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Empirical research on the influence of corporate digitalization on green innovation

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The link between corporate digitization and green innovation is now receiving attention from all spheres of life in light of the rapidly developing digital economy and the goal of sustainable development. This study explores how corporate digitalization affects green innovation, its mediating mechanism, and moderating effects by integrating resource-based theory, attention-based view, and institutional theory. We utilize the panel data of Chinese Shanghai and Shenzhen A-share manufacturing corporation data from 2011 to 2020 as samples and use the fixed effect model in linear regression of panel data for regression analysis. Research findings: 1) corporate digitalization fosters not only green innovation directly but also promotes green innovation by enhancing human capital. 2) Executive team environmental attention encourages the beneficial correlation between human capital and green innovation. 3) Media attention promotes the favorable relationship between corporate digitalization and green innovation. 4) Heterogeneity analysis revealed that the corporate digitalization effect on green innovation is more significant when firms are more prominent in high-tech industries. The findings encourage corporations to strengthen their digital strategy, infrastructure, and applications. In addition, they can also inspire green innovation to enable companies to develop sustainably.

KEYWORDS

corporate digitalization, green innovation, human capital, executive team environmental attention, media attention

1 Introduction

In the past few years, manufacturing corporates in China have been caught in the dilemma of low quality, low efficiency, and severe ecological damage while using resources for rapid development (Ji and Zhang, 2019). We must therefore draw attention to the waste and pollution problems in the manufacturing industry. The UN proposed the Sustainable Development Goal in 2021. To address the issues of global climate change, pollution, and waste, it took into account economic, social, and environmental concerns (Sinha et al., 2021). More and more academic research is being done from the standpoint of environmental science under the setting of the sustainable development goal (Sukma and Leelasantitham, 2022a). For instance, from the macro-level perspective, Hoseinzadeh et al. (2022a, 2022b) applied the PRISMI PLUS Toolkit to the city of Spain and the island of Procida with a comprehensive analysis of energy, economic and environmental. They demonstrated the approach to integrating renewable energy (solar and wind energy). This is crucial for the region's sustainable development and energy independence, as well as for reaching the decarbonization goal. Fayazi Rad et al. (2022) applied the advanced hydrogen production

device to the road infrastructure sector in Iran, which reduced carbon dioxide emissions and increased sustainability. Similarly, [Hoseinzadeh and Astiaso Garcia \(2022\)](#) explored renewable energy systems using solar and wind energy with great potential on Italian islands for economic and environmental benefits and sustainable development. From the viewpoint of environmental science and the microscale level of enterprises, studying how corporate behavior favorably impacts the economy, society, and environment has become crucial to advancing the sustainable development goal ([Sukma and Leelasantitham, 2022b](#)). Green innovation is a critical component of accomplishing the goal of sustainable development ([Song and Yu, 2018](#)). Corporate green innovation may promote sustainable growth, minimize adverse environmental effects, and increase environmental and economic advantages ([Hojnik and Ruzzier, 2016](#)). Therefore, from a micro perspective, corporations must seek out green innovation to promote sustainable development goals.

Meanwhile, digital technology is advancing rapidly and integrating with traditional businesses. These organizational environmental elements have a consequence on how companies change. Corporations must adhere to digital development and update their technologies, allowing them to drive green innovation and digitally enable stable, sustainable improvement ([Wen et al., 2021](#); [Sukma and Leelasantitham, 2022b](#)). It is practical to look at how corporate digitalization affects green innovation to promote corporate development.

Several researchers have already researched the connection between corporate digitization and green innovation. The environment may benefit from corporate digitalization ([Danish, 2019](#)). Big data technologies can simulate green innovation's process and predict its course, which can positively affect green innovation practices ([El-Kassar and Singh, 2019](#); [Li and Shen, 2021](#)) and enable companies to gain green competitiveness ([Tian et al., 2022](#)). Digitalization increases information transparency, which fosters shared commitment and trust, significantly boosts innovation, and enables sustainable development ([Dong et al., 2021](#); [Sukma and Leelasantitham, 2022a](#)). Corporate digitalization can increase the number and quality of green innovations ([Rao et al., 2022](#)). But as the study goes on, some researchers have discovered the phenomena known as the "digital paradox" because of the growth of digital technology ([Gebauer et al., 2020](#)), which instead increases energy consumption and pollution ([Avom et al., 2020](#)). Several researchers have presented a non-linear perspective on the impacts of corporate digitalization on green innovation. The "data-driven" effect of corporations promotes the upgrading of green innovation strategies, while corporate digitalization can inhibit green innovation due to the "curse of competence" and digital overload ([Hajli, 2015](#); [Dong and Netten, 2017](#); [Gebauer et al., 2020](#); [Cao et al., 2021](#); [Li and Shen, 2021](#)). There is disagreement over how corporate digitalization affects green innovation. Therefore, it is crucial to ascertain if corporate digitalization can foster green innovation.

Most current research concentrates on the direct relationships between corporate digitalization and green innovation. However, they still have not fully reveal how corporate digitalization affects green innovation internally. Corporate digitalization is only a means of green innovation ([Bartel et al., 2007](#)). Corporate environmental programs intimately tie to stakeholders who influence or engage in

environmental actions ([Ioanna et al., 2022](#)). The stakeholders of green innovation in enterprises are shareholders, managers, and employees ([Mitchell et al., 1997](#)). Stakeholders' behavior affects the effectiveness of IT projects and the quality of IT systems; whether corporate digitalization (such as IT technology) can successfully foster green innovation depends on people's background knowledge and experience ([Sukma and Leelasantitham, 2022b](#)). Thus, human capital is the nucleus resource of green innovation. Advanced digital resources for green innovation may be learned, absorbed, and used by human capital at a greater level. Following the resource-based theory, this study explores the mediating mechanism between corporate digitalization and green innovation from the human capital standpoint.

Most previous research has considered the moderating effect of corporate digitalization and green innovation from a single internal or external perspective ([Wei and Sun, 2021](#); [Cardinali and De Giovanni, 2022](#)), while we account for moderating effects from dual perspectives of corporations' internal and external environmental attention in this empirical study. Within the enterprise, the executive team's level of environmental awareness determines how much green innovation a company engages in, and it affects how resources are allocated for corporate green innovation ([Wang L. et al., 2022](#)). So we select executive team environmental attention as an internal environmental factor to explore its moderating effect on human capital and green innovation. The attention-based view combined with institutional theory provides a better understanding of how firms develop a competitive advantage ([Ocasio, 2011](#)). According to institutional theory, businesses must pursue green innovation initiatives to meet external institutional demand and boost organizational legitimacy. Prior research has concentrated on how coercive forces (such as government environmental rules) affect green innovation ([Wu et al., 2022](#)) while ignoring the impact of non-coercive pressures. Outside the enterprises, the media, as a non-coercive pressure, plays a guiding role in the topics concerned by corporates and the public. Media attention to environmental behavior can guide companies to use resources and technology for green innovation ([Wang and Zhang, 2021](#)). So we choose media attention as an external environmental factor to assess the moderating effects of media attention on corporate digitalization and green innovation.

Then, the following queries merit consideration:

Q1: What correlation exists between green innovation and corporate digitalization? Will it be heterogeneous among different corporations?

Q2: Can human capital serve as a mediating mechanism in corporate digitalization and green innovation?

Q3: From dual perspectives of internal and external environmental attention, what moderating effect does executive team environmental attention have on human capital and green innovation? And how can media attention play a moderating impact between corporate digitalization and green innovation?

To address the issues above, first, we analyze Q1 and Q2 per the resource-based theory and Q3 in accord with the attention-based view and institutional theory. Second, we utilize the fixed effect model in the linear regression of panel data to conduct an empirical test using the panel data of A-share manufacturing businesses in China from 2011 to 2020 as samples. After that, the robustness test is carried out, and the endogenous problem is alleviated. In further

research, heterogeneity analysis is carried out according to enterprise size and technological attributes.

The following are the main contributions: first, we empirically verify the micro mechanism of corporate digitalization and green innovation using the realistic background of green development and the digital economy. Second, from the view of human capital, we have unlocked the mediating role of corporate digitalization promoting green innovation, which offers suggestions for fully utilizing the environmental benefit potential of corporate digitalization. Third, we examine the moderating effect in light of dual internal and external environmental attention. We include executive team environmental attention as an internal factor in the “corporate digitalization-human capital-green innovation” research framework. Media attention is an external factor in the “corporate digitalization-green innovation” research framework. As a result, it provides a more situational empirical analysis of the relationship between green innovation and corporate digitalization.

2 Theoretical analysis and research hypotheses

2.1 The impact of corporate digitalization on green innovation

Corporate digitization is a strategic act. It uses digital resources to formulate and execute corporate actions to achieve digitalization at all levels of manufacturing, sales service, and management (Bharadwaj et al., 2013; Nambisan et al., 2019).

The resource-based theory states that corporations can achieve superior performance and a competitive edge by utilizing priceless, uncommon, unique, and irreplaceable resources (Wernerfelt, 1984; Barney, 1991). Thus, Valuable and unique digital resources within a corporation may provide it with a competitive edge. The company's internal resources may also be combined with digital resources for green innovation. The following are the primary aspects that corporate digitalization has affected green innovation.

In R&D and manufacturing, companies use digital technologies such as blockchain to collect and analyze financial market information to provide financing support for R&D and manufacturing of green innovations. Corporate digitalization enables reallocating and optimizing resources and efficiently uses resources in manufacturing business processes, generating green energy-saving technologies (Chuang and Huang, 2018; Cardinali and De Giovanni, 2022). Advanced sensors, artificial intelligence, and other digital technologies enable to monitor of the manufacturing process autonomously, in real-time, and precisely. These also optimize the procedure for high loss and low output, thus achieving green process innovation (Müller and Voigt, 2018; Li et al., 2022). Big data analytics and other digital technologies can access and analyze enormous volumes of data, identify obstacles to green innovation, and evaluate possible advantages through insight.

Corporate digitalization in sales can obtain high-quality information and improve information processing to meet consumers' green needs. This study by Johnson et al. (2017) claimed that green customer preferences could be gathered and analyzed using digital resources. Therefore, the development of corporate digitalization can quickly gain insight into green

information in the market, close the distance with customers and conduct real-time communication to promote green innovation (Hajli, 2015; Dong and Netten, 2017). Additionally, corporate digitization supports green innovation by enabling businesses to swiftly respond to changing environmental conditions and get dynamic knowledge about external ecological governance and other issues. Consequently, we put up the following hypotheses.

Hypothesis 1: Corporate digitalization will foster green innovation.

2.2 The impact of corporate digitalization on human capital

Human capital combines workers' experience, talents, and physical strength and has economic value (Youndt et al., 2004; Subramaniam and Youndt, 2005). In this study, human capital refers to stakeholders' skills, knowledge, and experience, which can guide enterprises to realize strategic decisions. According to most academics, corporate digitalization benefits the human capital of businesses.

Corporate digitalization can optimize its human resource structure to enhance the human capital level. In the process of external recruitment, corporate digitalization requires the intellectual development of enterprises. Advanced equipment with cutting-edge technology will replace the low-skilled workforce, thus increasing the demand for highly qualified workers. Therefore, corporates can use digital technologies to break the limitation of information time and space, place recruitment information precisely, establish a job seeker information database, and conduct precise recruitment to optimize human capital structure and accumulate human capital (Gilch and Sieweke, 2021). In the internal performance appraisal process, digital resources dynamically detect employees' work and provide reasonable performance incentives according to their abilities. The excellent performance evaluation system is conducive to attracting higher levels of talent and adjusting the human capital structure (Baptista et al., 2020; Schuetz and Venkatesh, 2020), thus improving the human capital level of the company.

Corporate digitalization can also enhance the quality of their human resources to enhance the human capital level. Employees need to learn and use digital technologies to cope with the unconventional tasks such as R&D and production that emerge from the digital development of companies (Kozanoglu and Abedin, 2021; Cetindamar et al., 2022). Employees then utilize common digital platforms and digital technologies to interact and cooperate with individuals in the same business or even across industries, making it simpler to get new information and experience both within and outside the workplace (Leonardi, 2021; Cetindamar et al., 2022), thereby improving human capital. The following hypotheses are offered based on the analysis above.

Hypothesis 2: Corporate digitalization will improve corporates human capital level.

2.3 The impact of human capital on green innovation

New or enhanced goods, procedures, management, and services make up a green innovation. It can minimize the adverse environmental effects while simultaneously adding value to customers and businesses (Hojnik and Ruzzier, 2016). Green innovation bases its attention on innovation and places a greater emphasis on environmental conservation and green value. People are the core carrier of all production factors (Marchiori et al., 2022), but the significant determinants of green innovation are the knowledge, technology, skill, and experience integrated into human capital. Developing an innovation strategy as part of a talent plan is essential for encouraging green innovation. Some academics contend that a corporates' ability to green innovation is influenced by its amount of human capital (Adomako and Nguyen, 2020; Gerhart and Feng, 2021; Munawar et al., 2022). The following factors dominate how corporate human capital affects green innovation:

In corporate manufacturing, when updating environmental protection equipment and improving production and management practices, the experience and knowledge possessed by human capital can replace the need for natural resources and reduce environmental degradation and resource waste (Yao et al., 2019; Ahmed et al., 2020). In sales services, companies with higher human capital have more robust analytical capabilities and extensive information sources (King and Tucci, 2002). This enables them to understand customers' environmental consumption needs on time and have the ability to predict future ecological consumption needs (Munawar et al., 2022) to encourage green innovation among corporations. Additionally, research suggests that people are more likely to support the advancement and use of green technology if their human capital is better, their personal qualities are higher, and so on (Yong et al., 2019; Mansoor et al., 2021; Asiaei et al., 2022), and resist the consumption pattern that is not conducive to environmental sustainability (Yao et al., 2019). We put out the following hypotheses in light of the study above.

Hypothesis 3: The increase in corporate human capital level will encourage green innovation.

2.4 The mediating role of human capital

The resource-based view asserts that human capital is a valuable asset. Human capital refers to stakeholders' skills, knowledge, and experience. Referring to the research of Ioanna et al. (2022), we use priority to map and analyze the stakeholders of corporate green innovation in Figure 1. First, the CEO, managers, and shareholders have the highest priority since they will implement the company's strategy. Second, the R&D department, manufacturing department, customer service department, and functional department staff are responsible for making decisions, so they have medium priority. Finally, the enterprise's external stakeholders—consumers, suppliers, the government, and the general public—impact its strategic conduct. Still, they have no decision-making or execution authority and have the lowest priority. The following mainly analyzes the mediating role of human capital owned by

internal stakeholders in enterprise between corporate digitalization and green innovation.

In recruitment and selection, corporates use digital technologies to establish a job search information database to understand the environmental protection concepts of job seekers (Deng et al., 2022) and select employees with solid environmental awareness to enhance corporate green human capital. In internal learning and training, corporate digitalization can use the Intranet to establish an environmental knowledge management system, and provide employees with environmental protection training, to enhance human capital's ability to acquire, analyze and integrate environmental experience, which is beneficial for green innovation (Antunes and Pinheiro, 2020; Cardinali and De Giovanni, 2022). In addition, digital elements precisely match external environmental changes with internal data processing to achieve "linkage empowerment". The relationship network formed by the "internal and external linkage" of digital resources can enhance the interaction with strategic partners and stakeholders, strengthen cooperative relationships, and promote organizational learning of green knowledge (Deng et al., 2022), then encouraging green innovation. Researchers put out the following hypotheses in light of the study above.

Hypothesis 4: Corporate digitization promotes green innovation by improving the human capital level.

2.5 The moderating effect of executive team environmental attention

As per the attention-based view (ABV), corporate managers' attention determines organizational behavior (Ocasio, 1997). When the executive team pays attention to external environmental information, it determines whether the event is an opportunity or a challenge for their corporates based on their experience and takes further actions to achieve the corporate's strategy (Ocasio, 1997; Boone et al., 2019). Corporate green innovation behavior results from the guidance of the executive team's environmental attention. The empirical research of Wang L. et al. (2022) also argued that corporate green innovation strategies result from the guidance of the executive team's environmental attention. Most previous studies took the executive team's environmental attention as a driving factor for corporate green innovation but ignored its moderating effect.

Corporate human capital's successful implementation of green innovation activities is closely related to the executive team's environmental attention. The process of attention to action is the moderating effect of the executive team's environmental attention on human capital and green innovation. With being intensely environmentally conscious, the executive pays more attention to the environmental system, media coverage, and public awareness, and they can better understand the environment's information (Peng and Liu, 2016). As a result, they make more significant efforts to implement green innovation inside corporations. They are fully aware of the significance of environmental concerns and how to relate them to business development. The executive team will devote more human resources to green innovation because of this

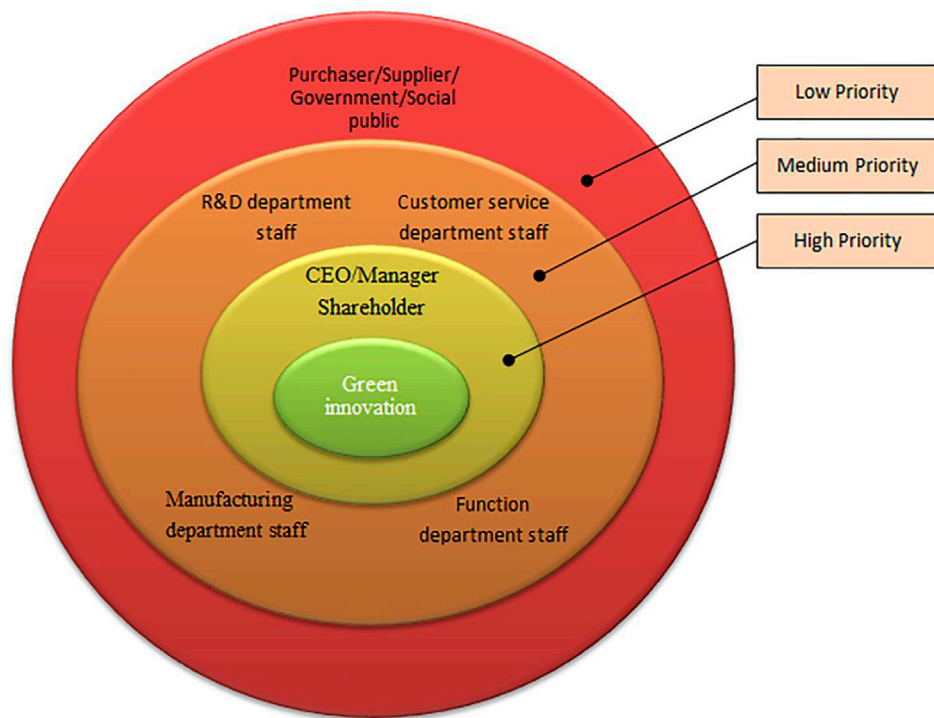
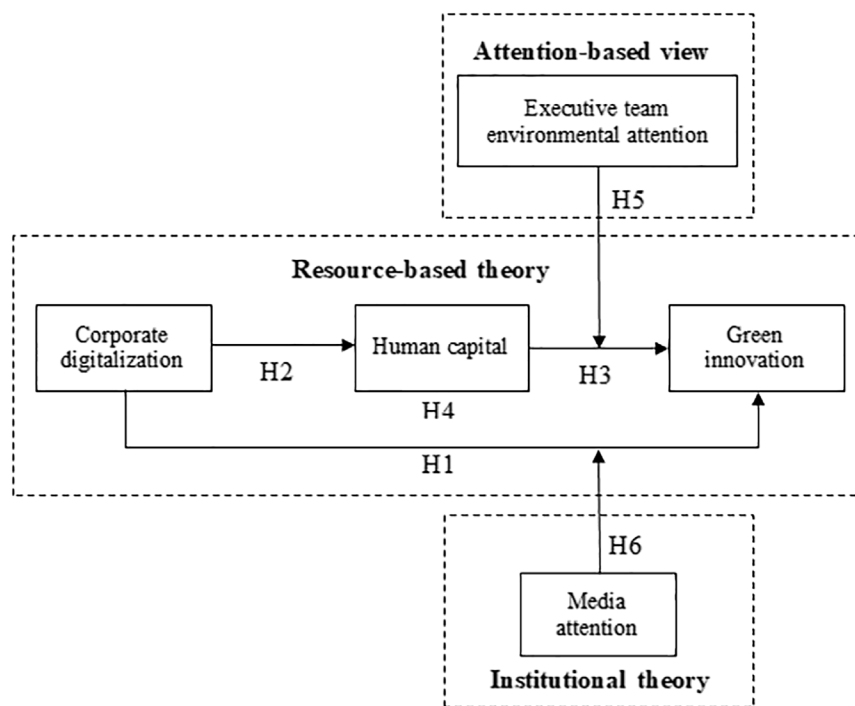


FIGURE 1 Stakeholders mapping.



H4: Corporate digitalization → Human capital → Green innovation

FIGURE 2 Research conceptual model.

choice, which will also impact corporate resource allocation. Considering this, here are some hypotheses that we put forth.

Hypothesis 5: The executive team's environmental attention promotes the positive relationship between human capital and green innovation.

2.6 The moderating effect of media attention

According to institutional theory, organizations need to increase organizational legitimacy in response to external institutional pressures. Studies have demonstrated that when environmental awareness grows, informal institutional pressure (such as media attention) encourages corporations to implement green innovations and achieve environmental legitimacy (Wang and Zhang, 2021; He et al., 2022). Thus, corporations with more media attention can strengthen their digital strategies and use digital resources and technologies to implement green innovation.

On the one hand, the media provides public information about corporate digitization and green innovation. As the general public becomes more environmentally conscious, investors will use the information on corporate green investments reported in the media as a reference, and consumers will be more willing to purchase environmental products stimulated by advertisements (Nyilasy et al., 2014; Zahid et al., 2018). To enhance their environmental legitimacy, companies use media information to understand the relevant green needs of their stakeholders and use corporate digitalization to encourage green innovation based on the relevant ecological dynamics. On the other hand, as an informal supervision mechanism outside the corporate (Chang et al., 2020), the media promotes a positive connection between corporate digitalization and green innovation. Media attention can expose corporate environmental violations (Chang et al., 2020; Wang and Zhang, 2021). The social pressure created by media exposure of corporate environmental violations can affect the image and reputation of a corporate (Wang F. et al., 2022). Therefore, corporates will balance economic and environmental benefits to maintain their reputation, build a green image (Cheng and Liu, 2018), and encourage green innovation through corporate digitalization. The following hypotheses have been put forth based on the study mentioned above.

Hypothesis 6: Media attention promotes the positive relationship between corporate digitalization and green innovation.

Based on the above hypotheses, our Research conceptual model is shown in Figure 2.

3 Research design

3.1 Sample and data

The research sample used in this work was the data of Chinese Shanghai and Shenzhen A-shares manufacturing enterprises from 2011 to 2020. We screened the initial data as follows: 1) dismissed ST, *ST, and other specially treated enterprises during

the observation period, and 2) dismissed the samples with missing values for the main variables. Finally, we obtained the balance panel data of 405 companies with 4,050 observations.

We choose the sample for the following considerations: First, A-share companies refer to ordinary shares listed in Chinese Shanghai and Shenzhen and are subscribed to and traded in RMB. Chinese stocks also have B-shares, H-shares, N-shares, etc., which are foreign stocks and need more sample data. We selected Chinese Shanghai and Shenzhen A-shares listed companies based on the data's accuracy and the research sample's integrity. Second, large-scale manufacturing is the major contributor to excessive resource consumption and environmental damage. Using manufacturing corporations as research samples, we can propose specific implications for minimizing environmental damage. Third, per the Listing Rules of the Shanghai Stock Exchange (Revised in 2019), "ST (Special Treatment)" will be added to the Stock's name if a listed firm encounters financial losses for two consecutive years or if its net assets are less than the face value of the Stock. When a company loses money for three consecutive years or has suffered financial losses for less than 3 years, "*ST" will be appended to the Stock's name, indicating that delisting may occur at any time. Thus, we dismiss ST and *ST companies since they apply to bankruptcy accounting rather than standard accounting rules and might raise suspicions of financial fraud.

Data sources: Corporate digitalization data came from the China Financial Research Center platform; corporate green innovation data came from CNRDS databases; human capital data came from the Wind database; media attention data came from the financial news of Chinese listed companies in CNRDS databases; executive team environmental attention data came from Wingo financial text data platform; all other related data came from CSMAR databases.

3.2 Main variables description

3.2.1 Dependent variable: Green innovation

According to studies by Johnstone et al. (2010) and Li et al. (2017), the quantity of green patent applications of enterprises reflects green innovation. We gauge green innovation (GI) by utilizing the number of green patent applications plus one and taking the natural logarithm. Adding one is to avoid the circumstance that the quantity is zero and cannot take a natural logarithm. Table 2 displays the variable's construction and sources.

3.2.2 Independent variable: Corporate digitalization

Since annual reports can reflect the development direction and strategic decisions of corporates (Donovan et al., 2021), most scholars use text analysis to estimate the number of digital keywords in annual reports to measure corporate digitalization (Hossnofsky and Junge, 2019; Ricci et al., 2020; Li and Shen, 2021; Wen et al., 2022). Following the studies of the previous academics, we measure corporate digitization (Dig) by the ratio of a digitalization-related word number in annual reports to the overall word number. Table 2 displays the variable's construction and sources.

TABLE 1 Executive team environment attention keywords.

Executive team environment attention keywords	
safe production, protection, exceedance, ozone layer, dust removal, atmosphere, low carbon, carbon dioxide, prevention, exhaust, waste gas waste, wastewater, waste, sludge, dust, wind, boiler, filter, environmental, environment, recycling, methane, emission reduction, consumption reduction, degradation, noise reduction, energy saving, conservation, purification, sustainable development, renewable, air, waste, waste, process reengineering, green, energy consumption, energy, emission, exhaust, discharge, destruction, habitat, clean, fuel, waste, ecology, biomass, water treatment, acid, solar, natural gas, soil, desulfurization, denitrification, tail gas, greenhouse gas, pollution, sewage, no acid, solar, natural gas, soil, desulfurization, denitrification, tail gas, greenhouse gas, pollution, sewage, non-hazardous, paperless, species, consumption, recycling, soot, flue gas, liquefied gas, toxic, organic, waste heat, reuse, noise, heavy metals, natural resources	

TABLE 2 Variable definitions and construction.

Variable types	Variable	Variable name	Variable measurement	Sources
Dependent Variable	GI	Green innovation	Natural logarithm of 1 plus the quantity of green patents application	CNRDS
Independent Variable	Dig	Corporate digitalization	Frequency of digitalized related words/whole quantity of Annual words (%)	China Financial Research Center platform
Mediating variable	HC	Human capital	Bachelor’s degree or above/Number of employees	Wind
Moderating Variables	TMEA	Executive team environmental attention	Environment-related word frequency/Total number of MD&A words (%)	Wingo financial text data platform
	MA	Media attention	the natural log of 1 plus online financial news quantity	Wind
Control Variables	Age	Corporate age	Natural logarithm of 1 plus the corporate establishment years	CSMAR
	Growth	Operating income growth rate	(Operating income current year amount - Operating income prior year amount)/Operating income prior year amount	CSMAR
	Share	Ownership concentration	Sum of the shares held by the top 10 shareholders	CSMAR
	ROA	Return on assets	Net income/total assets ending balance (%)	CSMAR
	SOE	Nature of ownership	0 for other corporates, 1 for state-owned ones	CSMAR
	MPR	Marginal profit ratio	(Sale revenue-Variable cost)/Sale revenue	CSMAR

3.3.3 Mediating variable: Human capital

Employee skills and knowledge levels will increase as business human capital increases. Employee education levels correlate with their skill and knowledge levels. Improved education levels correlate with higher employee quality. As a result, they will learn, assimilate, and apply digital materials more sensitive (Bartel et al., 2007; Zhang et al., 2022). Referring to the research of Wiersema and Bantel (1992), the researchers evaluate human capital (HC) in this study by the percentage of employees with bachelor’s degrees or higher in the enterprise.

3.3.4 Moderating variables: Executive team environmental attention and media attention

Attention will be reflected in the vocabulary used by individuals. Frequently used vocabulary information can reflect the focus of individual attention (Sapir, 1944). Therefore, the pertinent environmental keywords in annual reports will show senior executives’ attention. First, we adopt environmental attention keywords list of Wu and Hua (2021), as shown in Table 1. Second, relying on the research of Wang L. et al. (2022) and Wu and Hua (2021), we count the

environmental attention keywords in the managerial discussion and analysis (MD&A) section through the Wingo financial text data platform. Then we utilize the proportion of executive team environment attention keywords in MD&A to the entire words number as a measure for executive team environmental attention (TMEA).

Similar to research by Wang F. et al. (2022) and Cheng and Liu (2018), the number of pertinent news reports usually measures media attention. With the Internet’s rapid expansion, online reporting has become the primary media attention channel. To gauge media attention (MA), this study employs online financial news quantity plus one and takes the natural logarithm.

3.3.5 Control variables

Following prior studies by (Chuang and Huang, 2018; Cardinali and De Giovanni, 2022; Li et al., 2022), the control variables in this research are Age, Growth, Share, return on assets (ROA), nature of ownership (SOE), and marginal profit ratio (MPR). Table 2 displays the Variable’s construction and sources.

3.4 Regression models

Panel linear regression models involve mixed regression models, fixed effect models, and random effect models. The fundamental premise of the mixed regression model is the absence of an individual effect. However, there might be a unique situation in corporate development because each enterprise has a specific geographical, social, and economic context. In a panel regression model, there are two forms of individual effects: the random effect and the fixed effect. The Hausman test should be conducted to verify whether the data apply to the fixed effect model or the random effect model. Because the general Hausman test statistics are not robust in heteroscedasticity, we conduct the robust Hausman test employing Stata17.0 (Wooldridge, 2010). The outcome exhibits that $p = 0.0074$, that is, $p < 0.01$, disproving the null assumption of a random effect. So the fixed effect model is accepted. Then, we add the annual dummy variable to examine whether there is a yearly effect. The test outcome of the combined significance of annual dummy variables demonstrates that $F(9, 404) = 8.46$, $\text{Prob} > F = 0.000$, clearly rejecting the null hypothesis of “no time impact”, and the model exists as an annual effect. Therefore, we choose the two-way fixed effect for individuals and time model and heteroscedasticity-robust standard errors during parameter estimation to prevent heteroscedasticity issues.

This study presents corporate human capital (HC) as a mediating variable to examine whether corporate digitalization can affect green innovation through corporate human capital. There was control over the yearly fixed effect and the individual fixed effect based on the theoretical analysis previously presented to assess the mechanism of corporate digitalization’s influence on green innovation. Consistent with the analysis principle of the mediation effect (Baron and Kenny, 1986), the two-way fixed effect model in linear regression of panel data, the measurement model is developed:

$$GI_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 Control_{it} + \gamma_i + \gamma_t + \epsilon_{it} \quad (1)$$

$$HC_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 Control_{it} + \gamma_i + \gamma_t + \epsilon_{it} \quad (2)$$

$$GI_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 HC_{it} + \beta_3 Control_{it} + \gamma_i + \gamma_t + \epsilon_{it} \quad (3)$$

To further examine the moderating effect, this study introduces the interaction terms of human capital and executive team environmental attention, and the interaction terms of corporate digitalization and media attention, and builds the following model:

$$GI_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 HC_{it} + \beta_3 TMEA_{it} + \beta_4 HC_{it} \times TMEA_{it} + \beta_5 Control_{it} + \gamma_i + \gamma_t + \epsilon_{it} \quad (4)$$

$$GI_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 MA_{it} + \beta_3 Dig_{it} \times MA_{it} + \beta_4 Control_{it} + \gamma_i + \gamma_t + \epsilon_{it} \quad (5)$$

Among them, i indicates the listed company; t indicates time; the dependent variable GI_{it} indicates green innovation of firm i in year t ; independent variable Dig_{it} indicates corporate digitalization of firm i in year t ; mediating variable HC_{it} indicates human capital of firm i in year t ; moderating variables $TMEA_{it}$ indicates executive team environmental attention of firm i in year t , MA_{it} indicates media attention of firm i in year t ; $Control_{it}$ indicates control variables; γ_i specifies the individual fixed effect; γ_t designates the annual fixed effect. ϵ_{it} specifies random perturbation terms.

TABLE 3 Descriptive statistics.

Variable	N	Mean	SD	Min	Max
GI	4,050	0.654	1.079	0	6.267
Dig	4,050	0.126	0.212	0	3.169
HC	4,050	0.279	0.177	0.023	1
TMA	4,050	0.768	0.824	0	7.411
MA	4,050	5.285	1.097	0.693	9.763
Age	4,050	2.824	0.363	1.099	3.714
Growth	4,050	0.473	7.327	-2.083	423.0
Share	4,050	55.73	14.78	8.780	94.48
ROA	4,050	0.038	0.0860	-2.008	0.863
SOE	4,050	0.402	0.490	0	1
MPR	4,050	1.014	0.209	-3.929	8.059

3.5 Descriptive statistics

Table 3 displays the findings of the descriptive statistics. The minimum and highest values of green innovation (GI) are 0 and 6.267, showing a disparity in various corporates’ green innovation. Corporate digitalization (Dig) ranges from 0% to 3.169%, with a mean value of only 0.126% and a standard error is 0.177%, demonstrating that there are significant variances and that corporate digitization is often at a low degree. Human capital (HC) has a mean value of 0.279 and the minimum value of 0.023, which shows that there is also a difference in human capital levels among companies. The fraction of environmental issues in MD&A is relatively low, and there is a big difference between firms, according to the mean value of executive team environmental attention (TMEA), which is 0.768, and the minimum value, which is 0. The overall mean of media attention (MA) is 5.285, and the standard deviation is 1.097, showing a lot of variance in media attention giving to different firms. Additionally, the age of the sample firms ranges from 1.099 to 3.714 and the proportion of top 10 shareholders ranges from 8.78% to 94.48%, falling within an appropriate range. Operating income is increasing at a rate greater than 0.1, demonstrating that the company has a good growth trend. The sample companies’ average growth rate is 0.43, suggesting that they are generally in a solid growth phase. ROA greater than 0 signifies a good return on assets, and the mean value of the sample companies is 0.038, showing that the average profitability of the companies is high. MPR greater than 0 indicates that increasing product sales increase corporate revenue. The average MPR of the sample companies is 1.014, meaning a satisfactory average marginal profit margin. The outcomes of the descriptive statistics reflect that the data selection is appropriate.

3.6 Correlation analysis

We conducted a simple OLS regression for correlation analysis, and Table 4 displays the findings. Corporate digitalization and green

TABLE 4 Correlation analysis.

Variable	GI	Dig	HC	TMA	MA	Age	Growth	Share	ROA	SOE	MPR
GI	1										
Dig	0.123***	1									
HC	0.194***	0.376***	1								
TMA	0.187***	-0.090***	-0.038**	1							
MA	0.318***	0.026	0.078***	-0.022	1						
Age	0.020	0.007	0.050***	0.019	-0.006	1					
Growth	-0.010	-0.003	-0.002	0.003	-0.007	-0.005	1				
Share	0.046***	-0.043***	-0.068***	0.005	0.138***	-0.233***	0.036**	1			
ROA	0.018	-0.014	0.042***	-0.036**	0.104***	-0.022	0.002	0.184***	1		
SOE	0.070***	-0.012	0.070***	0.006	0.094***	0.217***	-0.005	-0.002	-0.012	1	
MPR	0.011	0.017	0.037**	-0.016	0.012	0.021	0.001	-0.036**	0.357***	0.001	1

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

innovation's Pearson correlation coefficient fulfilled the 1% statistical test. Additionally, human capital, executive team environmental attention, media attention, and green innovation are positively correlated. The results indicate that corporates with higher digitalization, higher human capital levels, more executive team environmental attention, and more media attention will be more conducive to green innovation. The VIF is 1.21 at the maximum after the variance inflation factor test, demonstrating no multicollinearity. Therefore, our variable selection is reasonable.

4 Discussion

In this section, the outcomes of models (1)–(5) using the two-way fixed effect model with heteroscedasticity-robust standard errors are derived and contrasted with the results of several experts' earlier studies. Second, the robustness test (such as replacing variables measurement and estimated models) is conducted, and the endogenous problem is alleviated. Additionally, the fixed effect model is utilized to explore the heterogeneity of corporate scale and technology features. Finally, the study's theoretical and practical enlightenment is provided.

4.1 Regression analysis

Table 5 displays the outcomes of corporate digitalization on green innovation and mediating function of human capital. Column 1) of Table 5 evaluates the impact of corporate digitalization on green innovation. With a correlation value of 0.391, the findings demonstrate that corporate digitalization and green innovation are statistically relevant at the 5% level, indicating corporate digitalization fosters green innovation, which confirmed the findings of Danish. (2019), Li and Shen (2021), Tian et al. (2022), and Rao et al. (2022), so H1 has been verified. However, this goes against the conclusion reached by Avom et al. (2020). The correlation between corporate digitalization and human capital is

relevant at the 5% level, as displayed in column 2) of Table 5, with a correlation value of 0.072, affirmed that corporate digitization promotes the enhancement of human capital level, indicating that H2 has been verified. As is evident from column 3) in Table 5, human capital and green innovation are relevant at a 5% level, and the coefficient value is 0.594, showing increasing the level of human capital encourages green innovation, and H3 has been verified. These results also confirm Munawar et al. (2022), Yao et al. (2019), and Asiaei et al. (2022).

This study further verifies the mediating role of human capital between green innovation and enterprise digitalization. According to column 4) in Table 5, corporate digitalization and green innovation are highly associated at the 10% level, while human capital and green innovation are related at the 5% level. It is preliminarily shown that human capital mediates the connection between corporate digitalization and green innovation to some extent, so H4 is preliminarily verified.

To further verify the mediating effect, Bootstrap method regression was used with 1,000 sampling times (Preacher and Hayes, 2008), and as shown in Table 6, there is no 0 within the 95% confidence interval. Further analysis reveals that human capital has a partial mediation function in corporate digitalization and green innovation. The results also confirm the finding of Ren et al. (2022).

A regression test is carried out following model 4) to investigate the moderating role of executive team environmental attention on the interaction between human capital and green innovation. The outcomes are in Table 5's column 5). The model findings reveal that the interaction term between human capital and executive team environmental attention is associated at the 5% level, which verifies H5. A regression test is performed according to model 5) to assess the moderating impact of media attention within corporate digitalization and green innovation. The statistics are displayed in column 6) of Table 5. The interaction effect between corporate digitalization and media attention is positive at the 1% level. It suggests that media attention is favorably moderating the link between corporate digitalization and green innovation, supporting H6.

TABLE 5 Regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	GI	HC	GI	GI	GI	GI
Dig	0.391** (0.198)	0.072** (0.028)		0.352* (0.201)	0.322 (0.196)	0.358* (0.183)
HC			0.594** (0.261)	0.543** (0.264)	0.601** (0.238)	
TMA					0.038 (0.030)	
HC×TMA					0.542** (0.224)	
MA						0.043* (0.024)
Dig×MA						0.304*** (0.113)
Age	0.053 (0.209)	-0.073*** (0.028)	0.107 (0.210)	0.092 (0.208)	0.088 (0.208)	0.047 (0.197)
Growth	-0.001*** (0.000)	-0.001** (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001** (0.000)	-0.001*** (0.000)
Share	0.002 (0.002)	0.000 (0.000)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)
ROA	0.049 (0.144)	-0.004 (0.028)	0.053 (0.138)	0.051 (0.141)	0.044 (0.142)	0.039 (0.141)
SOE	0.009 (0.112)	0.029 (0.020)	-0.014 (0.111)	-0.007 (0.111)	0.011 (0.106)	-0.005 (0.108)
MPR	-0.018 (0.036)	0.003 (0.010)	-0.019 (0.035)	-0.020 (0.036)	-0.020 (0.036)	-0.017 (0.036)
Constant	0.211 (0.567)	0.394*** (0.078)	-0.020 (0.582)	-0.003 (0.576)	-0.026 (0.579)	0.051 (0.569)
Year FE	YES	YES	YES	YES	YES	YES
Symbol FE	YES	YES	YES	YES	YES	YES
N	4,050	4,050	4,050	4,050	4,050	4,050
R-squared	0.036	0.142	0.036	0.039	0.046	0.043

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses. The following table is the same.

TABLE 6 Mediating effect test results.

Effect test	Observed Coef	Bootstrap Std.Err	z	P> z	Normal-based [95%Conf.Interval]	
Direct effect	0.3183	0.0483	6.59	0.000	0.2236	0.4130
Indirect effect	0.2950	0.0918	3.21	0.001	0.1151	0.4748

TABLE 7 Robustness test: Replace dependent variable indicator.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	GI	HC	GI	GI	GI	GI
Dig	0.393** (0.184)	0.072** (0.028)		0.355* (0.188)	0.339* (0.184)	0.354** (0.167)
HC			0.584*** (0.223)	0.533** (0.227)	0.572*** (0.214)	
TMA					0.010 (0.027)	
HC×TMA					0.340* (0.182)	
MA						0.058*** (0.021)
Dig×MA						0.334*** (0.110)
Age	0.080 (0.186)	-0.073*** (0.028)	0.134 (0.189)	0.119 (0.187)	0.115 (0.187)	0.075 (0.170)
Growth	-0.001* (0.000)	-0.001** (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.001* (0.000)
Share	0.003 (0.002)	0.000 (0.000)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)
ROA	0.026 (0.128)	-0.004 (0.028)	0.030 (0.123)	0.027 (0.125)	0.028 (0.127)	0.014 (0.124)
SOE	0.046 (0.092)	0.029 (0.020)	0.023 (0.090)	0.031 (0.090)	0.040 (0.086)	0.031 (0.087)
MPR	-0.008 (0.031)	0.003 (0.010)	-0.009 (0.029)	-0.010 (0.030)	-0.012 (0.030)	-0.007 (0.029)
Constant	-0.077 (0.517)	0.394*** (0.078)	-0.304 (0.538)	-0.287 (0.534)	-0.287 (0.537)	-0.304 (0.500)
Year FE	YES	YES	YES	YES	YES	YES
Symbol FE	YES	YES	YES	YES	YES	YES
N	4,050	4,050	4,050	4,050	4,050	4,050
R-squared	0.033	0.142	0.033	0.036	0.040	0.046

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses. The following table is the same.

4.2 Robustness test

4.2.1 Replace the dependent variable indicator

Since green invention patents are more innovative and creative (Tong et al., 2014), green invention patents may more accurately represent corporate green innovation. In the robustness test, we use green invention patents quantity plus one and take the natural logarithm to evaluate green innovation. Table 7 displays the

outcomes, and it is clear that the regression outcomes are in line with those of prior regressions, making the outcomes of this study robust.

4.2.2 Replace the independent variable indicator

Grounded on the study of Wen et al. (2022), this research adopts the aggregate quantity of corporate digitalization-related terms in annual reports plus one and takes the natural logarithm to evaluate

TABLE 8 Robustness test: Replace independent variable indicator.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	GI	HC	GI	GI	GI	GI
Dig	0.051** (0.020)	0.006* (0.003)		0.048** (0.020)	0.044** (0.020)	0.043** (0.020)
HC			0.594** (0.261)	0.562** (0.258)	0.620*** (0.232)	
TMA					0.033 (0.030)	
HC×TMA					0.555** (0.221)	
MA						0.046* (0.024)
Dig×MA						0.026** (0.013)
Age	0.060 (0.209)	-0.072*** (0.027)	0.107 (0.210)	0.100 (0.208)	0.094 (0.208)	0.071 (0.206)
Growth	-0.001*** (0.000)	-0.001*** (0.000)	-0.001* (0.000)	-0.001 (0.000)	-0.001* (0.000)	-0.001*** (0.000)
Share	0.002 (0.002)	0.000 (0.000)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)
ROA	0.038 (0.142)	-0.005 (0.028)	0.053 (0.138)	0.040 (0.139)	0.036 (0.141)	0.038 (0.139)
SOE	0.014 (0.112)	0.029 (0.021)	-0.014 (0.111)	-0.002 (0.111)	0.015 (0.106)	0.009 (0.110)
MPR	-0.015 (0.036)	0.003 (0.011)	-0.019 (0.035)	-0.017 (0.035)	-0.019 (0.035)	-0.017 (0.036)
Constant	0.135 (0.566)	0.385*** (0.078)	-0.020 (0.582)	-0.081 (0.576)	-0.093 (0.579)	-0.082 (0.593)
Year FE	YES	YES	YES	YES	YES	YES
Symbol FE	YES	YES	YES	YES	YES	YES
N	4,050	4,050	4,050	4,050	4,050	4,050
R-squared	0.036	0.136	0.036	0.039	0.046	0.040

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses. The following table is the same.

corporate digitization. Table 8 displays the outcomes of the two-way fixed effects model. The findings are in line with those of the prior study, as seen from the table, making the conclusions in this work robust.

4.2.3 Model replacement

Green innovation in this article is the number of green patent applications, but the quantity of green patents has an amount of 0 values in the actual data of selected firms. Therefore, this paper

further employs the Tobit regression model for robustness testing. Table 9 presents the findings, and it is clear that the Tobit model outcomes coincide with the previous two-way fixed effects regression results mentioned above.

4.2.4 Endogenous test

The two-way fixed effects model and robust standard errors are utilized in the testing, but the possible presence of two-way causality

TABLE 9 Robustness test: Tobit model estimation.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	GI	HC	GI	GI	GI	GI
Dig	1.009*** (0.244)	0.091*** (0.011)		0.846*** (0.245)	0.834*** (0.243)	0.929*** (0.243)
HC			1.815*** (0.342)	1.649*** (0.344)	1.652*** (0.342)	
TMA					0.158*** (0.054)	
HC×TMA					0.750*** (0.257)	
MA						0.151*** (0.044)
Dig×MA						0.307** (0.147)
Age	-0.121 (0.253)	-0.060*** (0.012)	-0.079 (0.251)	-0.062 (0.251)	-0.069 (0.246)	-0.141 (0.249)
Growth	-0.008 (0.013)	-0.001*** (0.000)	-0.007 (0.013)	-0.008 (0.014)	-0.008 (0.014)	-0.008 (0.013)
Share	0.004 (0.004)	0.000** (0.000)	0.003 (0.004)	0.004 (0.004)	0.004 (0.004)	0.003 (0.004)
ROA	-0.024 (0.393)	-0.001 (0.015)	-0.061 (0.392)	-0.071 (0.391)	-0.120 (0.389)	-0.042 (0.388)
SOE	0.204 (0.152)	0.030*** (0.007)	0.135 (0.151)	0.154 (0.151)	0.192 (0.148)	0.176 (0.149)
MPR	0.048 (0.239)	0.003 (0.006)	0.059 (0.235)	0.060 (0.235)	0.072 (0.232)	0.063 (0.238)
Constant	-1.058 (0.754)	0.360*** (0.036)	-1.491** (0.755)	-1.581** (0.753)	-1.644** (0.742)	-1.692** (0.766)
sigma_u	1.888*** (0.090)	0.160*** (0.006)	1.861*** (0.089)	1.851*** (0.088)	1.793*** (0.086)	1.830*** (0.089)
sigma_e	1.119*** (0.024)	0.058*** (0.001)	1.117*** (0.024)	1.115*** (0.023)	1.112*** (0.023)	1.114*** (0.023)
Year FE	YES	YES	YES	YES	YES	YES
Symbol FE	YES	YES	YES	YES	YES	YES
N	4,050	4,050	4,050	4,050	4,050	4,050

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses. The following table is the same.

can cause bias in the study results. To address the possible endogeneity problem, we use two approaches. First, the independent variables lagging one stage behind are used for regression with green innovation of corporates, as indicated in

column 1) of Table 10. Corporate digitalization lagging one period still has a correlation with green innovation at the 1% level. Second, relying on the research of Li and Shen (2021), the average value of corporate digitalization in the same city and

TABLE 10 Endogeneity test results.

Variable	(1)	(2)	(3)
	GI	First stage regression	Second stage regression
		Dig	GI
L.Dig	0.578*** (0.209)		
Dig			0.656*** (0.093)
Avg-Dig		1.001*** (0.009)	
Age	0.107 (0.273)	-0.020*** (0.005)	-0.009 (0.056)
Growth	-0.001** (0.000)	0.000 (0.000)	-0.002 (0.002)
Share	0.003 (0.002)	0.000 (0.000)	0.004*** (0.001)
ROA	0.047 (0.126)	0.043** (0.021)	0.152 (0.214)
SOE	0.015 (0.116)	0.019*** (0.003)	0.160*** (0.035)
MPR	-0.016 (0.030)	0.002 (0.009)	0.017 (0.087)
Constant	0.070 (0.749)	0.034* (0.019)	0.137 (0.195)
Year FE	YES	YES	YES
Symbol FE	YES	YES	YES
N	3,645	4,050	4,050
R-squared	0.037	0.757	0.031
Under identification test (KP LM statistic)			204.011***
Weak identification test (KP Wald F statistic)			2,763.371 [16.38]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses. The critical value of the F test for weak instrumental variables identified at the significance level of 10% in Square.

industry is selected as the instrumental variable and assigned Avg-Dig. The mean value of corporate digitalization (Dig) within the same city and industry links to corporate digitization, but it has no direct bearing on corporate green innovation. Therefore, the instrumental variable ensures the relevance and externality of the instrumental variable. The Kleibergen-Paap rk LM statistic is relevant at the 1% level, which denies the null hypothesis that the instrumental variable is not adequately identified. The Kleibergen-Paap rk Wald F statistic is larger than the F statistic at the 10% significance level proposed by Stock et al. (2002), with weak instrumental variables being the null hypothesis denied. The instrumental variables employed for this work are, in aggregate,

appropriate and reliable. Columns 2) and 3) of Table 10 display the two-stage least squares regression for the instrumental variables, and the outcomes remain robust.

4.3 Heterogeneity analysis

The inconsistent corporate traits may contribute to the variation in the effects of corporate digitalization on green innovation, given contradictory findings in previous studies by other scholars. Therefore, this paper further conducts grouping regression for sample firms according to corporate size and technological attributes.

TABLE 11 Further analysis results.

	(1)	(2)	(3)	(4)
	Large-scale corporates	Small-scale corporates	High-tech corporates	Non-high-tech corporates
Variable	GI	GI	GI	GI
Dig	1.065*** (0.378)	-0.021 (0.198)	0.905** (0.381)	0.349 (0.213)
Age	0.528 (0.613)	-0.055 (0.228)	-0.551 (0.342)	0.228 (0.244)
Growth	-0.001* (0.000)	-0.001 (0.001)	-0.000 (0.001)	-0.001*** (0.000)
Share	0.004 (0.004)	-0.001 (0.002)	-0.004 (0.004)	0.004 (0.002)
ROA	0.328 (0.431)	-0.096 (0.115)	0.209 (0.286)	0.013 (0.160)
SOE	-0.118 (0.168)	0.116 (0.162)	0.401 (0.351)	-0.003 (0.129)
MPR	-0.009 (0.166)	-0.006 (0.028)	-0.019 (0.027)	-0.022 (0.062)
Constant	-0.958 (1.723)	0.482 (0.631)	1.697** (0.797)	-0.227 (0.679)
Year FE	YES	YES	YES	YES
Symbol FE	YES	YES	YES	YES
N	2025	2025	786	3,264
R-squared	0.062	0.016	0.038	0.043

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard error statistics are in parentheses.

In this paper, we grouped firms according to the median assets of all sample firms. Firms with assets more than the median assets of the sample firms are grouped into large-scale firms, while the rest are small and medium-scale firms. The regression coefficient in the group of large-scale enterprises is considerably relevant at the 1% level, while the group of small-scale firms is not, by the grouping statistics in columns 1) and 2) of Table 11. The cause may be that large-scale corporations with resources and capabilities are conducive to carrying out digital transformation activities and have higher risk-taking and resource allocation capabilities, which will accelerate green innovation. Therefore, the consequence of corporate digitalization on green innovation is more obvious in large-scale enterprise groups compared to small and medium-scale enterprises.

In this paper, we classify enterprises into high-tech and non-high-tech corporations based on whether they qualify as high-tech corporates. The outcomes are in Table 11's columns 3) and 4). The statistical test of corporate digitalization on green innovation is relevant at the 5% level in the high-tech corporate group, while the non-high-tech corporate group is not significant. The reason may be that high-tech corporations have a stronger innovation foundation and capability, and their digitalization level is also higher, and they can smoothly

embed corporate digitalization into organizational decision-making and production process for green innovation. Given this, green innovation of high-tech firms is more significantly affected by corporate digitalization than non-high-tech ones.

4.4 Theoretical implications

The following are the main contributions of this work. First, empirical studies of corporate digitalization on green innovation at the micro-scale are not numerous and do not yield consistent findings given the reality of the digital economy and corporate environmental development. This paper empirically verifies the beneficial influence of corporate digitalization on green innovation at the micro level of corporates, which enriches the micro research on green innovation in the setting of the digital era. Second, prior research has concentrated on the direct impacts of corporate digitalization and green innovation (El-Kassar and Singh, 2019; Li and Shen, 2021), but human capital is the core resource of production factors, and digital resources need to be shared, absorbed, and transformed into human capital by employees to promote green innovation better. This research

reveals the mediating role in the evolutionary path from corporate digitalization to green innovation from the human capital perspective. Third, most previous research has considered the moderating effect of corporate digitalization and green innovation from a single internal or external perspective (Wei and Sun, 2021; Cardinali and De Giovanni, 2022). In this study, we choose boundary conditions from internal and external perspectives, such as executive teams' environmental attention and media attention. Then we respectively identify their moderating mechanisms in "corporate digitalization–human capital–green innovation" and "corporate digitalization–green innovation", which provide a more contextualized perspective for a comprehensive examination of corporate digitalization and green innovation.

4.5 Practical implications

The research's results suggest the following practical implications. First, the government should actively guide corporate in digital transformation and green development. According to the differences in corporate scale and technological attributes, the government should promptly introduce different relevant support policies, such as subsidies, tax relief, simplification of administrative approval, and improvement of environmental regulations. These measures can reduce the hindrance and risk of corporates in digital transformation and green development. Second, corporates should strengthen digital strategy, enhance digital infrastructure construction and application, improve environmental awareness, and promote green R&D and manufacturing and green sales services by relying on digital technology to realize effective sharing of green information and resources inside and outside corporates. According to the view of human capital, corporates should make use of digitalization to improve the level of human capital, such as fully introducing professionals in the field of digital technology, using various digital platforms for employee training, and encouraging employees to use information management systems for knowledge share. In addition, corporates should pay attention to matching people and jobs, actively carry out green practices and training, and utilize human capital to support green innovation. Third, the executive team should strengthen their attention to the environment, keep abreast of internal and external green information, and allocate internal and external resources reasonably to promote green innovation. Employees should support the executive team in making decisions that are conducive to the sustainable growth of the corporates. Fourth, the media should increase their coverage of corporate environmental practices and keep their reports factual, timely, and accurate to convey information to the public. Corporations should accept media attention and establish an excellent communication mechanism with the media. It will not only enable the media to perform an effective monitoring function but help corporates to develop a positive green image and maintain their reputation in front of the general public.

4.6 Limitations and future directions

However, this work does have some limitations. Firstly, this paper only uses digitization-related word frequency to measure the overall situation of corporate digitization. It is not yet a good reflection of the

investment and level of digitization in business processes such as manufacturing and sales services. In the future, the measurement of corporate digitization can be further refined in terms of specific details. Second, these research samples are limited to manufacturing corporates, and in the future, we can explore whether the model has consistent findings and inherent mechanisms for different types of corporates. Finally, the dimensions of green innovation can be further refined in the future, for instance, social-based innovation and self-interest innovation, to enrich relevant research and get more targeted practical implications.

5 Conclusion

The study of corporate digitalization and green innovation is the focus of current academic concern and also has important practical significance for digital economy development and corporate sustainability. This study explores the effect of corporate digitalization on green innovation and the function of human capital as an intermediary. It further discusses the moderating effects of two environmental attention, specifically the internal factors—executive team environmental attention, and the external factors—media attention. An empirical test was employed using the fixed effect model based on the panel data of A-share manufacturing companies in Chinese Shanghai and Shenzhen from 2011 to 2020. These are the conclusions: 1) Corporate digitalization can greatly enhance corporate green innovation. After the robustness and endogeneity tests, the findings are still valid. 2) Based on the influence mechanism, corporate digitalization can foster green innovation by enhancing corporates' human capital. 3) The executive team's environmental attention inspires a favorable interaction between human capital and green innovation, and media attention plays the same function in corporate digitalization and green innovation. 4) Further research reveals that the consequence of corporate digitalization on green innovation is more significant for large-scale and high-tech enterprises. This research expands on existing micro-research on green innovation in the context of the digital age. It identifies the mediating role in the evolutionary path from corporate digitalization to green innovation in a more contextualized perspective. Additionally, the study provides practical guidance for businesses, the executive team, and the media, along with positive recommendations to the government to support sustainable growth and corporate digital development.

Data availability statement

Publicly available datasets were used in this work. The specific panel data of this study has been uploaded to the [Supplementary Material](#) section.

Author contributions

JL, LW, and FN wrote, edited, and modified the work. LW analyzed the data, created and edited the charts. JL, LW, and FN revised the manuscript. All authors contributed to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2023.1137271/full#supplementary-material>

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