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Digital technology application and enterprise competitiveness: the mediating role of ESG performance and green technology innovation

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Abstract
With the continuous advancement of the digital economy development strategy and the concept of green transformation, the impact of digital technology application (DTA) on enterprise competitiveness (EC) has attracted widespread academic attention. Based on the dynamic capabilities theory and stakeholder theory, this study proposes a theoretical framework that elucidates how enterprise DTA contributes to EC through potential mediating variables such as environmental, social, and governance performance (ESGP) and green technology innovation (GTI), as well as potential moderating variables such as enterprise scale (ES) and cash holdings (CH). The study collects data from 1,089 listed companies in the Yangtze River Delta (YRD) and Pearl River Delta (PRD) in China between 2018 and 2020, both of which are crucial growth poles of the Chinese economy. The study examines the impact of DTA on EC and finds that DTA enhances EC. The study also finds that there is the suppressing effect of ESGP and GTI in DTA on EC, with ESGP serving as a mediator between DTA and GTI. Furthermore, the study explores the effects of DTA on EC and GTI on EC, using ES and CH as moderating variables. The results show that ES negatively moderates the relationship between DTA and EC, while CH does not have a moderating effect. The study also conducts comparative analyses of companies in the YRD and PRD, revealing some differences between the two regions' enterprises, but these differences are not significant. This study not only contributes to the expansion of EC-related theories but also enhances the understanding of the interaction between DTA and EC, and helps analyze the practical impact of DTA on EC in different regions' enterprises. On the one hand, DTA can enhance ESGP, GTI, and EC to achieve sustainable development for enterprises in the context of twin transitions. On the other hand, the government can effectively encourage small-scale enterprises to enhance the actual effects of DTA, thereby enhancing EC.

Keywords Digital technology application · Enterprise competitiveness · ESG performance · Green technology innovation · Cash holding · Enterprise size

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1 Introduction

Enterprise competitiveness reflects an enterprise's ability to outperform its competitors and focuses on economic value creation and relative performance (Wang et al., 2022b). However, competitiveness is not static and sustainable. It is influenced by the environment, and in order to maintain and expand their position and advantage in the market, firms need to constantly adapt to market changes to achieve sustainable competitive advantage (Huang et al., 2015). In recent years, more and more countries have undergone digital transformation to adapt to market changes and achieve competitiveness (Dabbous et al., 2023). In addition, emerging digital technologies, such as 3D printing, artificial intelligence (AI), virtual reality (VR), blockchain, cloud computing, and big data, have become disruptive drivers of digital transformation (Van Veldhoven & Vanthienen, 2022). Nowadays, digital technology application (DTA) is exponentially growing worldwide, and most countries have considered it as a strategic tool for industrial development and business success (Fu, 2022). As a result, many scholars are exploring the impact of DTA on enterprise competitiveness (EC). Most scholars believe that DTA allows firms to boost resource efficiency, utilize virtualization and visualization to exploit business opportunities, and ensure business continuity and success (Al-Swidi et al., 2023). Consequently, today DTA has altered firms' business strategies, including production strategy, to boost production efficiency and increase EC (Dabbous et al., 2023).

Recently, a series of natural disasters, stock collapse, and enterprise disputes have happened worldwide, making the world pay attention to green development (Adomako & Mai Dong, 2022). Now that sustainability is increasingly seen as the driving force behind many economic policies. Consequently, the question of how to ensure the sustainable competitiveness of companies has become a hot topic of discussion today (Dabbous et al., 2023). From the above, we can see that digitalization and greening have gradually become two major trends in global economic and social transformation, which have received wide attention from various countries (Verhoef et al., 2021). In China, digitalization and greening have received great attention. Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China has been promulgated, focusing on deploying digital development and green development. These plans clearly point out that digital development and green development are the new engines for China's economic growth to achieve high-quality development, and only the deep integration of digital development and green development promotes each other while enhancing enterprise competitiveness (China, 2021). The dynamic innovation of the digital economy will give great momentum to green development, which is considered the future direction of socio-economic development, and green development, in turn, provides new guidelines for fostering innovations in the digital economy (Yang & Han, 2023). Further, these two development strategies complement each other to provide ways for enterprises to build competitiveness in adversity (Li et al., 2022; Sun & Tang, 2022). In this context, the concept of twin transitions was born, which conveys the undisputed complementarity between digital and green transformation (Dabbous et al., 2023). However, most scholars currently study the impact of these transformations on enterprise competitiveness from digitization and greening separately. For instance, Awan et al. (2022), Chatterjee and Mariani (2022), and Dabbous et al. (2023) studied the impact of digital transformation on enterprise competitiveness. In contrast, Li et al. (2019), Tang et al. (2022) and Wang et al. (2022d) examined the effect of green transformation on enterprise competitiveness.

Only a few scholars have integrated digitization and greening into one exploration to assess how such transformation influences enterprise competitiveness. In this context, the findings of this paper will address the void in the existing literature to help companies to achieve sustainability commitments while rationally allocating limited resources available to ensure economic efficiency and enterprise competitiveness (Del Río Castro et al., 2021).

Environmental, social, and governance (ESG) performance has been a top priority for any business firm in the context of green transformation. To realize an enterprise's sustainable development efforts, the enterprise must adopt a stakeholders-oriented approach, focusing on reducing externality and maximizing social value (Xie et al., 2019). Prior literature has found that in a firm, investors will usually be affected by its ESG score (Drempetic et al., 2020). Additionally, enterprises with good ESG performance (ESGP) will be in favor of investors (Park & Oh, 2022). Wu et al. (2022b) showed that technology is vital for reaping the maximum potential of ESGP of an enterprise. In line with that, Gao et al. (2021) found that ESG prompts an enterprise's sustainable development efforts. Prior literature on ESG focuses on the following aspects: examining the effect of ESG performance on shareholder value, organizational performance, corporate philanthropy, transparency, and organization and system theory (Li et al., 2021). However, only a few scholars have examined ESG performance as a mediating variable in the link between the sustainability efforts of enterprises and their competitiveness.

In the context of sustainability, green technology innovation (GTI) has also become important for enterprises (Hong et al., 2021). An enterprise that carries out GTI will result in a "win–win" situation while protecting the environment and increasing the economic value it generates simultaneously (Fang & Shao, 2022). Zhao and Qian (2023) have evidenced that diffusion of technology adoption can significantly enhance an enterprise's GTI potential. Guo et al. (2020) proposed that GTI prompts sustainable development efforts of enterprises. Further in line with them, Zhang et al. (2020b) have also found that attracting more investors will benefit an enterprise's GTI and foster the development of GTI. However, until now, not many scholars have investigated how the ESGP of an organization affects its GTI potential.

It is undeniable that enterprise scale (ES) has a moderating effect on the relationship between DTA and EC. The development of small-scale enterprises will be subject to many restrictions. In contrast, large-scale enterprises have more resources and comprehensive management systems (Annarelli et al., 2021). Therefore, large-scale enterprises are more conducive to developing and adopting digital technology, thereby enhancing their competitiveness. However, with limited funds, this effect will take up the proportion of the funds the enterprise uses for GTI and add to the company's capital pressure (Fang & Shao, 2022). Thus, a large cash flow will help enterprises innovate smoothly.

Although the concepts discussed above (e.g., DTA, EC, ESGP, and GTI) are conceptually interlinked broadly, empirical findings are scattered, and linkages remain understudied in prior literature. Against this backdrop, grounded on the dynamic capabilities view and stakeholder theory, this paper proposes a theoretically driven model to investigate how DTA drives the EC through GTI and ESGP. The outcome of this study contributes to the existing literature in several important ways. First, this paper proposes a theory-driven model to investigate the specific impact paths of corporate DTA affecting EC from the perspective of digitization and greening. In this model, this paper introduces ESGP and GTI as mediating variables and ES and CH as moderating variables in order to complement existing research gaps. Second, this paper will provide a better understanding of some aspects of the twin transitions concept, which is still an emerging topic. Third, this paper

compares and analyses the differences between the development of listed companies in the two major urban agglomerations in China, the Yangtze River Delta and the Pearl River Delta, to provide suggestions for developing the two urban agglomerations.

The remainder of the paper is structured as follows. The evolution of hypotheses and their theoretical foundation are reviewed in the next section. Then the chosen study approach, data analysis, findings, and discussion are presented. This article concludes by outlining the study's theoretical and practical contributions as well as its limits in terms of research.

2 Theoretical background and hypotheses development

2.1 Theoretical background

This paper has examined how the DTA of a business firm contributes to EC, explicitly focusing on the pathways through which ESGP and GTI can mediate them and the moderating effects of ES and cash holding (CH). For this purpose, the dynamic capability view (DCV) and stakeholder theory serve as the theoretical foundation of this paper.

According to the DCV, an enterprise's competitive edge stems from its capability to quickly adapt to changing external environmental conditions by introducing rapid and flexible innovations while utilizing its managerial skills for efficient coordination and bundling of organizational capabilities (Teece et al., 1997). Thus, developing new technologies and the appropriate application of digital technology may assist businesses in increasing resource utilization and managerial effectiveness, which will enhance EC (Shan et al., 2019). In addition, the DCT also highlights the crucial role that capital plays in achieving an enterprise's competitive advantage (Teece & Pisano, 1994). The enterprise's existing resources may serve as the basis for its creative actions, sustaining its competitive edge. However, compared with large-scale enterprises, financing small- and medium-sized enterprises is more complex (Lu et al., 2022). Therefore, large-scale enterprises can invest more funds in developing and adopting digital technology, thereby improving their competitiveness (Guan et al., 2023).

The stakeholder theory was developed in this context due to the rapidly changing enterprise environment (Freeman & Mcvea, 2005). Stakeholder theory emphasizes that to obtain resources from stakeholders and foster the growth of the enterprise, the interests of stakeholders should be taken into consideration by businesses (Freeman, 2016). Further, the stakeholder theory also shows that enterprise managers have to make efforts to keep cooperative relationships with stakeholders by balancing their interests (Bridoux & Stoelhorst, 2022). Enterprises can obtain competitive advantages by concentrating on ESGP and GTI since stakeholders have become more aware of concerns about the enterprise's environment, social responsibility, and governance in recent years (Esposito De Falco et al., 2021).

2.2 Hypotheses development

2.2.1 Digital technology application and enterprise competitiveness

The rapid pace of continuous technological progression and accelerated technological changes has become essential for countries worldwide (Stankovic et al., 2021). In addition,

in the contemporary marketplace defined by rapid technological changes, developing and adopting digital technologies and strategic thinking will benefit business firms in becoming competitive (Xue et al., 2022). The production processes of businesses are evolving due to the advancement of modern electronics, information, and manufacturing technology, which turns traditional manufacturing into intelligent manufacturing and boosts the organization's flexibility and competitiveness (Dos Santos et al., 2021). Furthermore, DTA can promote the rise in the high-end value chain and stimulate the production efficiency of enterprises (Wu et al., 2021). As the DCV emphasized, primary sources of competitive advantages for a business firm in the shifting competitive landscape lie in its dynamic capabilities, which are also regarded as a component of competence or capacity and allow enterprises to develop new goods and procedures and adapt to shifting market conditions (Hartono et al., 2020). Thus, we hypothesize the following:

H1: DTA has a positively impact on the EC.

2.2.2 Digital technology and enterprise's ESG performance

ESG is a systematic framework that can assess an enterprise's business practices and performance on various sustainability and ethical issues, including environment, social responsibility, and enterprise governance factors (Li et al., 2021). Due to the ubiquitous nature of the DTA and the rapid growth of the digital economy, enterprises' production efficiency has significantly increased, and their approach to business development has altered dramatically. As we can see, technology is already crucial in implementing ESG practices within enterprises (Ren et al., 2023). Firstly, it is possible and practical for the general public to become aware of the ESG practices of enterprises due to the accessibility, interaction, and real-time nature of the Internet. In addition, the Internet has facilitated business firms' environmental management initiatives by increasing the intelligence and accuracy of environmental supervision, government, and services (Wu et al., 2022a, 2022b). Secondly, the development of digital technology has enabled enterprises to fulfill their social responsibilities better. For example, enterprises may produce environmentally friendly products and safeguard endangered species by utilizing emerging technologies like AI and machine learning (Lobschat et al., 2021). Thirdly, using DTA in the workplace can improve the availability, accessibility, and openness of real-time information (Ren et al., 2023), reducing the irrationality of managers' decision-making (Riaz et al., 2022). Thus, we hypothesize the following:

H2: DTA has a positive impact on ESGP of enterprises.

2.2.3 Digital technology application and green technology innovation

Big data, AI, and other digital technologies have increasingly become the primary forces behind innovation and change. One of the key differences between GTI and conventional innovation is the twin externality of knowledge overflow and environmental conservation (Shao & Chen, 2022). Digital technology is used by businesses to manage massive amounts of data better, increase information availability, support decision-making, guarantee that production and manufacturing processes adhere to environmental requirements, and lessen negative environmental consequences through process innovations (Li & Shen, 2021; Shao & Chen, 2022). Moreover, enterprises employ cutting-edge digital technologies to locate

and acquire additional network resources, understand consumers' needs, wants, and industry trends, and quickly develop green innovations while enhancing resource networks (Xue et al., 2022). Thus, we hypothesize the following:

H3: DTA has a positive impact on GTI.

2.2.4 Enterprise's ESG performance and enterprise competitiveness

ESG has always driven an enterprise's business strategy and performance (Arvidsson & Dumay, 2022). Environment, society, and governance are the three key components of an organization's ESGP. As emphasized in the stakeholder theory, enterprises with strong ESGP will assist enterprises in building investor confidence and attracting additional resources. Therefore, enterprises with good ESGP maximize benefits to their stakeholders and consider optimizing resource allocation to promote sustainable development efforts (Gao et al., 2021). The environmental performance of an enterprise reflects the effective use of the best environmental protection management methods to continuously improve its efficiency and effectiveness concerning pollution prevention and resource utilization, which helps the enterprise to achieve a competitive advantage (Ren et al., 2023). The social performance of an enterprise not only emphasizes that the enterprise strengthens the relationships between the stakeholders by creating diversified and comprehensive values for all its stakeholders in its full potential (Li et al., 2021). The governance performance of an enterprise includes two aspects: internal governance and external governance. Through a successful institutional framework, it coordinates the interaction between the company and the stakeholders, and in the end, it defends the interests of the enterprise and all its stakeholders (Li et al., 2021; Ren et al., 2023). Therefore, we hypothesize the following:

H4: Enterprise's ESGP has a positive impact on EC.

2.2.5 Green technology innovation and enterprise competitiveness

The global industrial revolution and rapid technological progression have made GTI a central tenant in the enterprises operating in the modern marketplace (Yu et al., 2021). China recently stressed the value of green innovation and developed several constitutional laws to raise the bar for GTI (Hong et al., 2021). GTI is a broad phrase encompassing all relevant innovations focusing on reducing resource consumption, environmental devastation, and human harm. Examples of GTI include technological research and development, technology-enabled production, social consumption research, and trash recycling (Yin et al., 2020). Unlike non-GTI, GTI may enhance the intermediate manufacturing process while lowering pollutants, thus reducing a company's overall operating costs and increasing EC (Cai et al., 2020). In addition, by using GTI, enterprises may increase resource efficiency and foster long-term growth (Hong et al., 2021). Thus, we hypothesize the following:

H5: GTI has a positive impact on EC.

2.2.6 Enterprise's ESG performance and green technology innovation

In their ESG research, most scholars have primarily concentrated on the market for enterprise operations, enterprise structure, leadership and ownership, and enterprise risk

and performance (Gillan et al., 2021). The stakeholder theory emphasizes the importance of stakeholders in creating company value, and it predicts that managing stakeholder relationships will be the key to business success. Promoting ESG development reduces the pressure on stakeholders and maintains long-term relationships with them (Zhang et al., 2020a). The good environmental performance of an enterprise indicates that the enterprise uses environmentally friendly materials for production and manufacturing (Ge et al., 2022). Consequently, businesses will be required to enhance their research and development expenditure and boost resource utilization throughout corporate manufacturing (Xu et al., 2021).

Enterprises will project a positive picture of green responsibility practice to the outside world if they actively engage in environmental protection and disseminate information related to their environmental-friendly operations. As a result, businesses could attract investors and receive significant financial aid from the government (Xiao et al., 2022), to support the research and development of enterprises to stimulate their innovation potential. To foster high-quality research and development capabilities and enter and strengthen its own GTI, an enterprise must integrate emerging technologies into its key business processes and practices (Huang et al., 2023). A sound enterprise management mechanism will help reduce coordination costs and lessen the risks of major enterprise innovation decisions (Ge et al., 2022). Therefore, enterprises are incentivized to live up to stakeholder expectations by upholding their social commitments, enhancing environmental protection, and standardizing enterprise governance. They are also incentivized to assist other businesses in obtaining the funding they require for technological innovation to increase their competitiveness. Based on this, we hypothesize the following:

H6: Enterprise's ESGP has a positive impact on GTI.

2.2.7 Enterprise's ESG performance as a mediator

The higher an organization's ESG rating, the lower its investment portfolio risk is. Due to the investment it will get from stakeholders, businesses will be able to improve their resources, advance their technology, and gain a competitive advantage (Lee et al., 2021). Enterprise environmental governance, social responsibility fulfillment, and enterprise governance may all be affected by the growth and deployment of digital technology by businesses, boosting stakeholder ties, attracting investment, and enhancing the EC.

As per the prior literature on the ESG performance of enterprises, only a few scholars discuss ESGP as a mediating variable. For instance, Xu et al. (2021) recently found that green innovation is improved with a stronger ESGP. The new generation of information technology can break innovation boundaries, reduce transaction costs, improve collaborative innovation, and thus promote enterprise GTI (Zhao & Qian, 2023). Therefore, enterprises are motivated to boost their investment in research and development funds, extend DTA to promote their own ESGP, decrease the distance with stakeholders to get more resources, and promote the GTI of their enterprises. Therefore, we hypothesize the following:

H7: An enterprise's ESGP has a mediating effect on the relationship between DTA and EC.

H8: An enterprise's ESGP plays a mediating effect on the relationship between DTA and GTI.

2.2.8 Green technology innovation as a mediator

AI, cloud computing, and big data analytics are examples of digital technologies impacting an enterprise's innovative business practices regarding waste reduction, green manufacturing, and efficient manufacturing. These technologies also increase the enterprise's utilization rate and support sustainable growth (Xue et al., 2022). Enterprise GTI will be supported by digital development to help boost enterprise performance and green transformation (Zhao & Qian, 2023), thereby enhancing the competitiveness of sustainable development initiatives of enterprises (Ashtianipour & Zandhessami, 2015). Therefore, DTA can promote GTI, thereby improving EC.

Enterprises with good ESGP will foster closer relationships with stakeholders, thus gaining more capital and resources, which allows them to expand their GTI by removing financial restrictions. At the same time, the greater the capabilities of an enterprise in fostering GTI, the enterprise will have good innovation output and transformation ability. Such capabilities make enterprise development meet the demand of environmental regulation, reduce the impact of environmental risk, and provide green products to make the enterprise always occupy a dominant position in the fiercely competitive marketplace. By formulating reasonable technological innovation strategies, enterprises use green innovation to achieve green sustainable development (Su & Li, 2021), thus strengthening the relationships with their stakeholders to obtain more resources and improve their EC. Therefore, we hypothesize the following:

H9: GTI mediates the impact of DTA on EC.

H10: GTI mediates the impact of an enterprise's ESGP on EC.

2.2.9 Enterprise scale and cash holding as a moderator

ES initially manifests itself in the enterprise's workforce. Different sizes of enterprises have different benefits in the DTA development process, as varying firm sizes will result in varying resources and capabilities (Del Giudice et al., 2021). Generally speaking, the larger the ES, the easier it will be to recruit and keep top-tier scientific and technological talent, the easier it will be for the enterprise to innovate with its human capital reserves, and the more positive adjustment effect the EC will have. This suggests that large-scale enterprises can become competitive compared to their small-scale counterparts in the face of a generally stable marketplace (Annarelli et al., 2021). In addition, large-scale enterprises take advantage of having a quality human capital and knowledge base and a more mature internal management and learning management system (Yusof et al., 2020), which can be used to develop and adopt digital technology to solve difficulties more flexibly in par with the rapid technological changes (Wang et al., 2022a). At the same time, it will increase the workforce efficiency of traditional manufacturing firms, thus strengthening the competitive market positioning.

Because cash is the most liquid asset in an enterprise's resource portfolio, the enterprise's cash policy is crucial to the enterprise's financial strategy (Zhang et al., 2022). In the meantime, an enterprise's cash flow is of great strategic significance for the enterprise's

daily operations and sustainable development initiatives, which can respond to the uncertainty and economic crisis of the modern marketplace (Liao et al.). Innovation activities rely on the cash holding (CH) of corporations due to the high cost of GTI (Alam et al., 2022). Therefore, when enterprises have large CH, they can devote more to GTI activities and then will transform into EC. Thus, we hypothesize the following:

H11: ES plays a positive moderating effect on the relationship between DTA and EC.

H12: CH plays a positive moderating effect on the relationship between GTI and EC.

In summary, the hypothesized research model of this paper is shown in Fig. 1.

3 Methodology

3.1 Sampling and data collection

According to the China Securities Regulatory Commission (CSRC), industry classification standards not only consider ESG scores in the Wind database since 2018 but also consider the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) as two economic growth poles in China, playing an important role in China's economic development (Wang et al., 2022c). Therefore, this paper selects China's A-share listed companies in YRD and PRD from 2018–2020 as the sample. The sample used for this paper is selected as follows to guarantee the reliability and integrity of the data evaluated: (1) Exclude the companies with an abnormal business status (ST and *ST) during 2018–2020. (2) Exclude the seriously lacking ESGP during the observation period. (3) All continuous variables are winsorized

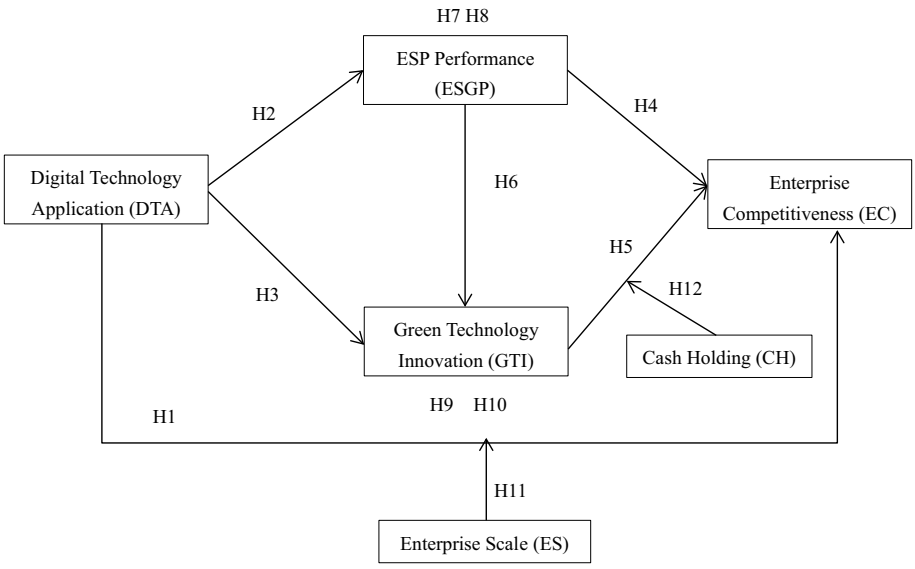

Fig. 1 Hypothesis research model

at the upper and lower 1% significance levels. In the end, 3,267 effective observations were obtained from 1089 listed companies. Raw data were processed by manual curation, and the empirical analysis was conducted using Stata17 software.

With the help of Python text mining, the count frequency of keywords related to DTA is obtained from the annual reports of the selected companies. Green patent data refer to the green list of international patent classifications published by the World Intellectual Property Organization (WIPO), which is selected in the patented database of the China National Intellectual Property Administration. Other data were extracted from the Wind and China Stock Market & Accounting Research (CSMAR) databases and hand-organized.

3.2 Measurement development

3.2.1 Enterprise competitiveness

In this paper, EC is the explained variable and measured, referring to Su and Li (2021). Accordingly, this article employs the asset contribution rate of enterprises to quantify EC since it can accurately depict the business performance and competitiveness level of businesses. The specific calculation formula is as follows:

$$\mathrm{EC} = (\text{total profit} + \text{total tax} + \text{interest expense})/\text{average total assets} \tag{1}$$

3.2.2 Digital technology application

In this paper, the explanatory variable is DTA. The annual reports of the selected listed companies objectively reflect the business development and their status of reforming the enterprise (Pivac et al., 2017). Referring to Li and Shen (2021), this paper selects the number of keywords related to digital technology in the annual report published by an enterprise to measure DTA. These are the precise operations: First, manually organized the annual reports and various regular and temporary announcements of Chinese A-share listed companies. It then used Python text analysis technology to search keywords related to big data technology, artificial intelligence technology, DTA, and cloud computing technology and, finally, organized the frequency of keywords. A detailed description of related variables is given in Table 1.

3.3 Data analysis

The following measuring model is created to investigate how DTA affects EC:

$$\mathrm{Com}_{it} = \beta_0 + \beta_1 \mathrm{Digit}_{it} + \beta_2 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{2}$$

The following measuring model is created to investigate how DTA affects an enterprise's ESGP:

$$\mathrm{ESG}_{it} = \alpha_0 + \alpha_1 \mathrm{Digit}_{it} + \alpha_3 \sum \mathrm{Contral}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{3}$$

The following measuring model is created to investigate how DTA affects GTI:

Table 1 Variable and measures

Type of variable	Variable name	Variable symbol	Variable declaration
Dependent variable	EC	Com	(Total profit + total tax + interest expense)/average total assets
Independent variable	DTA	Digit	Ln(the frequency of keywords related to Digital technology application on the annual report text + 1)
Mediator variable	ESGP	ESG	ESG composite score in the Wind database
	GTI	Green	Number of green patent applications
Moderator variable	ES	Scale	Ln(number of employees)
	CH	Cash	Cash and cash equivalents/Total assets
Control variables	Asset-liability ratio	Lev	Total liabilities / total assets
	Enterprise years	Age	Ln (years + 1)
	Capital-intensity	Ci	Ln(Total Assets / Staff Number)
	Return on assets	ROA	Net profit / Total assets
	Proportion of fixed assets	T	Net fixed assets / Total assets
	Development ability	Dev	(Current main income-previous main income) / previous operating income
	Number of board members	DN	Number of the Board of Directors
	CEO duality	D	Whether the chairman and the general manager are the same person; 0: No;1: Yes

$$\text{Green}_{it} = d_0 + d_1 \text{Digit}_{it} + d_2 \sum \text{Control}_{it} + \gamma_t + \text{Ind}_{it} + \eta_i + \varepsilon_{it} \quad (4)$$

The following measuring model is created to investigate how an enterprise's ESGP affects its EC:

$$\text{Com}_{it} = g_0 + g_1 \text{ESG}_{it} + g_4 \sum \text{Control}_{it} + \gamma_t + \text{Ind}_{it} + \eta_i + \varepsilon_{it} \quad (5)$$

The following measuring model is created to investigate how GTI affects EC:

$$\text{Com}_{it} = j_0 + j_1 \text{Green}_{it} + j_2 \sum \text{Control}_{it} + \gamma_t + \text{Ind}_{it} + \eta_i + \varepsilon_{it} \quad (6)$$

The following measuring model is created to investigate how an enterprise's ESGP affects GTI:

$$\text{Green}_{it} = h_0 + h_1 \text{ESG}_{it} + h_4 \sum \text{Control}_{it} + \gamma_t + \text{Ind}_{it} + \eta_i + \varepsilon_{it} \quad (7)$$

In the formulas above, i is the enterprise; t is the year; Com_{it} is the dependent variable which is the EC of the year; β_0 is the intercept item; Digit_{it} is the primary item of DTA; Control_{it} is the additional factors within the control that might have an impact on EC; γ_t is the time fixed effect to control other unobservable factors that change over time; Ind_{it} is the industry fixed effect; η_i is the regional fixed effect; and ε_{it} is the random error item.

4 Results analysis

4.1 Descriptive statistics

Table 2 displays the descriptive statistics regarding the key constructs used in this paper. The largest standard deviation is from GTI and EC. It shows that the GTI level and

Table 2 Descriptive statistics of the variables

Variable	*N*	Mean	Std	Min	Max
Com	3,267	−1.335	10.270	−52.560	20.620
Digit	3,267	1.306	1.202	0	4.331
ESG	3,267	6.087	0.788	4.610	8.350
Green	3,267	5.318	25.330	0	762
Scale	3,267	7.756	1.245	5.106	11.350
Cash	3,267	0.196	0.321	0.005	2.701
Lev	3,267	43.880	19.850	7.798	91.540
Age	3,267	3.076	0.261	2.398	3.664
Ci	3,267	−3.716	1.220	−7.285	−0.016
ROA	3,267	0.034	0.078	−0.336	0.232
T	3,267	0.224	0.346	0.001	2.649
Dev	3,267	0.196	0.568	−0.660	3.942
DN	3,267	8.384	1.733	5	18
D	3,267	0.334	0.472	0	1

competitiveness differ significantly among the enterprises. Although the enterprise size and CH fluctuate little overall, they have specific differences.

4.2 Baseline regression results

For the regression analysis, combining with the results of F test (F (1088, 2169) = 9.44, p < 0.001), LM test (chibar2 = 1676.19, p < 0.001), and Hausman test (chi2 = 120.64, p < 0.001), the original hypothesis was rejected, the fixed effects model was chosen. Table 3 displays the regression's findings. The regression's findings indicate that: (1) DTA significantly and positively affects EC, so H1 is assumed to be established. (2) DTA positively affects the enterprise's ESGP and GTI at the significance level of 5% and 1%, respectively,

Table 3 Baseline regression result

Variable	Com (1)	ESG (2)	Green (3)	Com (4)	Com (5)	Green (6)
Digit	0.5771***	0.0260**	1.6367***			
	(0.1531)	(0.0122)	(0.4185)			
ESG				-0.9176***		2.6715***
				(0.2217)		(0.6061)
Green					−0.0071	
					(0.0065)	
Lev	0.2168***	0.0032***	0.2000***	0.2222***	0.2206***	0.1979***
	(0.0098)	(0.0008)	(0.0267)	(0.0098)	(0.0099)	(0.0267)
Age	−0.6408	0.2917***	6.4832***	−0.2741	−0.4978	5.9619***
	(0.6686)	(0.0535)	(1.8284)	(0.6710)	(0.6709)	(1.8347)
Ci	−1.9446***	0.0039	1.3396***	−1.9970***	−1.9898***	1.1835**
	(0.1825)	(0.0146)	(0.4990)	(0.1818)	(0.1825)	(0.4972)
ROA	7.6640***	0.8186***	23.3722***	8.5237***	7.9365***	21.4685***
	(2.1886)	(0.1750)	(5.9851)	(2.1950)	(2.1982)	(6.0015)
T	−2.3747***	0.0882*	5.1676***	−2.5000***	−2.5399***	4.3945***
	(0.6043)	(0.0483)	(1.6524)	(0.6019)	(0.6039)	(1.6458)
Dev	−0.7796***	−0.0446*	−0.8759	−0.7740***	−0.7403**	−0.6357
	(0.2904)	(0.0232)	(0.7941)	(0.2902)	(0.2908)	(0.7934)
DN	0.4816***	0.0498***	0.4799*	0.5485***	0.5058***	0.4020
	(0.1042)	(0.0083)	(0.2850)	(0.1046)	(0.1044)	(0.2861)
D	−1.2347***	−0.0777***	2.7231***	−1.2851***	−1.1949***	2.9851***
	(0.3549)	(0.0284)	(0.9704)	(0.3551)	(0.3560)	(0.9708)
_cons	−20.0597***	4.5974***	−27.2821***	−15.8291***	−20.2418***	−39.5324***
	(2.2833)	(0.1826)	(6.2441)	(2.4995)	(2.2948)	(6.8341)
Year/ Industry/ region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	3267	3267	3267	3267	3267	3267
R^2	0.277	0.215	0.110	0.278	0.274	0.111

Robustness standard error in parentheses. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.the same in the following tables

so we assume that H2 and H3 are established. (3) Enterprise's ESGP has a significant negative impact on EC, so it is assumed that H4 is untrue. (4) GTI does not significantly impact EC, so it is assumed that H5 is untrue. (5) Enterprise's ESGP has a significant positive impact on GTI, so H6 is assumed to be established.

4.3 Robustness tests

In order to test the robustness of the above findings, the following method is used in this paper. If the results of the robustness test are consistent with the conclusions that have been drawn, the above conclusions are considered reliable.

First, the endogeneity test (2SLS) was performed. Although the fixed effects of time, industry, and province are controlled in the benchmark regression model, there may also be

Table 4 The results of robustness test of DTA and EC

Variable	Instrumental variable method	Replace independent variables	OLS model
	(1)	(2)	(3)
Digit	0.5228**		0.5771***
	(0.2078)		(0.1531)
Digit			
Is_Digit		1.0637**	
		(0.4417)	
Lev	0.2296***	0.2175***	0.2168***
	(0.0113)	(0.0098)	(0.0098)
Age	−0.9649	−0.5316	−0.6408
	(0.7865)	(0.6690)	(0.6686)
Ci	−1.8378***	−1.9801***	−1.9446***
	(0.2114)	(0.1823)	(0.1825)
ROA	9.8136***	7.6639***	7.6640***
	(2.5893)	(2.1917)	(2.1886)
T	−1.9388***	−2.5152***	−2.3747***
	(0.6908)	(0.6032)	(0.6043)
Dev	−0.6693**	−0.7390**	−0.7796***
	(0.3307)	(0.2905)	(0.2904)
DN	0.4998***	0.4994***	0.4816***
	(0.1223)	(0.1042)	(0.1042)
D	−0.8205**	−1.1991***	−1.2347***
	(0.4098)	(0.3553)	(0.3549)
_cons	−24.6704***	−20.8074***	−25.2910***
	(4.0889)	(2.3079)	(2.7124)
Year/Industry/region fixed effect	Yes	Yes	Yes
N	2178	3267	3267
R^2	0.3156	0.2750	0.2769
LM Statistics	1536.565***		
Cragg−Donald Wald F statistic	4999.435		

potential endogenous problems such as reverse causality. Therefore, the instrumental variable method is selected for testing. The lag phase of the DTA is chosen as the instrumental variable in this research, following the convention of most scholars (Hill et al., 2021). The test results are shown in column (1) of Table 4. The results showed that the LM statistic values passed the significance test and the Cragg–Donald Wald F statistic was greater than 10, indicating that there were no inadequately identified or weakly identified instrumental variables after the application of instrumental factors. Additionally, the link between DTA and EC is still in good agreement with the current research findings. This further confirmed the fact that this study's result is reliable.

Secondly, the independent variable is replaced (Is_Digit) based on whether the DTA keywords appear in the enterprise annual report (Caliskan et al., 2021). If it appears, it is 1; if there is no appearance, it is 0. As can be seen in column (2) of Table 4, the regression results are consistent with the initial results, so the conclusion is robust.

Finally, to further assess the reliability of the findings, the measurement methodology is changed. Referring to Luo et al. (2023), this paper considers replacing the original model with the OLS model with fixed effects. The test results in column (2) of Table 4 indicate that the conclusion is robust.

The robustness test for the remaining direct effects is performed as follows. First, the explanatory variable in Eq. (2) lagged for one period and performed the above regression while considering the explanatory variable's lag impact on the explained variable. The results are shown in column (1) of Table 5, and the regression results are the same as those indicated above. Thus, the reliability of the results is further confirmed.

Secondly, when the initial model was replaced, formula (4) used the OLS model for regression, and the regression results are listed in column (3) of Table 5. As the results show, an enterprise's ESGP still significantly and negatively affects its EC.

Finally, by changing the variables referring to Yi et al. (2023), GTI in Eqs. (3), (5), and (6) were replaced with the number of green invention patents (Green_I). The regression results are shown in columns (2), (4), and (5) in Table 5. The findings indicate that the initial conclusions are aligned with regression findings, demonstrating the conclusion's relative robustness.

4.4 Regression results for assessing the mediating effects

The positive relationship between DTA and EC has been tested above, but the transmission mechanism between the two has not been further discussed. Therefore, the following measurement model is created using the previously developed model as the foundation.

$$\mathrm{Com}_{it} = b_0 + b_1 \mathrm{Digit}_{it} + b_2 \mathrm{ESG}_{it} + b_3 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{8}$$

$$\mathrm{Green}_{it} = e_0 + e_1 \mathrm{Digit}_{it} + e_2 \mathrm{ESG}_{it} + e_3 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{9}$$

$$\mathrm{Com}_{it} = f_0 + f_1 \mathrm{Digit}_{it} + f_2 \mathrm{Green}_{it} + f_3 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{10}$$

$$\mathrm{Com}_{it} = i_0 + i_1 \mathrm{ESG}_{it} + i_2 \mathrm{Green}_{it} + i_3 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{11}$$

Table 5 Results of the remaining relationships' robustness test

Variable	Digit- > ESG l.Digit	Digit- > Green Replace variable	ESG- > Com OLS	Green- > Com Replace variable	ESG- > Green Replace variable
	(1)	(2)	(3)	(4)	(5)
l.Digit	0.0303**				
	(0.0149)				
Digit		0.2515**			
		(0.1020)			
ESG			−0.9176***		−0.9176***
			(0.2185)		(0.2217)
Green				−0.0376	
				(0.0266)	
Lev	0.0032***	0.0278***	0.2222***	0.2202***	0.2222***
	(0.0010)	(0.0065)	(0.0096)	(0.0098)	(0.0098)
Age	0.2870***	1.8956***	−0.2741	−0.4729	−0.2741
	(0.0665)	(0.4457)	(0.6615)	(0.6714)	(0.6710)
Ci	0.0009	0.3766***	−1.9970***	−1.9850***	−1.9970***
	(0.0178)	(0.1217)	(0.1793)	(0.1825)	(0.1818)
ROA	0.8491***	2.0472	8.5237***	7.8469***	8.5237***
	(0.2189)	(1.4590)	(2.1639)	(2.1933)	(2.1950)
T	0.0772	1.0964***	−2.5000***	−2.5347***	−2.5000***
	(0.0583)	(0.4028)	(0.5934)	(0.6037)	(0.6019)
Dev	−0.0473*	0.0723	−0.7740***	−0.7316**	−0.7740***
	(0.0279)	(0.1936)	(0.2861)	(0.2907)	(0.2902)
DN	0.0522***	0.1715**	0.5485***	0.5087***	0.5485***
	(0.0103)	(0.0695)	(0.1032)	(0.1044)	(0.1046)
D	−0.0661*	0.6454***	−1.2851***	−1.1900***	−1.2851***
	(0.0346)	(0.2366)	(0.3500)	(0.3559)	(0.3551)
_cons	4.5760***	−7.3423***	−21.0705***	−20.3239***	−21.0705***
	(0.2272)	(1.5222)	(2.8751)	(2.2960)	(2.9164)
Year/Industry/ region fixed effect	Yes	Yes	Yes	Yes	Yes
N	2178	3267	3267	3267	3267
R^2	0.2195	0.0796	0.0434	0.2742	0.2776

Based on Eqs. (7), (8), (9), and (10), benchmark regression was performed to assess the mediating effects, and the results are shown in Table 6. Regression results show that: (1) the direct and indirect effects between DTA and EC differ, indicating a suppressing effect of 0.04. This means that the more the ESGP more investment can be made; thus, H7 is not established. (2) The link between DTA and GTI is partially mediated by ESGP, which has a considerable mediating effect of 0.12. Thus, H8 is established. (3) The indirect impact is insignificant. Thus, to assess the role of GTI as the mediating variable in the relationship between DTA and EC necessitates the Bootstrap test.

Table 6 The benchmark regression results for assessing the mediating effects

Variable	ESGP as a mediator		GTI as a mediator	
	Com	Green	Com	
	(1)	(2)	(3)	(4)
Digit	0.6019***	1.5693***	0.5916***	
	(0.1527)	(0.4177)	(0.1534)	
ESG	−0.9505***	2.5857***		−0.9041***
	(0.2213)	(0.6053)		(0.2224)
Green			−0.0088	−0.0050
			(0.0065)	(0.0065)
Lev	0.2198***	0.1917***	0.2185***	0.2232***
	(0.0098)	(0.0267)	(0.0099)	(0.0099)
Age	−0.3635	5.7288***	−0.5835	−0.2440
	(0.6699)	(1.8320)	(0.6698)	(0.6722)
Ci	−1.9409***	1.3296***	−1.9328***	−1.9910***
	(0.1820)	(0.4977)	(0.1827)	(0.1820)
ROA	8.4421***	21.2556***	7.8706***	8.6321***
	(2.1901)	(5.9894)	(2.1935)	(2.1995)
T	−2.2909***	4.9396***	−2.3291***	−2.4778***
	(0.6029)	(1.6488)	(0.6051)	(0.6027)
Dev	−0.8220***	−0.7607	−0.7874***	−0.7773***
	(0.2898)	(0.7925)	(0.2904)	(0.2902)
DN	0.5290***	0.3511	0.4859***	0.5505***
	(0.1045)	(0.2859)	(0.1043)	(0.1047)
D	−1.3085***	2.9240***	−1.2106***	−1.2700***
	(0.3543)	(0.9689)	(0.3552)	(0.3556)
_cons	−15.6899***	−39.1695***	−20.3009***	−16.0287***
	(2.4941)	(6.8207)	(2.2898)	(2.5128)
Year/Industry/region fixed effect	Yes	Yes	Yes	Yes
N	3267	3267	3267	3267
R^2	0.2811	0.1154	0.2774	0.2777

4.5 Test for assessing mediating effect

To evaluate the aforementioned mediating effects, this article uses the Bootstrap statistical method, where the sampling 1,000 times is tested, and the confidence range of the deviation correction is used. The test results in Table 7 show that the path with ESGP as the mediator variable contains no 0 in the confidence interval, once again proving that hypothesis H8 holds true. The confidence interval of the mediating test of GTI between DTA and EC does not include 0, but because the direct effect and indirect effect have different symbols, there is a suppressing effect which is 0.02; The confidence interval of GTI between an enterprise's ESGP and EC includes 0, indicating that GTI does not play a mediating role between enterprise's ESGP and EC, so hypotheses 9 and 10 are untrue.

Table 7 Results of the bootstrap test

Path	Effect Type	Frequency in sampling	Estimated coefficient	Standard error	Upper limit of the 95% confidence interval	Lower limit of the 95% confidence interval
Digit- > ESG- > Green	Direct effect	1000	1.5693	− 0.0164	0.4496	2.5640
	Indirect effect	1000	0.0673	− 0.0044	0.0214	0.1603
Digit- > Green- > Com	Direct effect	1000	0.5916	0.1396	0.3591	0.7440
	Indirect effect	1000	− 0.0145	0.0068	− 0.0308	− 0.0027
ESG- > Green- > Com	Direct effect	1000	− 0.9040	0.1746	− 1.2817	− 0.4759
	Indirect effect	1000	− 0.0135	0.0087	− 0.0311	0.0037

4.6 Regression results for assessing the moderating effect

The following measurement model is designed to assess the moderating effect of ES and CH.

$$\mathrm{Com}_{it} = \phi_1 + \phi_2 \mathrm{Digit}_{it} + \phi_3 \mathrm{Scale} + \phi_4 X\_Z_1 + \phi_5 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{12}$$

$$\mathrm{Com}_{it} = \omega_1 + \omega_2 \mathrm{Green}_{it} + \omega_3 \mathrm{Cash} + \omega_4 X\_Z_2 + \omega_5 \sum \mathrm{Control}_{it} + \gamma_t + \mathrm{Ind}_{it} + \eta_i + \varepsilon_{it} \tag{13}$$

Among them, X_Z_1 represents the intersection of DTA and ES, and X_Z_2 represents the intersection of GTI and CH. This paper first decentralized DTA, GTI, and the two moderating factors to prevent the potential multicollinearity issues. To avoid the problem of covariance between the interaction term and the original variables, the continuous variables are centralized in this paper.

As demonstrated by the test outcomes indicated in Table 8, the multiplication term,X_Z_1, coefficient is significant, and it is the opposite of the symbol of DTA, which shows ES negatively moderates the relationship between DTA and EC. Therefore, H11 is rejected. The multiplication,X_Z_2, coefficient is not significant, indicating that CH does not moderate the interaction between GTI and EC. Thus, H12 is also rejected.

4.7 Heterogeneity analysis

The above research mainly focuses on assessing the overall impact of DTA on EC. However, the DTA deployment and adoption levels of listed companies selected from YRD and PRD differ. Therefore, this paper repeated the above regression model to YRD and the PRD, respectively. The results in Table 9 indicate differences between YRD and PRD in some aspects.

As seen in the regression results, firstly, YRD and PRD differ in some aspects, but not significantly. Secondly, although the ESGP of an enterprise has a negative impact on its EC for the companies selected from YRD, the impact is less than the same for the companies selected from the PRD. Thirdly, the DTA of enterprises in YRD and PRD significantly impacted the enterprise's ESGP. However, the coefficient for the companies selected from PRD is greater than those selected from YRD. In the end, the ESGP of the listed companies in PRD significantly affected GTI, while it was not the same for the companies selected from YRD.

5 Discussion and conclusion

5.1 Result discussion

This study uses the DCV and stakeholder theory as the theoretical foundation to examine the linkages between DTA and EC. To examine the mechanism through which the DTA of an enterprise influence its EC, we introduce the ESGP, GTI, ES, and CH.

Table 8 Results of the moderating effect tests

Variable	Com	
	(1)	(2)
Digit	0.2576*	
	(0.1496)	
Green		−0.0012
		(0.0161)
Scale	2.4717***	
	(0.1661)	
Cash		−1.9472***
		(0.7327)
X_Z_1	−0.2997***	
	(0.1078)	
X_Z2		−0.0086
		(0.0261)
Lev	0.1528***	0.2177***
	(0.0104)	(0.0099)
Age	−1.9256***	−0.5069
	(0.6522)	(0.6704)
Ci	−1.0282***	−2.1441***
	(0.1882)	(0.1914)
ROA	0.2395	8.4828***
	(2.1723)	(2.2065)
T	−2.3930***	−1.6564**
	(0.5838)	(0.6924)
Dev	−0.4377	−0.6856**
	(0.2817)	(0.2913)
DN	0.2294**	0.5173***
	(0.1024)	(0.1044)
D	−0.9710***	−1.1945***
	(0.3433)	(0.3559)
_cons	−26.3569***	−20.6053***
	(2.2455)	(2.2972)
Year/Industry/region fixed effect	Yes	Yes
N	3267	3267
R^2	0.3255	0.2756

1. DTA significantly influences EC, which shows that enterprises actively apply advanced digital technologies to enhance their competitiveness in the contemporary marketplace. The result is aligned with the findings of Hartono et al. (2020) and Ahmed et al. (2022), who also point out that advances in digital technology will help accelerate the digitalization process of companies and achieve increased competitiveness.
2. DTA significantly affects an enterprise's ESGP, indicating that developing and adopting sophisticated DTA will enhance its ESGP. The result is consistent with the findings of Wang et al. (2023) and Ren et al. (2023). The findings demonstrate that enterprises pri-

Table 9 The regression results for the heterogeneity analysis

Variable	ESG		Com		Green			
	YRD	PRD	YRD	PRD	YRD	PRD	YRD	PRD
Digit	0.0266	0.0124			0.7403**	2.2066**		
	(0.0173)	(0.0178)			(0.3008)	(0.8660)		
ESG			−0.4889*	−1.2408***			0.5677	4.9335***
			(0.2814)	(0.3690)			(0.4148)	(1.3171)
Lev	0.0027**	0.0052***	0.2394***	0.2065***	0.1206***	0.3141***	0.1215***	0.3026***
	(0.0011)	(0.0012)	(0.0127)	(0.0165)	(0.0187)	(0.0591)	(0.0187)	(0.0590)
Age	0.3084***	0.2494***	0.4509	−0.1118	0.3112	12.7400***	0.1782	11.7998***
	(0.0787)	(0.0762)	(0.9347)	(1.0378)	(1.3702)	(3.7014)	(1.3777)	(3.7041)
Ci	−0.0017	0.0018	−1.9021***	−2.3238***	1.6457***	1.5279	1.5792***	1.3082
	(0.0236)	(0.0197)	(0.2785)	(0.2662)	(0.4110)	(0.9567)	(0.4105)	(0.9503)
ROA	0.9388***	0.7438***	8.9297***	9.1561***	7.9094*	39.2692***	7.4041*	35.9720***
	(0.2512)	(0.2465)	(2.9811)	(3.3578)	(4.3716)	(11.9790)	(4.3941)	(11.9853)
T	0.1645	0.0758	1.1572	−2.7415***	0.7539	3.6414	−0.3677	2.6487
	(0.1619)	(0.0556)	(1.8917)	(0.7524)	(2.8170)	(2.7029)	(2.7883)	(2.6855)
Dev	−0.0095	−0.0956***	−1.1088***	−0.2793	0.6496	−2.4861	0.7080	−1.9088
	(0.0328)	(0.0334)	(0.3876)	(0.4552)	(0.5710)	(1.6250)	(0.5713)	(1.6248)
DN	0.0454***	0.0527***	0.5939***	0.5370***	0.5922***	0.4987	0.6180***	0.2384
	(0.0117)	(0.0121)	(0.1378)	(0.1653)	(0.2030)	(0.5874)	(0.2030)	(0.5899)
D	−0.1457***	−0.0173	−1.3804***	−0.8894	−1.0326	7.5271***	−0.8486	7.2880***
	(0.0386)	(0.0421)	(0.4575)	(0.5706)	(0.6722)	(2.0465)	(0.6743)	(2.0368)
Year/Industry/region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	4.5880***	4.6160***	−22.1572***	−14.9640***	−2.2552	−52.3748***	−4.7790	−74.0419***
	(0.2774)	(0.2592)	(3.5238)	(3.9098)	(4.8266)	(12.6001)	(5.1939)	(13.9554)

Table 9 (continued)

Variable	ESG		Com		Green			
	YRD	PRD	YRD	PRD	YRD	PRD	YRD	PRD
N	1839	1428	1839	1428	1839	1428	1839	1428
R^2	0.2358	0.2649	0.3139	0.2817	0.2261	0.1328	0.2243	0.1376

oritize lowering environmental pollution while concentrating on technical advancements and encouraging the establishment of enterprises with high quality. However, neither effect is significant in YRD and PRD. This is because of the benefit of economies of scale, which shows that the two regions together will play a greater role.

3. DTA significantly affects GTI. The result is the same as Li and Wang (2022). Because digital technology reduces the uncertainty inherently associated with the innovation process, it leads to higher economic performance (Lehrer et al., 2018). This study also finds that the said positive impact on the listed companies in PRD is higher than that of the listed companies in YRD, indicating that the DTA of listed companies in PRD has a more significant influence in fostering GTI.
4. An enterprise's ESGP has a significant negative impact on EC. However, the result is different from the study of Rabaya and Saleh (2022), who use international firms as an example to explore, while this paper is based on Chinese firms, and the difference in the selected objects will lead to differences in the conclusions.
5. This study further proves that GTI has no significant impact on EC. There is no unanimous conclusion on the impact of GTI on EC, with some scholars arguing that GTI has a positive impact on EC, profitability, and enterprise performance (Li et al., 2019) and others arguing the opposite insight (Climent & Soriano, 2011). The findings of this paper complement existing research by suggesting that when enterprises emphasize GTI, they tend to make more investments, thereby reducing their EC. The findings also discovered that the said negative impact on the listed companies in YRD is lower than those listed in the PRD. This shows that the listed companies in YRD pay more attention to their ESG development initiatives, reducing their competitiveness.
6. An enterprise's ESGP has a significant positive impact on GTI. This finding is similar to the study of Xu et al. (2021) and In et al. (2019). Enterprises with strong ESGP can boost enterprise value (Thompson & Garbacz, 2011). Therefore, stakeholders will be more inclined to invest in such enterprises to boost the growth of GTI and acquire additional resources (Li et al., 2023; Xi & Xu, 2014). This study further discovered that the listed companies in PRD follow the said significant positive impact, while those listed in YRD do not. It shows that an enterprise's ESGP is relatively well implemented in the listed companies in the PRD, and the listed companies in PRD can make good use of their own ESGP to foster GTI.
7. This study reveals the mediating effects of an enterprise's ESGP and GTI on the relationship between DTA and EC. These are novel findings. The mediating effect of an enterprise's ESGP is reflected through the suppressing effect on the relationship between DTA and EC. This is because ESGP will not directly impact EC; thus, the mediating effect is not statistically significant. At the same time, ESGP plays a significant mediating effect in the relationship between DTA and GTI, which shows that DTA can improve the enterprise GTI, enhancing its ESGP. Moreover, GTI has a suppressing effect on the relationship between DTA and EC. It may be because the impact of GTI on EC has a lagging effect, so it will not significantly impact EC in the current circumstances. Meanwhile, the findings indicate that GTI does not mediate an enterprise's ESGP and EC relationship.
8. This study also reveals the moderating effect of ES and CH on the relationship between DTA and EC. As the findings indicate, ES negatively moderates the impact of the DTA on EC. This is because the larger the enterprise, the weaker the flexibility and responsiveness (Ardito et al., 2021). As a result, due to the early stage's overwhelming input, the EC may not be effectively converted into DTA with time but instead may be reduced. Moreover, it was found that CH does not moderate the relationship between

GTI and EC. The explanation might be that although enterprises recently started making significant investments in GTI operations, the results of innovation activities are highly unpredictable. Consequently, enterprise financial asset speculation is more likely to be difficult (Palmer et al., 1995). However, Deloof (2001) study found that in an enterprise, if the chief executive officer (CEO)'s incentives are not aligned with stakeholder incentives, high cash reserves can create agency conflicts between CEOS and stakeholders. Therefore, in that case, the enterprise cannot gain the support of stakeholders. Therefore, based on the above argument, it can be justified why CH does not moderate the relationship between GTI and EC.

5.2 Conclusion

In order to analyze how the DTA of an enterprise influences its EC and how that interrelationship has changed over time, this research uses data from A-share listed companies in YRD and PRD from 2018 to 2020. To make that investigation robust, this article also investigates the moderating effects of ES and CH and the mediating effects of DTA and GTI on the relationship between DTA and EC.

5.2.1 Theoretical contributions

Based on DCV and stakeholder theory, this paper investigates the relationship between DTA and EC in firms by empirically examining the intervening variables that may affect this relationship. The theoretical contributions of this paper are as follows:

First, previous studies have mainly examined the relationship between DTA and EC in different research contexts. However, few studies have comprehensively examined the relationship between DTA and EC in firms by considering possible intervening variables in the dual contexts of green transformation and digital transformation. Therefore, this study complements the existing research on DTA and EC and provides a better understanding in response to the twin transitions. This study shows that a firm's DTA can enhance a firm's EC and improve its ESGP through profit maximization, rational allocation of resources, and management of multi-stakeholder interests (Gao et al., 2021).

Second, this study has expanded the scope of existing literature on investigating the relationship between DTA and EC by considering ES and CH as potential moderating variables that can influence the said relationship. Most prior studies have used ES and CH as control variables, and only a few have used them as moderating variables. This paper has found that ES has a negative moderating effect when the lower development of DTA within an enterprise. However, contrary to the expectation, CH does not moderate the relationship between GTI and EC, supporting the existing literature (Deloof, 2001).

Third and most importantly, although there are many studies on ESGP and GTI, most used ESGP and GTI as independent or dependent variables. Only a few scholars used ESGP and GTI as mediating variables in their studies. This study has contributed to addressing this void by examining the relationship between an enterprise's DTA and EC by considering ESGP and GTI as potential mediators. In par with the expectation, the empirical findings reveal that ESGP and GTI mediated the relationship between an enterprise's GTA and ECD. Moreover, an enterprise's ESGP can significantly positively foster GTI. Furthermore, an enterprise can stimulate the capability of GTI by enhancing ESGP, which shows that DTA can not only directly influence GTI but also indirectly impact GTI by improving ESGP.

5.2.2 Practical contributions

The findings of this paper offer several significant implications for managers and industry practitioners.

First, this study explains the impact of a firm's DTA on its EC by considering potential intervening variables such as ESGP, GTI, ES, and CH. Therefore, in the context of sustainable development, enterprise managers should recognize the important role of digital development and green development and should actively carry out activities such as digital technology training and training on applying advanced digital technologies to enhance EC. On the one hand, it breaks the original production and operation mode of the traditional manufacturing industry. It improves the willingness and confidence of enterprises to implement digital transformation to achieve green manufacturing. On the other hand, the collaborative, predictive, and intelligent analysis of digital technology will fully penetrate the whole process of green design, green production, processing, and market value transformation of enterprises, accelerating the promotion of green innovation technology. It further improves the collaborative innovation ability of enterprises by allowing deep integration of digital development and green development, thus allowing organizations to achieve the goals of energy saving, carbon emission reduction, and competitiveness enhancement.

Second, managers should pay attention to the construction of talents by stimulating the green innovation ability of enterprises, accelerating the synergistic development of talent construction and digital technology, and thus fundamentally promoting GTI. In addition, enterprise managers should also see the negative regulating effect of ES and pay attention to controlling the number of employees in enterprises to meet the demand for talent. Large enterprises should focus on appropriately streamlining their employees to make their enterprises more agile. In contrast, small enterprises should focus on the application of digital technology so that it can play the best role. What's more, the government can appropriately encourage small-scale enterprises to enhance the practical effects of their digital technology applications.

Third, when enterprises conduct ESG activities and invest in green innovation activities, they should consider the current cost issues and sustainable returns from them. In addition, enterprise managers should enhance their awareness of ESG concepts and recognize that by improving ESGP, enterprises can strengthen their GTI capabilities. Enterprise managers should designate a complete ESG disclosure system and actively participate in ESG activities to enhance the reputation of the enterprise to transmit information about enterprise's environment, social responsibility, and enterprise governance to the capital market, which can reduce friction in capital allocation, solve financing problems, and fundamentally promote green innovation in enterprises.

Finally, based on regional differences, local enterprises should establish regulations considering their unique traits and local circumstances to capitalize on their unique capabilities fully. Listed companies in YRD and PRD should pay attention to their ESG activities concerning social responsibilities, environmental and internal enterprise governance and link ESGP with green innovations. When an enterprise does it in the long-term, its EC will be improved. Listed companies in YRD and PRD should focus on their own ESG activities concerning social responsibilities and environmental and internal enterprise governance and link ESGP with green innovations. When an enterprise does it in long-term, its EC will be improved.

5.2.3 Limitations and future research directions

As with any empirical research study, this paper has shortcomings that open up possibilities for future studies.

The first limitation is caused by the data used in this study. Due to the issues in accessing reliable and updated data, this study adopts data from listed companies in the China YRD and PRD from 2018–2020. Therefore, the findings may not be generalizable to all enterprises in China. Hence, more studies are required to investigate how the DTA of an enterprise influence its EC by considering a broader sample, particularly from different regions within the country.

The second limitation is associated with the indicators used to measure the key constructs of the study. The number of keywords that appeared in the enterprise annual report is used in this study to gauge an enterprise's DTA. However, other areas of a company's operations also may reflect its DTA development and adoption. Future researchers can think about using more robust measurement scales to measure an enterprise's DTA. Third, the cross-sectional survey design used in this study restrained the inferences drawn about causality and interconnections among the concepts of interest. Thus, future research could collect data about an enterprise's DTA at time 1, ESGP and GTI at time 2, and finally, EC at time 3. Such a cross-lagged panel analysis would allow a more precise understanding of relationships between constructs.

Finally, this study has considered only ESGP and GTI as mediators in the relationship between DTA and EC. Further, ES and CH have only been considered moderators. However, some potential mediators and moderators can intervene in this relationship that this paper has not studied. Consequently, future researchers can consider expanding this model by incorporating possible intervening variables into this model.

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Declarations

Conflict of interest The authors declare no conflict of interest.

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References

Adomako, S., & Mai Dong, T. (2022). Sustainable environmental strategy, firm competitiveness, and financial performance: Evidence from the mining industry. *Resources Policy, 75*. https://doi.org/10.1016/j.resourpol.2021.102515

Ahmed, R. R., Streimikiene, D., Soomro, R. H., & Streimikis, J. (2022). Digital transformation and industry 4.0 initiatives for market competitiveness: Business integration management model in the healthcare industry. *Journal of Competitiveness, 14*(4), 6–24. https://doi.org/10.7441/joc.2022.04.01

Al-Swidi, A. K., Hair, J. F., & Al-Hakimi, M. A. (2023). Sustainable development-oriented regulatory and competitive pressures to shift toward a circular economy: The role of environmental orientation and Industry 4.0 technologies. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3393

Alam, M. S., Safiullah, M., & Islam, M. S. (2022). Cash-rich firms and carbon emissions. *International Review of Financial Analysis, 81*. https://doi.org/10.1016/j.irfa.2022.102106

Annarelli, A., Battistella, C., Nonino, F., Parida, V., & Pessot, E. (2021). Literature review on digitalization capabilities: Co-citation analysis of antecedents, conceptualization and consequences. *Technological Forecasting and Social Change, 166*. https://doi.org/10.1016/j.techfore.2021.120635

Ardito, L., Raby, S., Albino, V., & Bertoldi, B. (2021). The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance. *Journal of Business Research, 123*, 44–56. https://doi.org/10.1016/j.jbusres.2020.09.022

Arvidsson, S., & Dumay, J. (2022). Corporate ESG reporting quantity, quality and performance: Where to now for environmental policy and practice? *Business Strategy and the Environment, 31*(3), 1091–1110. https://doi.org/10.1002/bse.2937

Ashtianipour, Z., & Zandhessami, H. (2015, Aug 02–06). *An integrated ISM-DEMATEL model for evaluation of technological innovation capabilities' impact on the competitiveness of small & medium size enterprises (SMEs).* In: Paper presented at the Portland International Conference on Management of Engineering and Technology (PICMET), Portland, OR.

Awan, U., Bhatti, S. H., Shamim, S., Khan, Z., Akhter, P., & Balta, M. (2022). The Role of big data analytics in manufacturing agility and performance: Moderation-mediation analysis of organizational creativity and of the involvement of customers as data analysts. *British Journal of Management, 33*(3), 1200–1220. https://doi.org/10.1111/1467-8551.12549

Bridoux, F., & Stoelhorst, J. W. (2022). Stakeholder theory, strategy, and organization: Past, present, and future. *Strategic Organization, 20*(4), 797–809. https://doi.org/10.1177/14761270221127628

Cai, X., Zhu, B., Zhang, H., Li, L., & Xie, M. (2020). Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies. *Science of the Total Environment, 746(prepublish)*. https://doi.org/10.1016/j.scitotenv.2020.140810

Caliskan, A., Ozkan Ozen, Y. D., & Ozturkoglu, Y. (2021). Digital transformation of traditional marketing business model in new industry era. *Journal of Enterprise Information Management, 34*(4), 1252–1273. https://doi.org/10.1108/jeim-02-2020-0084

Chatterjee, S., & Mariani, M. (2022). Exploring the influence of exploitative and explorative digital transformation on organization flexibility and competitiveness. *IEEE Transactions on Engineering Management*, 1–11. https://doi.org/10.1109/TEM.2022.3220946

China, C. P. s. G. o. t. P. s. R. o. (2021). Outline of the 14th Five-Year Plan (2021–2025) for National economic and social development and vision 2035 of the People's Republic of China. Retrieved from https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm

Climent, F., & Soriano, P. (2011). Green and Good? The investment performance of US environmental mutual funds. *Journal of Business Ethics, 103*(2), 275–287. https://doi.org/10.1007/s10551-011-0865-2

Dabbous, A., Barakat, K. A., & Kraus, S. (2023). The impact of digitalization on entrepreneurial activity and sustainable competitiveness: A panel data analysis. *Technology in Society, 73*. https://doi.org/10.1016/j.techsoc.2023.102224

Del Giudice, M., Chierici, R., Mazzucchelli, A., & Fiano, F. (2021). Supply chain management in the era of circular economy: The moderating effect of big data. *International Journal of Logistics Management, 32*(2), 337–356. https://doi.org/10.1108/ijlm-03-2020-0119

Del Río Castro, G., González Fernández, M. C., & Uruburu Colsa, Á. (2021). Unleashing the convergence amid digitalization and sustainability towards pursuing the sustainable development goals (SDGs): A holistic review. *Journal of Cleaner Production, 280*, 122204. https://doi.org/10.1016/j.jclepro.2020.122204

Deloof, M. (2001). Belgian intragroup relations and the determinants of corporate liquid reserves. *European Financial Management, 7*(3), 375–392.

Dos Santos, L., da Costa, M. B., Kothe, J. V., Benitez, G. B., Schaefer, J. L., Baierle, I. C., & Nara, E. O. B. (2021). Industry 4.0 collaborative networks for industrial performance. *Journal of Manufacturing Technology Management, 32*(2), 245–265. https://doi.org/10.1108/jmtm-04-2020-0156

Drempetic, S., Klein, C., & Zwergel, B. (2020). The influence of firm size on the ESG score: Corporate sustainability ratings under review. *Journal of Business Ethics, 167*(2), 333–360. https://doi.org/10.1007/s10551-019-04164-1

Esposito De Falco, S., Scandurra, G., & Thomas, A. (2021). How stakeholders affect the pursuit of the Environmental, Social, and Governance. Evidence from innovative small and medium enterprises. *Corporate Social Responsibility and Environmental Management, 28*(5), 1528–1539. https://doi.org/10.1002/csr.2183

Fang, Y., & Shao, Z. Q. (2022). Whether green finance can effectively moderate the green technology innovation effect of heterogeneous environmental regulation. *International Journal of Environmental Research and Public Health, 19*(6). https://doi.org/10.3390/ijerph19063646

Freeman, R. E. (2016). A Stakeholder theory of the modern corporation. In C. Max (Ed.), *The corporation and its stakeholders* (pp. 125–138). University of Toronto Press.

Freeman, R. E., & Mcvea, J. (2005). A stakeholder approach to strategic management. In *The Blackwell Handbook of Strategic Management* (pp. 183–201).

Fu, Q. (2022). How does digital technology affect manufacturing upgrading? Theory and evidence from China. *Plos One, 17*(5). https://doi.org/10.1371/journal.pone.0267299

Gao, S., Meng, F., Gu, Z., Liu, Z., & Farrukh, M. (2021). Mapping and clustering analysis on environmental, social and governance field a bibliometric analysis using scopus. *Sustainability, 13*(13). https://doi.org/10.3390/su13137304

Ge, G., Xiao, X., Li, Z., & Dai, Q. (2022). Does ESG Performance promote high-quality development of enterprises in china? The mediating role of innovation input. *Sustainability, 14*(7). https://doi.org/10.3390/su14073843

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance, 66*. https://doi.org/10.1016/j.jcorpfin.2021.101889

Guan, F. Y., Tienan, W., & Tang, L. Q. (2023). Organizational resilience under COVID-19: The role of digital technology in R&D investment and performance. *Industrial Management andData Systems, 123*(1), 41–63. https://doi.org/10.1108/imds-04-2022-0220

Guo, R., Lv, S., Liao, T., Xi, F., Zhang, J., Zuo, X., . . . Zhang, Y. (2020). Classifying green technologies for sustainable innovation and investment. *Resources Conservation and Recycling, 153*. https://doi.org/10.1016/j.resconrec.2019.104580

Hartono, H., Halim, E., & Ieee. (2020, 2020 Aug 13–14). The effect of digital capability on competitiveness through digital innovation of E-travel business in Indonesia. In: Paper presented at the 5th international conference on information management and technology (ICIMTech), Bina Nusantara Univ, Sch Informat Syst, ELECTR NETWORK.

Hill, A. D., Johnson, S. G., Greco, L. M., O'Boylee, E. H., & Walter, S. L. (2021). Endogeneity: A review and agenda for the methodology-practice divide affecting micro and macro research. *Journal of Management, 47*(1), 105–143. https://doi.org/10.1177/0149206320960533

Hong, M., Li, Z. H., & Drakeford, B. (2021). Do the green credit guidelines affect corporate green technology innovation? Empirical research from China. *International Journal of Environmental Research and Public Health, 18*(4). https://doi.org/10.3390/ijerph18041682

Huang, K.-F., Dyerson, R., Wu, L.-Y., & Harindranath, G. (2015). From temporary competitive advantage to sustainable competitive advantage. *British Journal of Management, 26*(4), 617–636. https://doi.org/10.1111/1467-8551.12104

Huang, X., Zhang, S., Zhang, J., & Yang, K. (2023). Research on the impact of digital economy on regional green technology innovation: Moderating effect of digital talent aggregation. *Environmental Science and Pollution Research, 30*(29), 74409–74425. https://doi.org/10.1007/s11356-023-27279-5

In, S. Y., Rook, D., & Monk, A. (2019). Integrating alternative data (also known as ESG data) in investment decision making. *Global Economic Review, 48*(3), 237–260. https://doi.org/10.1080/1226508x.2019.1643059

Lee, D. D., Fan, J. H., & Wong, V. S. H. (2021). No more excuses! Performance of ESG-integrated portfolios in Australia. *Accounting and Finance, 61*, 2407–2450. https://doi.org/10.1111/acfi.12670

Lehrer, C., Wieneke, A., vom Brocke, J., Jung, R., & Seidel, S. (2018). How big data analytics enables service innovation: Materiality, affordance, and the individualization of service. *Journal of Management Information Systems, 35*(2), 424–460. https://doi.org/10.1080/07421222.2018.1451953

Li, C. C., & Wang, S. (2022). Digital optimization, green R&D collaboration, and green technological innovation in manufacturing enterprises. *Sustainability, 14*(19). https://doi.org/10.3390/su141912106

Li, D. Q., & Shen, W. T. (2021). Can Corporate Digitalization promote green innovation? The moderating roles of internal control and institutional ownership. *Sustainability, 13*(24). https://doi.org/10.3390/su132413983

Li, G. P., Wang, X. Y., Su, S. B., & Su, Y. (2019). How green technological innovation ability influences enterprise competitiveness. *Technology in Society, 59*. https://doi.org/10.1016/j.techsoc.2019.04.012

Li, T.-T., Wang, K., Sueyoshi, T., & Wang, D. D. (2021). ESG: Research progress and future prospects. *Sustainability, 13*(21). https://doi.org/10.3390/su132111663

Li, X., Wu, T., Zhang, H., & Yang, D. (2022). Digital Technology adoption and sustainable development performance of strategic emerging industries: The mediating role of digital technology capability

and the moderating role of digital strategy. *Journal of Organizational and End User Computing, 34*(8). https://doi.org/10.4018/joeuc.315645

Li, Z. H., Huang, Z. M., & Su, Y. Y. (2023). New media environment, environmental regulation and corporate green technology innovation:Evidence from China. *Energy Economics, 119*. https://doi.org/10.1016/j.eneco.2023.106545

Liao, J., Zheng, L. P., & Yuan, Y. The impact of corporate environmental responsibility on corporate cash holdings: evidence from the most polluting listed companies in China. *Kybernetes*. https://doi.org/10.1108/k-05-2021-0390

Lobschat, L., Mueller, B., Eggers, F., Brandimarte, L., Diefenbach, S., Kroschke, M., & Wirtz, J. (2021). Corporate digital responsibility. *Journal of Business Research, 122*, 875–888. https://doi.org/10.1016/j.jbusres.2019.10.006

Lu, Z. Q., Wu, J. J., Li, H. Y., & Nguyen, D. K. (2022). Local Bank, Digital Financial Inclusion and SME Financing Constraints: Empirical Evidence from China. *Emerging Markets Finance and Trade, 58*(6), 1712–1725. https://doi.org/10.1080/1540496x.2021.1923477

Luo, S. Y., Yimamu, N., Li, Y. R., Wu, H. T., Irfan, M., & Hao, Y. (2023). Digitalization and sustainable development: How could digital economy development improve green innovation in China? *Business Strategy and the Environment, 32*(4), 1847–1871. https://doi.org/10.1002/bse.3223

Palmer, K., Oates, W. E., & Portney, P. R. (1995). Tightening environmental standards: The benefit-cost or the no-cost paradigm? *Journal of Economic Perspectives, 9*(4), 119–132. https://doi.org/10.1257/jep.9.4.119

Park, S. R., & Oh, K.-S. (2022). Integration of ESG information into individual investors' corporate investment decisions: Utilizing the UTAUT framework. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.899480

Pivac, S., Vuko, T., & Cular, M. (2017). Analysis of annual report disclosure quality for listed companies in transition countries. *Economic Research-Ekonomska Istrazivanja, 30*(1), 721–731. https://doi.org/10.1080/1331677x.2017.1311231

Rabaya, A. J., & Saleh, N. M. (2022). The moderating effect of IR framework adoption on the relationship between environmental, social, and governance (ESG) disclosure and a firm's competitive advantage. *Environment, Development and Sustainability, 24*(2), 2037–2055. https://doi.org/10.1007/s10668-021-01519-5

Ren, X. H., Zeng, G. D., & Zhao, Y. (2023). Digital finance and corporate ESG performance: Empirical evidence from listed companies in China*. *Pacific-Basin Finance Journal, 79*. https://doi.org/10.1016/j.pacfin.2023.102019

Riaz, Z., Ray, P., & Ray, S. (2022). The impact of digitalisation on corporate governance in Australia. *Journal of Business Research, 152*, 410–424. https://doi.org/10.1016/j.jbusres.2022.07.006

Shan, S., Luo, Y., Zhou, Y., & Wei, Y. (2019). Big data analysis adaptation and enterprises' competitive advantages: The perspective of dynamic capability and resource-based theories. *Technology Analysis & Strategic Management, 31*(4), 406–420. https://doi.org/10.1080/09537325.2018.1516866

Shao, Y. M., & Chen, Z. F. (2022). Can government subsidies promote the green technology innovation transformation? Evidence from Chinese listed companies. *Economic Analysis and Policy, 74*, 716–727. https://doi.org/10.1016/j.eap.2022.03.020

Stankovic, J. J., Marjanovic, I., Drezgic, S., & Popovic, Z. (2021). The digital competitiveness of European countries: A multiple-criteria approach. *Journal of Competitiveness, 13*(2), 117–134. https://doi.org/10.7441/joc.2021.02.07

Su, Y., & Li, G. (2021). Green technological innovation ability,product differentiation and enterprise competitiveness:Analysis of energy saving and environmental protection industry listed companies. *Chinese Journal of Management Science, 29*(4), 46–56. Retrieved from <Go to ISI>://CSCD:6960128

Sun, Y., & Tang, X. W. (2022). The impact of digital inclusive finance on sustainable economic growth in China. *Finance Research Letters, 50*. https://doi.org/10.1016/j.frl.2022.103234

Tang, Y. C., Xia, N. N., Varga, L., Tan, Y. T., Hua, X. J., & Li, Q. M. (2022). Sustainable international competitiveness of regional construction industry: Spatiotemporal evolution and influential factor analysis in China. *Journal of Cleaner Production, 337*. https://doi.org/10.1016/j.jclepro.2022.130592

Teece, D. J., & Pisano, G. (1994). The Dynamic capabilities of firms: An introduction. *Industrial and Corporate Change, 3*(3), 537–556. https://doi.org/10.1093/icc/3.3.537-a

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533. https://doi.org/10.1142/9789812834478_0002

Thompson, H. G., & Garbacz, C. (2011). Economic impacts of mobile versus fixed broadband. *Telecommunications Policy, 35*(11), 999–1009. https://doi.org/10.1016/j.telpol.2011.07.004

Van Veldhoven, Z., & Vanthienen, J. (2022). Digital transformation as an interaction-driven perspective between business, society, and technology. *Electronic Markets, 32*(2), 629–644. https://doi.org/10.1007/s12525-021-00464-5

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research, 122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Wang, H., Li, Y., & Tan, Q. (2022a). Influence of digital transformation on firm performance based on meta-analysis. *Journal of Systems &andManagement, 31*(1), 112–123. Retrieved from <Go to ISI>://CSCD:7136095

Wang, H., Zheng, C., Liu, J., & Jiang, X. (2022b). Digital technology search and new venture performance in dynamic environments: The mediating role of competitive advantage. *Journal of Organizational and End User Computing, 37*(7). https://doi.org/10.4018/joeuc.308816

Wang, J., Song, Z., & Xue, L. (2023). Digital technology for good: Path and influence and mdash;based on the study of ESG performance of listed companies in China. *Applied Sciences, 13*(5), 2862. Retrieved from https://www.mdpi.com/2076-3417/13/5/2862

Wang, M., Wu, X.-F., Xie, Y.-H., & Chiu, Y.-H. (2022c). Comparative analysis of port efficiency in Yangtze River Delta and Pearl River Delta: A meta dynamic DDF approach. *Economic Research-Ekonomska Istrazivanja*. https://doi.org/10.1080/1331677x.2022.2129405

Wang, N., Zhang, S. J., & Wang, W. (2022d). Impact of environmental innovation strategy on green competitiveness: Evidence from China. *International Journal of Environmental Research and Public Health, 19*(10). https://doi.org/10.3390/ijerph19105879

Wu, W., Fu, Y., Wang, Z., Liu, X., Niu, Y., Li, B., & Huang, G. Q. (2022a). Consortium blockchain-enabled smart ESG reporting platform with token-based incentives for corporate crowdsensing. *Computers and Industrial Engineering, 172*, 108456. https://doi.org/10.1016/j.cie.2022.108456

Wu, W., Fu, Y. L., Wang, Z. C., Liu, X. L., Niu, Y. X., Li, B., & Huang, G. Q. (2022b). Consortium blockchain-enabled smart ESG reporting platform with token-based incentives for corporate crowdsensing. *Computers and Industrial Engineering, 172*. https://doi.org/10.1016/j.cie.2022.108456

Wu, Y.-Q., Lu, H.-X., Liao, X.-L., & Zhu, J.-M. (2021). Research on the digitization of manufacturing will enhance the competitiveness of the value chain based on advantage comparison. *Complexity, 2021*. https://doi.org/10.1155/2021/9917772

Xi, Y. Y., & Xu, E. M. (2014, Aug 17–19). *Corporate values, stakeholder orientation and social performance*. In: Paper presented at the 21st international conference on management science and engineering (ICMSE), Helsinki, FINLAND.

Xiao, Z., Peng, H., & Pan, Z. (2022). Innovation, external technological environment and the total factor productivity of enterprises. *Accounting and Finance, 62*(1), 3–29. https://doi.org/10.1111/acfi.12779

Xie, J., Nozawa, W., Yagi, M., Fujii, H., & Managi, S. (2019). Do environmental, social, and governance activities improve corporate financial performance? *Business Strategy and the Environment, 28*(2), 286–300. https://doi.org/10.1002/bse.2224

Xu, J., Liu, F., & Shang, Y. (2021). R&D Investment, ESG performance and green innovation performance: Evidence from China. *Kybernetes, 50*(3), 737–756. https://doi.org/10.1108/k-12-2019-0793

Xue, L., Zhang, Q. Y., Zhang, X. M., & Li, C. Y. (2022). Can digital transformation promote green technology innovation? *Sustainability, 14*(12). https://doi.org/10.3390/su14127497

Yang, Y., & Han, J. (2023). Digital transformation, financing constraints, and corporate environmental, social, and governance performance. *Corporate Social Responsibility and Environmental Management*. https://doi.org/10.1002/csr.2546

Yi, M., Guan, Y. Y., Wu, T., Wen, L., Lei, Y. M., & Xu, S. J. (2023). How does Chinese-style fiscal decentralization affect green technology innovation? *Environmental Science and Pollution Research, 30*(16), 46022–46037. https://doi.org/10.1007/s11356-023-25448-0

Yin, S., Zhang, N., & Li, B. (2020). Enhancing the competitiveness of multi-agent cooperation for green manufacturing in China: An empirical study of the measure of green technology innovation capabilities and their influencing factors. *Sustainable Production and Consumption, 23*, 63–76. https://doi.org/10.1016/j.spc.2020.05.003

Yu, C.-H., Wu, X., Zhang, D., Chen, S., & Zhao, J. (2021). Demand for green finance: Resolving financing constraints on green innovation in China. *Energy Policy, 153*. https://doi.org/10.1016/j.enpol.2021.112255

Yusof, N., Tabassi, A. A., & Esa, M. (2020). Going beyond environmental regulations—The influence of firm size on the effect of green practices on corporate financial performance. *Corporate Social Responsibility and Environmental Management, 27*(1), 32–42. https://doi.org/10.1002/csr.1771

Zhang, Q., Loh, L., & Wu, W. (2020a). How do environmental, social and governance initiatives affect innovative performance for corporate sustainability? *Sustainability, 12*(8). https://doi.org/10.3390/su12083380

Zhang, Q., Wang, J., & Geng, J. (2022). Corporate cash holding patterns from a performance perspective. *Singapore Economic Review, 67*(02), 821–848. https://doi.org/10.1142/s0217590821500405

Zhang, Y., Xing, C., & Wang, Y. (2020b). Does green innovation mitigate financing constraints? Evidence from China's private enterprises. *Journal of Cleaner Production, 264*. https://doi.org/10.1016/j.jclepro.2020.121698

Zhao, X., & Qian, Y. Y. (2023). Does digital technology promote green innovation performance? *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-023-01410-w

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