WEP Warwick Evans Publishing

Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 8
EMEHSS 2024

A Study on the Influence Effect of Digital Investment on the Environmental Performance of Listed Companies

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Abstract: With the rapid development of the digital economy and the continuous promotion of the green development strategy, whether the digital investment of enterprises can enhance their environmental performance has become an urgent issue to be explored. Taking A-share listed companies in China from 2017 to 2022 as a sample, this paper empirically analyzes the effects of digital investment on corporate environmental performance and the heterogeneity characteristics, and tests the mediating roles of agency costs and green technology innovation. It is found that digital investment can significantly enhance the environmental performance of listed companies, and the results of robustness test show that this conclusion still holds. In terms of the mechanism of action, digital investment will enhance the environmental performance of listed companies by reducing agency costs and promoting corporate green technology innovation. Heterogeneity analysis shows that digital investment can significantly improve the environmental performance of non-state-owned enterprises and non-heavily polluted enterprises. The conclusion enriches the research related to digital investment and corporate environmental performance, and also provides some references on how to improve the environmental performance of listed companies.

Keywords: Digital investment; environmental performance; agency costs; green technology innovation

1. Introduction

In recent years, environmental problems have become increasingly serious, with a series of negative impacts on human production and life, even to the point of threatening the survival of human beings, triggering widespread concern in countries around the world, and the relationship between human beings and the environment has become one of the most important issues facing the world. In the face of this historical situation, the Communist Party of China (CPC) has actively changed its governing philosophy, leading the Chinese people to implement the requirements of green development, and listed green as one of the five major development concepts in 2015, and pointed out in the report of the Twentieth National Congress that it "promotes green development, and facilitates the harmonious coexistence of human beings and the nature," and that "it is necessary to speed up the green transformation of development methods, and develop green low-carbon development". Green development is an inevitable requirement for the realization of sustainable development and high-quality development, and it is also a concrete embodiment of China's efforts to build a community of human destiny.

As the main body of market economic activities, the green transformation of enterprises is of great significance to the overall green development of the national economy. In recent years, the rapid development of digital technology and digital knowledge, as well as the wide application of modern information networks, have pressed the "accelerator button" for the green development of enterprises and provided new opportunities for the realization of the "dual-carbon" goal. In the literature, existing theoretical studies have proved that digitalization has a double effect of "increasing quantity and improving quality" on the green innovation performance of enterprises (Hao XING and Weijie TAN, 2022). Affirming the existence of a certain promotion effect of digital transformation on the green development of enterprises, it can be inferred that there is a certain positive impact on the environmental performance of enterprises. The results of Fu et al. (2023) show that digital investment

in manufacturing enterprises has a significant positive impact on breakthrough innovation, affirming the role of digital investment in manufacturing enterprises on the promotion of innovation.The research of Ye et al. (2023) and others proved that digital investment can improve environmental performance. Domestic academics have paid little attention to the research on the relationship between digital investment and corporate environmental performance, but digital investment has a direct impact on the development of digital talents and the investment in digital hardware and software equipment, which occupies an important position in the digital development and transformation of enterprises, and therefore may have a more obvious impact on corporate environmental performance. Whether digital investment improves the environmental performance of listed companies has become a question worthy of in-depth exploration.

Current research on the influence mechanism of digitalization on enterprise green development and innovation mainly focuses on the degree of information asymmetry, resource organization and synergism (Wang Haifeng and Han Gang, 2024), executive cognitive ability (Huang Weijuan and Li Shangpu, 2023), governmental attention (Song Jing et al., 2023), and enterprise Accelerating digital development can alleviate the degree of information asymmetry and ease financing constraints, and the massive application of digital products and technologies can effectively enhance resource organization and synergy, empowering enterprises to develop greenly and thus improve environmental performance, while also being affected by the cognitive ability of executives, government attention, and media supervision. Scholars at home and abroad have explored the relationship between digital transformation and enterprise development, as well as its impact on enterprise environmental performance from various angles, and the mechanism level has formed a number of perspectives, including information asymmetry, financing constraints, resource organization and synergistic, executive cognitive ability, government attention, media supervision, etc. The relevant theoretical results in the academic community have been relatively rich, but the relationship between digital investment and enterprise environmental performance has rarely been discussed. However, the relationship between digital investment and corporate environmental performance has rarely been discussed.

On the basis of existing theories, this paper will analyze the relationship between enterprise digital investment and environmental performance, and then explore the specific mechanism of its role in environmental performance, respectively, from the agency cost and green technological innovation to specifically analyze the path of digital investment affecting the environmental performance of enterprises, in order to provide a richer perspective and channel for the understanding of the relationship between digital investment and enterprise environmental performance. Subsequently, this paper will analyze the heterogeneity of digital investment on enterprise environmental performance from the perspective of property rights and enterprise nature, and examine the differentiated impacts of digital investment on environmental performance between state-owned and non-state-owned enterprises, as well as between heavily polluted and non-heavily polluted enterprises.

The possible marginal contributions of this paper are mainly in the following aspects: firstly, it discusses the relationship between digital investment and environmental performance of listed companies, theoretically explains how digital investment of listed companies affects environmental performance, and pays more attention to the digital investment carried out by companies. The second is to reveal the internal mechanism of digital investment affecting the environmental performance of listed companies, with the help of empirical models to clarify the path role of total asset turnover and green technology innovation of listed companies on the impact of digital investment on environmental performance; the third is to test the heterogeneity of the results of listed companies' environmental performance and explore the property rights and industry differences of digital investment on environmental performance.

2. Theoretical analysis and research hypotheses

2.1. Relationship between digital investment and environmental performance of listed companies

The concept of digital investment was presented in early theoretical studies in the form of spending on information and computing applications. Findings on the "productivity paradox" of information systems suggest that information system expenditures make a significant and meaningful contribution to firm output (Brynjolfsson and Hitt, 1996). Liu, L. and Ouyang, J. (1999) affirmed that the large-scale popularization of digital computing technology and network information technology has greatly contributed to the rapid development of e-commerce, online marketing, e-money and e-finance markets. Li Kedong (2001) pointed out that the key to digital learning is to use information technology as a cognitive tool for learning.

Research on environmental performance, especially on the construction of environmental performance assessment system, has been rich in theories. Meng Fanli (1999), in his discussion of environmental accounting information disclosure, proposed that the environmental performance of enterprises should reflect the implementation of environmental regulations, environmental quality, and environmental governance and utilization of pollutants. Yang, Dongning and Zhou, Changhui (2004) pointed out that an environmental performance assessment system based on the organizational capabilities of enterprises can create a continuous incentive for enterprises to improve their environmental performance. Hu Quying (2012) showed that active and effective preventive environmental management can lead to a win-win situation in terms of environmental and financial performance.

With regard to the relationship between digital investment and environmental performance, Xu et al. (2022) conducted a study from the perspective of digital investment, and the results show that ICT capital helps to improve carbon emission efficiency, pure technical efficiency, scale efficiency and technological progress, and has spatial spillover effects on the surrounding areas, among which ICT communication capital has the strongest impact on improving carbon emission efficiency. Information technology as an important part of enterprise digital investment can improve carbon emission efficiency, and carbon emission efficiency improvement can effectively improve the environmental performance of enterprises, so there may be a certain positive impact between digital investment and enterprise environmental performance. As for the impact mechanism of digital investment on corporate environmental performance, relevant studies are still relatively limited, and some theories suggest that technological innovation is an important intermediary channel for digital investment to promote corporate environmental performance, and that the degree of executive home country identification positively regulates the relationship between technological innovation and corporate environmental performance (Jin et al., 2023).Ye et al.'s (2023) study of some heavily polluted enterprises in China suggests that digital investment can improve corporate environmental performance. The results of Ye et al.'s (2023) study of selected heavily polluting firms in China suggest that digital investment can improve environmental performance, with both productivity and green innovation playing a mediating role.

Digital investment from within the enterprise can integrate human and financial resources, on the one hand, with the help of digital information technology and tools, organizational collaboration to reduce costs and improve the efficiency of investment decision-making; on the other hand, the gathering of digital knowledge of talent, strengthen the green innovation ability of enterprises, thereby improving productivity, pollution control and emission reduction efficiency, listed companies, by virtue of its relatively strong human and financial resources, to strengthen the digital investment, and ultimately is expected to achieve the improvement of environmental performance. performance improvement. Based on the existing research results and the above theoretical analysis, this paper proposes hypothesis H1.

H1: Digital investment can significantly improve the environmental performance of listed companies.

2.2. Intermediation effects of agency costs

Digital investment can strengthen the communication and practice between enterprise departments and personnel, alleviate the agency problems that may exist within the enterprise, reduce the agency cost, and improve the efficiency of decision-making and supervision. The research of Song Deyong et al. (2022) found that enterprise digitization mainly promotes enterprise green technology innovation by enhancing the level of information sharing and knowledge integration ability of enterprises. With the help of digital information network platform, shareholders, directors, partners and other relevant stakeholders can realize rapid information interaction, understand the management decision-making information, follow up the progress of investment projects, strengthen the supervision to improve the efficiency of investment decision-making, and promote the enhancement of corporate environmental performance. Digital transformation promotes corporate green innovation by alleviating financing constraints, weakening agency conflicts, and enhancing growth capabilities (Jin Yu et al., 2022). On the one hand, digital investment makes information transmission speed more rapid, improves the possibility of real-time supervision by the principal, and strict supervision of the agent weakens the traditional agency conflict and reduces the agency cost. On the other hand, with the help of digital technology, analyzing and mining data, obtaining effective information, simulating and predicting decision-making, multiple consideration of the benefits and risks brought by various investment options, reducing inefficient and ineffective investment in the process of green development of enterprises, and enhancing the efficiency of green investment, which in turn promotes the improvement of environmental performance. Accordingly, this paper proposes hypothesis H2.

H2: Digital investment can reduce agency costs and improve the environmental performance of listed companies.

2.3. Mediating effects of green technology innovation

The research results of Zhang Zhaoguo et al. (2020) and Zhang Hanyu et al. (2023) show that the application of digital technology significantly improves the overall environmental performance of enterprises, and corporate technological innovation is significantly positively correlated with environmental performance. The study of Qu Yuxiao (2023) points out that digital inclusive finance can enhance the level of green technology innovation and thus improve the environmental performance of enterprises. The study of Li Wanhong and Li Na (2023) found that green technology innovation has a significant role in promoting the environmental performance of manufacturing enterprises. Liu et al. (2024) found that digital transformation is conducive to the improvement of green technology innovation, and Gao, Zhilin and Tan, Wenhao (2024) found that the digital transformation of enterprises significantly improved their green technology innovation level, and it is more significant in state-owned enterprises and large enterprises. Digital investment improves the digitalization level of enterprises from both software and hardware levels, thus improving their technological innovation environment, and high-quality hardware and software conditions can promote enterprises to better carry out green technological innovation. When Ma and Zhang (2024) used the double-difference method to investigate the impact of low-carbon policy pilots on corporate environmental performance, they found that green technological innovation plays a part of the mediating effect. According to the existing theoretical results, enterprises increase the green invention and utility model innovation, enhance the green innovation ability, and promote the green development of production and service, which can help enterprises reduce energy consumption and pollution, and then improve the level of environmental performance. Accordingly, this paper proposes hypothesis H3.

H3: Digital investment can promote green technology innovation and improve the environmental performance of listed companies.

3. Research design

3.1 Sample selection and data sources

This paper takes the data of A-share listed companies from 2017-2022 as the initial sample, and refers to the established studies for processing, excluding financial industries, samples of ST* , ST and samples with missing main variables. Finally, 7033 observations are obtained. Considering the effect of extreme values, all continuous variables are subjected to the shrinking of upper and lower 1%. Except for the data of green invention and utility model patents, which are from CNRDS database, the other data are from CSMAR database.

3.2 Definition of variables

3.3.1 Explained variables

Environmental Performance (Ep):This paper refers to the study of Qu Yuxiao (2023) and adopts a comprehensive scoring method to construct the environmental performance (Ep) indicators of listed companies, which mainly include (1) environmental protection concept; (2) environmental protection objectives; (3) environmental protection management system; (4) environmental protection education and training; (5) special behaviors for environmental protection; (6) emergency response mechanism for environmental incidents; (7) "three simultaneous" system; (8) honors or awards for environmental protection; (9) whether it has passed ISO14001 certification. One point is awarded for satisfying one item and 0 point for not satisfying it, with the final summed score as a proxy variable for environmental performance.

3.3.2 Explanatory variables

Digital investment (Aggi): this paper draws on the research methods of Lou Runping (2023) and Fu Guohua et al. (2023), and divides digital investment into software digital investment and hardware digital investment. Among them, hardware digital investment mainly includes inputs about electronic equipment and computer office equipment in fixed assets, and software digital investment mainly includes inputs about information systems and software in intangible assets. This paper sums the two parts of the data and then goes to the natural logarithm, denoted as Aggi as a measure of digital investment.

3.3.3 Mediating variables

Agency cost (Toct):This paper is based on Chen Xiaohui et al. (2022) and Tian Jie et al. (2023), the higher the asset turnover rate the lower the agency cost, so the ratio of operating income to total assets is used to calculate the asset turnover rate, which is denoted as Totc to measure the agency cost of listed companies, and the larger the value represents the lower the agency cost.

Green technological innovation (Gre): Drawing on the studies of Zhang Zhaoguo et al. (2020) and Liu Zhiming et al. (2024), the number of green inventions and the number of green utility models applied for are used to measure the level of green technological innovation of listed companies, and the sum of the two is added to 1 to take the natural logarithm, in order to eliminate the problem of the right-skewed distribution of the green patent data, and the bigger the value indicates that the level of green technological innovation is higher.

3.3.4 Control variables

Referring to the existing literature, this paper selects a series of factors that may have an impact on the environmental performance of listed companies as the control variables in this paper, including: total assets taking the natural logarithm (TotalA), the proportion of shares held by the top ten shareholders (TopR), the gearing ratio (Alr), the net profit margin of the total assets (Roa), the size

of the board of directors (Nod), and the age of the enterprise (Enta). Specific variables are defined as shown in Table 1.

Table 1 Variable Definition Table

Variable type	variable symbol	variable name	calculation method
explanatory variable	Ep	Environmental performance	Environmental performance score
explanatory variable	Aggi	Digital Investments	Inputs related to electronic equipment and computerized office equipment in fixed assets and information systems and software in intangible assets, summed over natural logarithms
intermediary variable	Toct	agency cost	Asset turnover ratio
	Gre	Green Technology Innovation	Green Patent Applications
control variable	TotalA	Enterprise size	Logarithmic value of total assets of listed companies
	TopR	shareholding concentration	Sum of shareholdings of the top ten shareholders of the Company
	Alr	gearing	Total liabilities/total assets
	Roa	Net profit margin on total assets	Net profit/total assets
	Nod	Board size	Total number of directors
	Enta	Age of business	Founding Years

3.3 Modeling

In order to test the effect of digital investment (Aggi) on the environmental performance (Ep) of listed companies, the following model is constructed:

$$Ep_{it} = \alpha_0 + \alpha_1 Aggi_{it} + \alpha_2 Controls_{it} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (1)$$

where $Control_{it}$ denotes the set of other control variables affecting Ep, μ_i denotes industry fixed effects υ_t denotes time fixed effects, and ε_{it} denotes the random perturbation term.

In order to investigate the mediating effect played by agency cost (Totc) and green technology innovation (Gre) in the relationship between digital investment and environmental performance of listed companies, the following model is constructed, with M replacing the mediating variable:

$$M_{it} = m_0 + m_1 Aggi_{it} + m_2 Controls_{it} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (2)$$

$$Ep_{it} = \beta_0 + \beta_1 Aggi_{it} + \beta_2 M_{it} + \beta_3 Controls_{it} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (3)$$

The specific steps are: in (1) if the estimated coefficient of digital investment Aggi α_1 is significantly positive, it indicates that digital investment has a significant role in promoting the environmental performance Ep of listed companies, based on this, regression is carried out on (2) and (3), if the

estimated coefficient m_1 in (2) and the estimated coefficient β_2 in (3) are significant at the same time and in line with the economic significance, it is proved that the digital investment with the help of the agency cost and green technology innovation, it proves that digital investment affects the environmental performance of listed companies through the mediating factors of agency cost and green technology innovation.

4. Analysis of empirical results

4.1 Descriptive statistics and analysis

Table 2 shows the results of descriptive statistics for the main variables. The mean value of environmental performance Ep is 2.14 with a standard deviation of 2.12, and the mean value of digital investment Aggiw is 17.894 with a standard deviation of 1.62. This indicates that there is a large variation in environmental performance scores between firms, and there is also a significant difference in the activities of carrying out digital investment.

Table 2 Table of descriptive statistics

variable name	sample size	average value	(statistics) standard deviation	minimum value	upper quartile	maximum values
Ep	7033	2.140	2.120	0	2	9
Aggiw	7033	17.894	1.620	14.213	17.806	21.990
TotalAw	7033	22.319	1.220	20.036	22.172	25.997
TopRw	7033	59.520	15.320	24.310	60.090	93.580
Alrw	7033	0.410	0.190	0.060	0.406	0.866
Roaw	7033	0.040	0.075	-0.317	0.043	0.237
Nodw	7033	8.230	1.640	0	9	17
Entaw	7033	19.891	5.796	7.580	19.580	35

4.2 Baseline regression results

The regression results in Table 3 show the relationship between digital investment of listed companies and their environmental performance. As shown in column (1) of the table, the regression coefficient of digital investment Aggiw is 0.441, and it is significant at 1% statistical level, which indicates that digital investment can significantly enhance the environmental performance of listed companies, proving Hypothesis H1.As shown in column (2), after adding a series of control variables, the regression coefficient of digital investment Aggiw becomes 0.102, and it is still significant, proving that if the effect of control variables is not taken into account, it will exaggerate the promotion effect of digital investment on the environmental performance of listed companies.

Table 3 Benchmark regression

	(1)	(2)
	Ep	Ep
Aggiw	0.441***	0.102***
	(0.014)	(0.020)
_cons	-7.187***	-16.517***
	(0.537)	(0.647)
Controls	No	Yes
Year	Yes	Yes
Id	Yes	Yes
N	7033	7033
R^2	0.275	0.339
adj. R^2	0.268	0.332

Note: *, **, and *** indicate significant at the 1%, 5%, and 10% levels, respectively, with robust standard errors in parentheses.

4.3 Mechanism testing and analysis

In order to investigate that digital investment can enhance the environmental performance of listed companies through agency costs and green technology innovation, a joint test of the role of mechanisms is conducted using equations (2) and (3) above, and the results are shown in Table 6, which are shown in Columns (3) and (5), and the coefficients of digital investment (Aggiw) are 0.0953 and 0.0971, respectively, and are significant at 1% level, indicating that the digital investment has a direct impact on the environmental performance has a direct impact. The coefficients of total asset turnover (Totcw) and green technology innovation (Grew) are 0.0000295 and 0.0159 respectively and are significant at 5% and 1% levels, indicating that the lower the agency cost and the higher the level of green technology innovation, the stronger the effect of digitalization investment on environmental performance. As can be seen from columns (2) and (4), the coefficients of the impact of digital investment on total asset turnover and green technology innovation level are both positive and significant at the 1% level, indicating that digital investment can reduce agency costs and enhance the level of green technology innovation. In summary, digital investment of listed companies can improve the environmental performance of listed companies by reducing agency costs and improving the level of green technology innovation, proving hypothesis H2 and hypothesis H3.

Table 4 Mechanism tests

	(1)	(2)	(3)	(4)	(5)
	Ep	Totcw	Ep	Grew.	Ep
Aggiw	0.102***	243.572***	0.095***	0.034***	0.097***
	(0.020)	(18.849)	(0.020)	(0.009)	(0.020)
Totcw			0.0000295**		
			(0.0000128)		
Grew.					0.159***
					(0.026)
_cons	-16.517***	5907.353***	-16.692***	-4.177***	-15.853***
	(0.647)	(607.320)	(0.651)	(0.297)	(0.654)
Controls	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Id	Yes	Yes	Yes	Yes	Yes
N	7033	7033	7033	7033	7033
R^2	0.339	0.358	0.339	0.211	0.342
adj. R^2	0.332	0.351	0.332	0.202	0.335

4.4 Robustness tests

4.4.1 Endogenous treatment

Considering the possible sample self-selection problem in the research process, it is possible that enterprises in some specific industries (e.g., the information technology industry) are more inclined to make digital investments, coupled with the fact that these enterprises themselves emit relatively fewer pollutants, the cost of green development is lower compared to enterprises in other industries, and therefore their environmental performance may be relatively better, which may generate a certain degree of bias in the research results. This paper adopts the Heckman two-stage model to deal with this kind of endogeneity problem. In the first stage, the 0~1 variable Ep1 is generated to measure whether enterprises have taken measures to carry out environmental management, and the Probit model is used to regress it to calculate the Inverse Mills Ratio (IMR); in the second stage, the IMR is substituted into the original model to carry out the regression analysis, and the results of the test are shown in Table 4. The results show that the Inverse Mills Ratio is significant at the level of 1%, which indicates that there is a sample selection bias problem in the original model. bias problem. Meanwhile, the results of the second stage of estimation after adding IMR show that the coefficient of the impact of digital investment on the environmental performance of listed companies is still significant and positive at the 1% level, indicating that the result that the digital investment of listed companies can significantly improve environmental performance is robust.

Table 5 Endophytic treatments

	(1)	(2)
	Ep1	Ep
Aggiw		0.135***
		(0.024)
IMR		1.558***
		(0.361)
_cons	-6.343***	-19.494***
	(0.669)	(1.291)
Controls	Yes	Yes
N	6906	4954
R^2		0.290
adj. R^2		0.279

4.4.2 Substitution of explanatory variables

In order to further verify the robustness of the empirical analysis results, referring to the research methodology of Qu Yuxiao (2023), the environmental performance (Epi) is re-measured from the perspective of environmental protection and comprehensive management, which consists of the following: emission reduction and treatment of exhaust gases, emission reduction and treatment of wastewater, treatment of dust and soot, utilization and disposal of solid wastes, treatment of noise, light pollution, radiation, etc. and the implementation of cleaner production, with a total of six aspects. According to the data of CSMAR, the disclosure degree of each item (no description, qualitative or quantitative) was assigned a score of 0, 1, or 2, respectively, and finally the environmental performance (Epi) was obtained to replace the original explanatory variables, which was substituted into the model for regression analysis. The results are shown in Table 5.The results show that the regression coefficients of digitization investment are still significantly positive at the 1% level after

replacing the measurement of the explanatory variables, which is not significantly different from the previous findings, indicating that the conclusions are more robust.

Table 6 Replacement of explanatory variables

	(1)	(2)
	Ep	Epi
Aggiw	0.102***	0.098***
	(0.020)	(0.027)
_cons	-16.517***	-11.889***
	(0.647)	(0.884)
Controls	Yes	Yes
Year	Yes	Yes
Id	Yes	Yes
N	7033	7033
R^2	0.339	0.202
adj. R^2	0.332	0.194

4.5 Heterogeneity analysis

The above results suggest that digital investment can enhance the environmental performance of listed companies, but does this enhancement effect vary depending on the ownership of the enterprise and the industry it belongs to? To this end, this paper will explore the effect of digital investment on the environmental performance of enterprises in different contexts in terms of the nature of their property rights and whether the industry they belong to is a heavy polluting industry.

4.5.1 Heterogeneity of property rights

The full sample is divided into SOEs and non-SOEs and regressed again to test the effect of property rights heterogeneity of digital investment on environmental performance. Columns (1) and (2) in Table 7 show the results of the heterogeneity test for different property rights properties, and it can be seen that the coefficients of both state-owned enterprises and non-state-owned enterprises are positive, but the coefficients of the impact of non-state-owned enterprises are larger and more significant. The possible reasons are: on the one hand, the nature of digital investment belongs to investment behavior, and non-state-owned enterprises are more risk-averse compared to state-owned enterprises and are more inclined to make digital investments. On the other hand, it may be due to the fact that state-owned enterprises have easier access to the relevant resource elements of environmental protection and environmental governance, as well as tax incentives from government departments, which may have weakened the promotion effect of digital investment on environmental performance to a certain extent; whereas non-state-owned enterprises have their own constraints such as lack of elements, financing constraints and other limiting factors, coupled with the increasingly stringent governmental environmental protection standards, and need to seek ways to break through a series of energy saving, emission reduction and pollution prevention difficulties, and therefore are more inclined to make digital investment. In addition, non-state-owned enterprises have constraints such as lack of factors and financing constraints, coupled with increasingly stringent government environmental standards, and need to find ways to break through a series of energy saving and pollution prevention and control dilemmas, and therefore are more likely to carry out digital investment, which is more obvious in the impact of the effect, and the coefficient of the between-

groups test further verifies that the digital investment in the non-state-owned enterprises has a more obvious role in the improvement of environmental performance.

4.5.2 Industry heterogeneity

The sample enterprises are categorized into heavy polluters and non-heavy polluters according to the "List of Listed Companies for Environmental Protection Verification Industry Classification and Management" published in 2008, and the results of columns (3) and (4) in Table 7 show that the impact coefficients of enterprises in non-heavy polluters industries are larger and more significant. The results indicate that digital investment is more significant in enhancing environmental performance in non-heavily polluting firms, and the between-groups coefficient test shows that this result is significant at the 10 percent level. This may be due to the fact that non-heavily polluting firms have more innate green attributes and less pressure to carry out environmentally friendly production and operation compared to heavily polluting firms (Haifeng Wang and Gang Han, 2024). Digital investment is from software and hardware facilities to improve the digitalization level of enterprises, but it cannot fundamentally change the attributes of heavy polluters, so the effect of digital investment on environmental performance of this type of enterprises is not obvious.

Table 7 Heterogeneity analysis

	(1) nationalized business	(2) non-state enterprise	(3) Heavily polluting enterprises	(4) Non-heavily polluting enterprises
	Ep	Ep	Ep	Ep
Aggiw	0.053	0.104***	0.054	0.120***
	(0.045)	(0.023)	(0.043)	(0.023)
_cons	-15.441***	-15.499***	-14.454***	-16.635***
	(1.178)	(0.860)	(1.343)	(0.669)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Id	Yes	Yes	Yes	Yes
N	1626	5407	1658	5375
R^2	0.370	0.330	0.254	0.324
adj. R^2	0.344	0.321	0.242	0.316
Chow Test	7.20		3.55	
P-Value	0.0000		0.0594	

5. Research findings and policy recommendations

With the data of A-share listed companies from 2017 to 2022, this paper analyzes the impact of enterprises' digital investment on their environmental performance, and explores the internal mechanism in depth, and draws the following conclusions: digital investment can significantly enhance the environmental performance of listed companies, and this conclusion still holds after the endogeneity and robustness tests; the mechanism test concludes that digital The mechanism test concludes that digital investment can enhance environmental performance by reducing corporate agency costs and promoting corporate green technology innovation; the results of the heterogeneity

test show that the enhancement effect of digital investment on environmental performance is more obvious in non-state-owned enterprises and non-heavily polluted enterprises.

Based on the findings of this paper, the following policy recommendations are put forward: First, enterprises should increase their digitalization investment, update their hardware and software facilities in a timely manner, and improve their digitalization level so as to enhance their environmental performance. At the same time, the government should increase policy support and guidance to encourage enterprises to actively invest in the field of digital information, etc., to achieve the improvement of the digitalization level of each market entity. Secondly, with the help of digital production and operation, to help enterprises to improve operating income at the same time, to promote the improvement of asset turnover, through information sharing and real-time supervision, to reduce agency costs, and to promote the green environmental projects on the ground. At the same time, enterprises should make good use of digital hardware and software facilities to increase green technological innovation and promote the improvement of environmental performance. Third, the government needs to fully consider the differences in enterprise property rights and industry attributes, and formulate differentiated policies for state-owned enterprises and heavily polluting enterprises to achieve precise support.

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