maintaining the unity of ecological and socio-economic benefits, which is related to China's ecological and environmental governance. Compared with traditional means of innovation, green innovation has a higher level of capital investment, a stricter risk assessment system, a longer innovation cycle and positive externalities similar to those of public goods (Chen, 2008). Because the costs of green innovation for firms are greater than the benefits, which, to a certain extent, firms worry about to carry out green innovation.

At this stage, artificial intelligence technology is booming globally, leading the scientific and technological revolution and industrial change, while promoting the development of new quality productivity. Firms can reduce their labor costs and production expenses to a great extent by replacing human operations with industrial robots, and can improve the accuracy of their production activities. Industrial robotics application, as a carrier of artificial intelligence technology and enterprise integration development, can optimize the production process, improve the efficiency of green innovation and become a set of manufacturing technology innovation. Automation control capability is the key for industrial robots to boost manufacturing firms to carry out green innovation and realize clean production. Based on this, this paper explores whether applying AI technology to firms can promote them to carry out green innovation, so that we can provide suggestions for firms to enhance the level of green innovation.

2. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

The application of artificial intelligence has the characteristics of technology bias, which can empower the production and operation activities of enterprises, and then affect the corporate green innovation.

First of all, AI application can realize green innovation by improving firm production efficiency. Firms will put intelligent equipment into all aspects of production, not only to achieve 24-hour full-cycle visualization, automation and intelligent production management, but also to reduce the use of low-skilled labor, to achieve a long time procedural work, low maintenance costs and low error rate of intelligent manufacturing, improve productivity. The higher the productivity is, the more it will help to alleviate the constraints of financing is, which in turn will provide financial support for the green R & D process innovation (Zhao *et al.*, 2021).

Secondly, AI application can also realize green innovation by eliminating information asymmetry for R&D personnel. Information redundancy will lead to information devaluation, and information scarcity will lead to insufficient power for green innovation. Artificial intelligence application can not only break the spatial and temporal limitations of information collection and transmission, realize the timeliness and accuracy of the information transmission of green R&D personnel, and make up for the information asymmetry gap, but also enhance the matching of information between demand and supply, and effectively reduce the interception of information in the horizontal transmission and the distortion of information in the vertical transmission (Kong *et al.*, 2022). The more efficient the information access of green R&D personnel is, the more it helps to promote faster access to key information about green innovations is, which in turn initiates innovations such as green processes.

Finally, AI application can also achieve green innovation by enhancing competitive advantage and decision optimization. Industrial robots are catalysts and endogenous drivers of product innovation, which can bring competitive advantage to enterprises and promote the emergence of innovations by leveraging the effectiveness of internal control, and also promote green innovation by expanding and optimizing human information processing capabilities and improving decision-making quality (Tan *et al.*, 2019). In addition, AI application can also have an impact on the green innovation of manufacturing enterprises through the channels of cost savings, knowledge spillover and human capital. Based on the above analysis, the following hypotheses are proposed.

H1: Artificial Intelligence application have a positive contribution to corporate green innovation

3. DATA SELECTION AND STUDY DESIGN
3.1 Data Sources
In this paper, we use 2010-2023 as the initial data sample and also do the following treatments to the data. ①we exclude the samples with missing data values. ②we exclude ST, *ST and delisted companies. ③1% Windsor shrinkage technique is applied to all continuous variables. After the above treatments, 37259 observations were finally obtained. All data in this article comes from the China CSMAR database.

3.2 Study Design
The following econometric model is constructed to test the impact of AI application on corporate green innovation.

$$Green_{jit} = \alpha_0 + \alpha_1 \times AI_{jit} + \alpha \times Controls + Firm + Year + \mu \quad （1）$$

Where, Green denotes corporate green innovation. Corporate green innovation is measured by the sum of the number of green invention patents and utility model patents filed by enterprises (Huang *et al.*, 2023; Hao *et al.*, 2024). AI denotes artificial intelligence application explanatory variables. In this paper, we use the frequency of words related to AI application in the annual reports of enterprises as a measure, such as the frequency of words such as automation, mechanization, intelligence, and machine and so on. Controls denotes some columns of control variables. Referring to the existing literature (Xu *et al.*, 2023; Zhao and Qian, 2024), this paper controls for firm size (SIZE), liability ratio (LIA), proportion of independent directors (IND), cash ability (CASH), two jobs in one (TWO), board size (BOARD), management cost ratio (MCR) and Tobin's Q value (TOBIN). α is the coefficient to be estimated; u is the random disturbance term. Firm and year are individual and annual dummy variables, respectively.

Table 1: Type, name, symbol and definition of related variables

Variable Type	Variable Name	Variable Symbol	Variable Definition
Dependent variable	Corporate green innovation	Green	The sum of the number of green invention patents and utility model patents
Independent variable	Artificial intelligence application	AI	The frequency of words related to AI application in the annual reports
Control variables	Firm size	SIZE	Natural logarithm of firm asset
	Liability ratio	LIA	Firm liability divided by firm asset
	Proportion of independent directors	IND	Number of independent directors divided by total board size
	Cash ability	CASH	Firm net cash flow from operations divided by assets

Variable Type	Variable Name	Variable Symbol	Variable Definition
	Two jobs in one	TWO	If the chairman and general manager are the same person, take the value 1, otherwise 0
	Board size	BOARD	Size of the Board of Directors
	Management cost ratio	MCR	Administrative expenses divided by operating income
	Tobin's Q value	TOBIN	Ratio of market value to replacement value of assets

4. ANALYSIS OF EMPIRICAL RESULTS

4.1 Descriptive Statistical Analysis

Table 2 presents the results of the descriptive statistical analysis of this paper. It can be seen that the average value of corporate green innovation is 1.3531 from the results, which initially indicates that China's listed companies are not high in corporate green innovation application, less than 2 items per firm. The maximum value of AI application is 34 and the minimum value is 0, indicating that there is still some variation in AI application among firms. The liability ratio mean is 0.4069, indicating that listed companies in China as a whole do not have large debts and have a low risk of bankruptcy. In addition, the mean value of the management cost ratio of 0.0848 also indicates that the agency problem between management and shareholders is not very serious in China.

Table 2: Results of descriptive statistical analysis

Variables	Number	Mean	SD	Min	P25	Median	P75	Max
GREEN	37259	1.3531	4.5584	0.0000	0.0000	0.0000	0.0000	33.000
AI	37259	1.5794	4.9243	0.0000	0.0000	0.0000	1.0000	34.000
SIZE	37259	22.141	1.2778	19.867	21.215	21.943	22.864	26.138
LIA	37259	0.4069	0.2053	0.0502	0.2395	0.3962	0.5584	0.8874
IND	37259	0.3752	0.0523	0.3333	0.3333	0.3529	0.4286	0.5714
CASH	37259	0.0474	0.0687	-0.1571	0.0090	0.0471	0.0879	0.2409
TWO	37259	0.3061	0.4609	0.0000	0.0000	0.0000	1.0000	1.0000
BOARD	37259	8.4624	1.6146	5.0000	7.0000	9.0000	9.0000	14.000
MCR	37259	0.0848	0.0659	0.0081	0.0418	0.0684	0.1067	0.3999
TOBIN	37259	2.0104	1.2567	0.8461	1.2493	1.6028	2.2799	8.2643

4.2 Multivariate Regression Analysis

Table 3 reports the multiple regression results of this paper. As can be seen from the results, the coefficient of AI application on corporate green innovation is significant at the 1% level of 0.0406 when no control variables are added, which initially indicates that AI application helps to enhance corporate green innovation. When control variables are added, the coefficient of AI application on corporate green innovation is still significant at 0.0353 at 1% level, indicating that AI application does help to promote corporate green innovation. The above results indicate that artificial intelligence application helps to enhance corporate green innovation.

Table 3: Results of multivariate regression analysis

Variables	GREEN (1)	GREEN (2)	GREEN (3)
AI	0.0406*** (8.2765)		0.0353*** (7.1335)
SIZE		0.2637*** (6.6341)	0.2393*** (6.0014)
LIA		0.0790 (0.5398)	0.0558 (0.3820)
IND		0.6414 (1.2482)	0.6916 (1.3468)
CASH		-0.4464* (-1.7096)	-0.4021 (-1.5403)
TWO		-0.0647 (-1.2883)	-0.0666 (-1.3267)
BOARD		-0.0136 (-0.6740)	-0.0123 (-0.6123)

Variables	GREEN (1)	GREEN (2)	GREEN (3)
MCR		-1.7854*** (-4.6722)	-1.6071*** (-4.1998)
TOBIN		0.0697*** (3.8888)	0.0688*** (3.8413)
Cons	1.2988*** (83.545)	-4.5859*** (-5.0214)	-4.1343*** (-4.5195)
Year fixed effect	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes
obs	36866	36866	36866
F value	68.50***	12.69***	16.95***
Adj R-squared	0.6782	0.6784	0.6789

Note: ***, **, * denote significant at the 1%, 5%, and 10% levels, respectively

4.3 Robustness Tests Analysis

In order to ensure that the findings of this paper are reliable and robust, the following four additional robustness tests are done in this paper. Firstly, we replace the core variable, replacing the total number of green innovation application with the total number of green innovations obtained. The results are Table 4(1). Secondly, we exclude the effect of the new crown epidemic, and adjust the sample interval to 2010-2019. The results of the regression are Table 4(2). Thirdly, we exclude the anomalous data that the number of green innovations is zero, which may be that the CSMAR has not counted the green innovations of the enterprises, and so it is measured by zero. The results for Table 4(3). Fourthly, we exclude the abnormal data of zero number of AI application, which may also be not counted by CSMAR, so it is measured by zero. The result is Table 4(4). The above results show that the coefficient of AI application on corporate green innovation is significantly positive at 1% level, indicating that the conclusion that AI application promotes corporate green innovation is robust and reliable.

Table 4: Results of robustness tests analysis

Variables	GREEN (1)	GREEN (2)	GREEN (3)	GREEN (4)
AI	0.0499*** (5.0320)	0.0379*** (5.5045)	0.0465*** (2.5821)	0.0262*** (3.2169)
SIZE	0.2728*** (3.4152)	0.1127** (2.1749)	0.8794*** (4.3684)	0.7661*** (5.3235)
LIA	0.0299 (0.1020)	0.2058 (1.1368)	-1.0170 (-1.2823)	-0.3148 (-0.6224)
IND	0.5225 (0.5079)	-0.2712 (-0.4353)	2.2608 (0.9975)	1.4841 (0.9559)
CASH	0.8603* (1.6451)	-0.1963 (-0.6398)	-2.5482** (-1.9868)	-0.7398 (-0.9770)
TWO	0.0645 (0.6410)	-0.0432 (-0.6818)	-0.2165 (-0.8953)	0.1669 (1.1775)
BOARD	-0.0228 (-0.5644)	-0.0051 (-0.2081)	-0.0361 (-0.4069)	-0.0799 (-1.2825)
MCR	-0.3179 (-0.4147)	-1.3457*** (-2.8980)	-4.0873* (-1.9347)	-1.1641 (-1.0780)
TOBIN	0.0296 (0.8239)	0.0481** (2.1351)	0.3201*** (3.4969)	0.0786 (1.5892)
Cons	-5.0328*** (-2.7461)	-1.2221 (-1.0355)	-13.822*** (-3.0068)	-14.791*** (-4.4856)
Year fixed effect	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
obs	36866	22833	7808	9024
F value	5.46***	6.70***	5.62***	6.19***
Adj R-squared	0.5654	0.6850	0.6241	0.7353

4.4 Analysis of the Differential Impact

Table 5 reports the results of the differential impact of AI application on corporate green innovation, where Table 5(1)-(2) shows the results of regressions on management shareholding, while Table 5(3)-(4) shows the results of regressions

on whether a firm is a heavy polluter or not. It can be seen that the impact of AI application on corporate green innovation is more strongly significant in high management shareholding than in low management shareholding from the results, indicating that higher management shareholding helps to strengthen the promotion of AI application on corporate green innovation. Meanwhile, we can also see that the impact of AI application on corporate green innovation is more strongly significant in non-heavily polluted firms compared to heavily polluted firms, indicating that the promotion of AI application on corporate green innovation is mainly reflected in non-heavily polluted firms.

Table 5: Results of the differential impact analysis

Variables	Management Shareholding Ratio		Whether heavy polluters	
	High MSR	**Low MSR**	**Non-heavily polluted**	**Heavily polluted**
	(1)	**(2)**	**(3)**	**(4)**
AI	0.0556***	0.0385**	0.0328***	0.0260
	(5.8214)	(2.0063)	(6.3069)	(0.7756)
SIZE	0.4791***	-0.1632**	0.3199***	0.1384*
	(4.3104)	(-2.0773)	(6.6786)	(1.7216)
LIA	0.6612*	0.0971	0.2384	-0.8179***
	(1.7253)	(0.3466)	(1.3486)	(-2.8940)
IND	0.2836	0.5838	0.1781	0.9478
	(0.2216)	(0.6194)	(0.2948)	(0.9571)
CASH	0.5845	-0.3272	-0.7435**	0.6480
	(1.0279)	(-0.6890)	(-2.4448)	(1.2649)
TWO	-0.1879*	0.0170	-0.0831	0.0109
	(-1.7190)	(0.1481)	(-1.4228)	(0.1098)
BOARD	-0.0470	-0.0534	-0.0491**	0.0311
	(-0.8451)	(-1.4149)	(-2.0372)	(0.8372)
MCR	-2.4249***	-1.6134**	-1.4726***	-0.9892
	(-2.6944)	(-2.2651)	(-3.4421)	(-0.9938)
TOBIN	0.0384	-0.0232	0.0653***	0.0612
	(0.9865)	(-0.6339)	(3.2113)	(1.5160)
Cons	-8.8242***	-5.2609***	-5.3784***	-2.3811
	(-3.5879)	(-2.8786)	(-4.9303)	(-1.2849)
Year fixed effect	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
obs	9014	8977	7808	8323
F value	9.81***	1.85***	5.62***	1.99***
Adj R-squared	0.6540	0.7240	0.6241	0.6494

4.5 Analysis of the Undifferentiated Impact

Table 6 reports the results of the undifferentiated impact of AI application on corporate green innovation, where Table 6(1)-(2) shows the results of regressions on whether state-owned firms or not, while Table 6(3)-(4) shows the results of regressions on whether manufacturing or not. As can be seen from the results, the coefficients of AI application on corporate green innovation are significantly positive regardless of state-owned enterprises or non-state-owned enterprises, indicating that the promotion effect of AI application on corporate green innovation has not shown significant differences in the nature of property rights. At the same time, the impact of AI application on corporate green innovation is also significantly positive in manufacturing and non-manufacturing industries, indicating that the promotion effect of AI application on corporate green innovation does not show significant differences in industry attributes.

Table 6: Results of the undifferentiated impact analysis

Variables	Whether state-owned firms or not		Whether manufacturing or not	
	State-owned	**Non-state-owned**	**Manufacturing**	**Non-manufacturing**
	(1)	(2)	(3)	(4)
AI	0.1016***	0.0141***	0.0502***	0.0334***
	(8.0530)	(2.6152)	(6.2613)	(5.6589)
SIZE	-0.1775**	0.4881***	0.4386***	0.0864
	(-2.3157)	(10.135)	(7.7627)	(1.4278)
LIA	0.6381**	-0.0478	-0.1861	0.0681
	(2.1662)	(-0.2742)	(-0.9309)	(0.3044)
IND	2.0340**	-0.5142	1.4090**	-0.8817
	(2.4300)	(-0.7717)	(2.0576)	(-1.1434)

Variables	Whether state-owned firms or not		Whether manufacturing or not	
	State-owned	Non-state-owned	Manufacturing	Non-manufacturing
	(1)	(2)	(3)	(4)
CASH	-0.3864	-0.3999	-0.5801	-0.1415
	(-0.8096)	(-1.2883)	(-1.6164)	(-0.3907)
TWO	0.0583	-0.1074*	-0.0827	-0.0481
	(0.5170)	(-1.9161)	(-1.2775)	(-0.6014)
BOARD	-0.0154	-0.0311	-0.0341	0.0322
	(-0.4712)	(-1.1718)	(-1.2528)	(1.0866)
MCR	-3.0416***	-0.7449*	-1.8739***	-1.5701***
	(-3.7885)	(-1.7007)	(-3.1987)	(-3.2441)
TOBIN	0.0538	0.1006***	0.0765***	0.0295
	(1.3538)	(5.0070)	(3.3617)	(0.9923)
Cons	4.8261***	-9.0738***	-8.3066***	-0.8488
	(2.7258)	(-8.2259)	(-6.4567)	(-0.6056)
Year fixed effect	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
obs	12174	24630	24757	12072
F value	10.53***	16.79***	17.14***	6.90***
Adj R-squared	0.7383	0.6427	0.6780	0.6862

5. CONCLUSIONS AND IMPLICATIONS

Nowadays, artificial intelligence technology is integrated into all operational aspects of manufacturing activities such as production and management, which has a significant impact on corporate green innovation. Empirical studies have found that there is a significant positive relationship between AI application on corporate green innovation. Heterogeneity indicates that the promotion effect of AI application on corporate green innovation is more obvious in the high management shareholding ratio and non-heavily polluting enterprise group, while there is no difference in the nature of property rights and industry attributes.

Based on the above conclusions, the following points are proposed. We should not only pay attention to the absorption and utilization of new knowledge and technology, improve the level of human capital, optimize the structure of the workforce, introduce high-level talents, quickly master the cutting-edge knowledge and technology, and then realize the transformation of green results and innovation output at a higher level, but also recognize the strategic importance of improving the level of green innovation for its sustainable development, and integrate the concept of green development into the innovation of green processes and green product innovation for the sake of long-term interests. It should also recognize the strategic importance of improving the level of green innovation for its sustainable development, and integrate the concept of green development into green process innovation and green product innovation in the long-term interest, continuously improve the production process and product quality. Meanwhile, it is also necessary to incorporate the fulfillment of environmental responsibility and green innovation into the corporate culture, to comply with the green development concept in the new era of the country, to establish a good corporate image and reputation, and to increase the trust of the relevant social stakeholders.

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