

Regional digital economy development and enterprise ESG performance —— comes from the empirical analysis of the panel data of Chinese A-share listed companies

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Abstract. With the development of China's digital economy, enterprise ESG performance has a new development direction and source of power. This paper explores the impact of the booming development of digital economy on the ESG performance of micro enterprises. This paper takes the panel of a-share listed companies in Shanghai and Shenzhen from 2008 to 2020 as the original sample. This paper empirically tests the influence effect and mechanism of digital transformation on the ESG performance of enterprises under the background of digital economy. The study found that the development of digital economy has a significant promoting and positive impact on the ESG performance of enterprises. Further mechanism analysis found that the digital economy mainly promotes ESG performance by improving the green innovation performance of enterprises and total factor productivity. From the perspective of digital economy development background, this paper provides theoretical support and empirical basis for improving the ESG performance of Chinese enterprises and promoting the development path of ESG in China.

Keywords: enterprise ESG, development of digital economy, digital innovation, digital finance.

1. Introduction

In the 20th CPC report, General Secretary Xi Jinping pointed out that "high-quality development is the top task for building a modern socialist country in an all-round way", and accelerating the transformation of green development has become an important strategic direction to promote high-quality development of China's real economy. ESG refers to the acronym of environment (Environment), social responsibility (Social) and corporate governance (Governance). It is the extension and enrichment of green investment concept and corporate social responsibility, and is also an important standard for the international community to measure the level of green and sustainable development of enterprises. Promote the development of enterprise ESG not only highly fit China's economic construction, political construction, cultural construction, social construction, ecological civilization construction of "five one" the overall layout and "innovation, coordination, green, open, sharing" the new development concept, and to build the new development pattern of "binary" economy and achieve the goal of "double carbon" national strategy is of great significance. In recent years, our country ESG development is given priority to driven by policy, in September 2018, the CSRC revised the governance standards of listed companies established the basic framework of ESG information disclosure, in September 2020 the Shenzhen stock exchange revised the Shenzhen stock exchange listed company information disclosure work assessment method of listed company ESG need to take the initiative to disclose and assessment.

In recent years, the development and innovation of the new generation of digital economy, represented by artificial intelligence, blockchain, cloud computing and big data, have provided effective technical means for enhancing the practical ability and application of enterprise ESG, and become an important technical force to promote the development of enterprise ESG. The 14th Five-Year Plan for the Development of the Digital Economy points out the need to strengthen the construction of digital infrastructure and improve the governance system of the digital economy. In the Overall Layout Plan for Digital China Construction issued by the CPC Central Committee and The State Council in February 2023, it is emphasized that the construction of digital China is an important engine for promoting Chinese-style modernization in the digital era and a strong support

for building new national competitive advantages. The new digital transformation environment formed by the development of digital economy has become an important way for enterprises in various industries to actively carry out ESG practice activities and achieve sustainable development. The deep integration of digital technology and the real economy, on the one side, While being able to record the production and operation activities of the enterprise, Use the big data analysis for the tracking and management of enterprise internal information, Thus in the information collection, decision support, operation management and other aspects to greatly reduce the cost and improve efficiency; on the other hand, Can meet the needs of enterprise ESG information disclosure, information management and capital market regulation, Not only enhances the authenticity, comprehensiveness and timeliness of ESG information disclosure, And improve the efficiency and convenience of ESG information management and operation, This helps to enhance the practical ability of the enterprise ESG, Improve corporate ESG performance.

To this end, this paper systematically combs the research on the development of digital economy and enterprise ESG performance at home and abroad, and selects the panel data of a-share listed companies in 2008-2020 as the research object to empirically investigate the impact of digital economy on the ESG performance of enterprises and its action mechanism. The empirical results of this paper show that the development of regional digital economy has a significant role in promoting the ESG performance of enterprises, and the conclusion is still stable and reliable after a series of endogenous treatments and robustness tests. Among them, digital economy mainly promotes ESG performance by improving enterprise green innovation performance and total factor productivity.

Compared to the existing studies, The possible marginal contributions of this paper are as follows: First, This paper expands and enriches the relevant research results of enterprise ESG, Choose from digital innovation, digital finance and industrial structure optimization, Discuss the relationship between the development of digital economy and enterprise ESG; next, From the three dimensions of environment, social responsibility and corporate governance, Integrating the information on digital innovation, digital finance and industrial structure optimization, Exploring the promoting effect of digital economy development on the ESG performance of enterprises, And through empirical analysis of panel data; last, This paper analyzes the enterprise ESG performance and green innovation performance in heavy pollution industries, In practice, it can provide theoretical support for developing regional differentiated digital economy development and enterprise ESG performance.

2. Literature review and theoretical hypotheses

2.1. Enterprise ESG performance

ESG is the acronym of environmental (environmental), social responsibility (social) and corporate governance (governance), which includes three aspects of environmental, social responsibility and corporate governance, among which environmental responsibility refers to environmental risk management by reducing pollutant emission and improving energy efficiency; social responsibility refers to the necessary obligations to employees, communities, customers and other stakeholders; and governance ability refers to the comprehensive level of the enterprise in governing the environment, structure, mechanism and behavior.

The three theoretical pillars supporting ESG are the theory of sustainable development, the theory of economic externalities, and the theory of corporate social responsibility (Huang Shizhong, 2021). ESG is an investment concept that takes into account corporate environment, social responsibility and governance performance in investment decisions. It is an extension and enrichment of the concept of green development and responsible investment. It focuses on the performance of non-financial fields of enterprises, and can be used to comprehensively evaluate the sustainable development performance of enterprises.

ESG investment originated from socially responsible investment and gradually developed into an independent investment philosophy. ESG investment is becoming a global trend. ESG investment has many advantages, such as reducing risk, improving returns, and promoting sustainable development.

ESG investment is not only a social responsibility, but also can enhance corporate value. Studies have shown that good ESG performance companies generally have higher market value and better operating performance. At the same time, enterprises should integrate ESG into strategic planning and daily management to achieve sustainable development and long-term value creation.

Corporate ESG rating is an important tool for assessing corporate sustainability and social responsibility. Enterprises should strengthen the importance of ESG information disclosure, improve the system and standards of ESG information disclosure, and improve the quality and transparency of ESG information disclosure (Ting-Ting Li, 2021). At the same time, enterprises should also actively benchmark the mainstream ESG information disclosure framework in the international market, strengthen cooperation and exchanges with international institutions, and promote the improvement of ESG information disclosure level in China. ESG risk management is an important part of enterprise management. Enterprises should incorporate ESG factors into the risk management system, identify and evaluate the potential ESG risks, and take corresponding measures to manage and control them. This helps companies reduce risks, improve returns and achieve sustainable development goals.

Enterprise ESG performance can also realize the value spillover effect. First, ESG practice performance can significantly reduce the financing costs, relieve the financial pressure of the enterprise, and thus improve the book value of the enterprise. Second, the good image of ESG practice performance can significantly improve the degree of market attention, and release many positive and effective signals to stakeholders, so as to improve enterprise performance. Third, the enterprise ESG performs well, which can effectively alleviate the externality problems generated by the green innovation of enterprises (Group operation & Qian Xu, 2019). The promotion of corporate ESG is also conducive to its long-term green development and financial performance improvement. First, green innovation can increase the recognition of relevant stakeholders, suppliers and the public, which is conducive to enterprises to reduce external financing costs and further improve their performance. Second, the R & D investment will reduce the production cost of the enterprise, realize the scale effect of the enterprise, so as to significantly improve the economic performance of the enterprise. Third, it helps to improve the positive image of the enterprise and obtain the support of government policies to bring additional benefits to the enterprise (Zhang Xiaomei & Rao Jing, 2023).

2.2. Digital economy development

The digital economy refers to the economic activity driven through digital technology and information networks. According to different classification criteria, the digital economy can be divided into different types, such as information economy, knowledge economy, new infrastructure, etc. The digital economy has become a new driving force for global economic development, showing a trend of rapid growth (Bidda Sky, 2023). The continuous innovation and application of digital technology, as well as the popularization of the Internet, the Internet of Things, artificial intelligence and other technologies, have provided a broader space and opportunities for the development of the digital economy. The practice and application of digital economy have penetrated into various fields, such as e-commerce, online education, intelligent manufacturing, smart city, etc. These application scenarios provide a broader space and opportunities for the development of the digital economy, and also provide new ideas and methods for the transformation and upgrading of traditional industries (Guifu Chen, 2022).

With the development and innovation of the new generation of digital economy, such as artificial intelligence, blockchain, cloud computing and big data, the deep integration of digital economy and traditional economy has become a new feature of economic development (Jing Wenjun, 2019). It is mainly manifested in three aspects: first, enterprises apply Internet and other technologies to engage in related economic activities, such as e-commerce is more frequent and daily; second, digital economy as an economic form affects the traditional economy, and the proportion of online shopping of consumer goods is increasing steadily year by year; third, the service mode and technology of enterprise economy are constantly innovating, and the business model of big data and cloud

computing realizes the integration of industrial chain and supply chain, improving the trade achievement rate.

From the perspective of economic effects, the digital economy can drive high-quality economic development. Tranos et al. (2020) explored the impact of the early application of digital technology in the UK on regional productivity levels 16 years later, and found that the digital economy has had a long-term and positive effect on local economic growth. Zhao Tao et al. (2020) found that the digital economy can enable high-quality economic development by stimulating mass entrepreneurship and enhancing entrepreneurial activity. Yang Wenpu (2022) believes that the development of digital economy provides a fundamental driving force for economic and social development by promoting the improvement of production efficiency and stimulating the expansion of consumption on the demand side, and thus drives the high-quality development of the economy.

In terms of social effects, the digital economy helps to promote common prosperity. The digital economy can build a sharing mechanism to promote common prosperity by promoting balanced regional development, promoting urban-rural integration, and narrowing the income gap and industry gap (Shi Bo and Hu Xijuan, 2022). Narrowing the income gap is an essential requirement for achieving common prosperity. Borowiecki et al. (2021) pointed out that the development of the digital economy has alleviated the income inequality of residents, but some scholars believe that the income gap between urban and rural areas will further expand due to the existence of the "digital divide" (Chen Wen and Wu Ying, 2021).

2.3. Theoretical analysis and research hypotheses

Firstly, the development of the digital economy has brought digital innovation, which is innovation in products, services, and business models based on digital technologies and is inherent in the digital economy. The output of digital innovation will become new innovative resources that drive the continuous evolution and development of the digital economy, and digital innovation promotes ESG.

In terms of the environment, digital innovation can optimize resource utilization and production processes by improving information technology and intelligence levels, reducing energy consumption and emissions, and thereby reducing the negative impact on the environment. Digital innovation can also promote the development of a green economy. Digital technology can facilitate information sharing and knowledge exchange, promote the research and application of green technology, and promote the development of green industries. In addition, digital innovation can enhance public environmental awareness and participation. (Bai Fuping et al., 2023).

In terms of social responsibility, digital innovation can improve corporate transparency and information disclosure levels. Digital innovation makes corporate operational data more transparent, allowing companies to communicate more directly with all sectors through the internet and social media platforms, thus establishing trust relationships. (Xu Weixiang & Zhou Jianping, 2022). Digital innovation can also enhance cooperation between companies and stakeholders. Through digital platforms, companies can interact with suppliers, customers, employees, shareholders, etc. in real time to strengthen their connections and cooperation. This helps companies better understand the needs and concerns of stakeholders, improving their social responsibility performance. In addition, digital innovation can enhance corporate competitiveness by optimizing production processes, improving efficiency and customer satisfaction through the application of digital technologies.

In terms of corporate governance, digital innovation can improve governance efficiency by introducing advanced information technology and optimizing governance structures while enhancing internal controls through data analysis and monitoring. (Wang Canxiong, 2023). Digital innovation can also optimize investor relations management.

Secondly, the development of the digital economy has also brought digital finance, which refers to a new generation of financial services that combines traditional financial services with internet and information technology tools. Digital finance can provide technical solutions for financial technology and improve services through digital technologies. Specific business activities of digital finance

include five categories: infrastructure, payment and clearing, financing, investment management, and insurance. Digital finance promotes ESG. (Mingyue Fang A, 2023).

In terms of environment, digital finance can provide more financial support for enterprises by providing innovative financial products and services, promote enterprises to carry out environmental protection work and sustainable development, and then improve the environmental performance of enterprises (Jing Wenjun, 2019). Second, digital finance can introduce advanced information technology to carry out comprehensive risk assessment and monitoring of enterprises and improve the efficiency of environmental governance. Third, digital finance can enhance their environmental awareness and sense of responsibility to fulfill social responsibility by supporting enterprises and projects that fulfill their social responsibility, and thus promote the improvement of corporate environmental performance (Cen Cai A, 2023). Fourth, digital finance can provide enterprises with more channels and opportunities for environmental protection investment and financing through innovative financial products and services, and then promote the improvement of enterprise environmental performance.

In terms of social responsibility, promote environmental protection enterprises and project financing. Digital finance can provide innovative financial products and services for environmental protection enterprises and projects, and green credit and green bonds can provide more financial support for environmental protection enterprises and projects to promote the development of environmental protection undertakings. The second is to improve the efficiency of environmental governance. By introducing advanced information technology, digital finance conducts comprehensive risk assessment and monitoring of environmental protection projects and enterprises, and improves the efficiency of environmental governance (Liuyang Xue A, 2023). Third, to promote the development of green financial market. Digital finance can realize information sharing and optimal resource allocation through Internet platform and big data analysis, improve the transparency and efficiency of green financial market, and promote the development of green financial market (Sheng Minqian & Ouyang Wenhui, 2023). Fourth, enhance enterprises' environmental awareness and social responsibility. Digital finance can enhance enterprises' environmental awareness and sense of responsibility to fulfill social responsibility through publicity and practice.

In terms of corporate governance, the first is to optimize the corporate governance structure. By introducing advanced information technology, digital finance optimizes the governance structure of enterprises and improves the operational efficiency and market competitiveness of enterprises. Second, enhance the competitiveness of enterprises. Digital finance can realize information sharing and optimal resource allocation through the Internet platform and big data analysis, improve the market share and profitability of enterprises, and enhance the competitiveness of enterprises (Xiangdai & Yang Shuangcheng, 2022). Third, to improve the risk management level of enterprises. By introducing advanced risk management methods, digital finance can comprehensively assess and monitor the risks of enterprises, and provide more accurate and timely data support for the risk management of enterprises. Fourth, to enhance corporate image and reputation. Digital finance can develop green finance business by supporting enterprises and projects fulfilling social responsibilities, promote enterprises to pay attention to environmental protection and sustainable development, and promote the promotion of corporate image and reputation.

Thirdly, the development of digital economy also promoted the optimization of industrial structure, industrial structure optimization refers to the industrial adjustment, make the industry to achieve coordinated development, and meet the rationalization and advanced social growth, promote the coordinated development between the national economy, make the industry development and the whole national economic development, ESG has a positive role in promoting the enterprise.

In terms of environment, the optimization of industrial structure can promote enterprises to achieve green transformation. In the process of industrial structure adjustment, enterprises need to adapt to the new market demand, and actively introduce and develop the environmental protection industry, so as to reduce environmental pollution and resource waste. In this process, the green transformation of the enterprise is realized, and it also helps to improve the economic benefits and social image of

the enterprise (Niu et al., 2022). Second, the optimization of industrial structure can promote the sustainable development of enterprises. With the increasing attention of the society to environmental protection, enterprises need to actively take environmental protection measures. The optimization of industrial structure makes enterprises pay more attention to resource conservation and environmental protection, so as to contribute to the sustainable development of the society while realizing their own development (Yang, 2023). Third, the industrial structure optimization can improve the competitiveness of enterprises. In the increasingly fierce market competition, enterprises need to constantly optimize their own industrial structure, enhance their competitiveness with the help of the advantages of green transformation, and also help to improve the corporate social responsibility and brand image.

In terms of social responsibility, the optimization of industrial structure requires enterprises to pay more attention to the fulfillment of social responsibility, including the responsibility of environmental protection, social welfare, fair competition and other aspects (Qiongyu Huang, 2023). This makes enterprises have to pay more attention to social responsibility and take active actions to fulfill social responsibility in order to meet the needs of the market and society. Second, to improve the social image and reputation of enterprises, the optimization of industrial structure requires enterprises to pay more attention to the performance of social responsibilities, actively participate in social public welfare undertakings, and improve the social image and reputation of enterprises. Third, promote the cooperation between enterprises and stakeholders. The optimization of industrial structure requires enterprises to pay more attention to the needs and opinions of stakeholders, establish a good cooperative relationship with them, and jointly promote the fulfillment and sustainable development of social responsibilities (Zhou & Liu, 2023).

In terms of corporate governance, the first is to improve the level of corporate governance, establish a more perfect and scientific governance system, to adapt to the needs of the market and the society, and pay more attention to the standardization and effectiveness of corporate governance (Ren et al., 2023). Second, enhance the competitiveness of enterprises. The optimization of industrial structure can reduce the concentration degree of the industry and help enterprises to achieve sustainable development. This makes enterprises must pay more attention to their own management and improve their core competitiveness and market position. Fourth, to promote enterprise innovation and development, the optimization of industrial structure requires enterprises to continue to innovate and develop to adapt to the needs of the market and society. This makes enterprises have to pay more attention to their own innovation ability and governance level to promote the long-term sustainable development of enterprises (Chen Xiaohong, 2022).

The development of digital economy plays an important leading role in China's economic and social development. Emerging digital technologies such as big data, cloud computing, artificial intelligence and 5G are the basic conditions for enterprises to practice the concept of ESG development. The development and innovation of the new generation of digital economy will effectively promote the development of ESG in enterprises. Based on the above analysis, this paper proposes the hypothesis:

H: The development of the digital economy can promote the ESG performance of enterprises.

3. Sample selection and the empirical design

(1) Sample selection and data source

In this paper, the panel of a-share listed companies in 2008-2020 is selected as the original sample. The original data of listed companies are from tai'an (CSMR) database and processed. Based on the research objects of this paper, the further screening process of samples is as follows: (1) screening by the industry classification code of the 2012 version of CSRC, excluding the financial industry samples; (2) excluding the samples of ST enterprises during the research period; (3) excluding the samples with asset-liability ratio greater than 1; (4) to eliminate the influence of extreme values on the empirical analysis, the tail analysis is 1% of all continuous variables.

(2) Enterprise ESG performance

ESG is the environment (environmental), social responsibility (social) and corporate governance (governance) three words of abbreviation, is a kind of enterprise environment, social responsibility and management performance in investment philosophy, is the extension of green development and responsibility investment concept and rich, its focus on the enterprise performance in the field of financial, can be used for comprehensive evaluation of the sustainable development of enterprise performance.

In this paper, the third-party evaluation agency and the ESG evaluation system are used to measure the ESG performance of enterprises. The ESG evaluation system is 1-9. The higher the score, the better the ESG performance is.

(3) Development of regional digital economy

About digital economy index measure there are two methods, one is the digital infrastructure digital economy application digital industrialization and digital dimension construction index system, the other is directly using the digital pratt & whitney financial index or tencent institute of digital economy index to measure the city digital economy development level. For comprehensive consideration of each dimensions of the digital economy, the city level of digital economy development research, considering the digital infrastructure, digital industry, digital technology, digital application dimension and data availability, finally adopt (1) Internet users, (2) mobile phone users, (3) information transmission and technology services employment proportion (4) per capita telecom business total (5) city digital pratt & whitney financial index five indicators as dimension construction of digital economy index system, using principal component analysis after standardized processing.

(4) Empirical model setting

In this paper, the panel bidirectional fixed effect model (TWFE) is used for the empirical analysis. The model construction is shown in equation (1):

$$ESG_{ict+1} = \alpha_0 + \alpha_1 Digit_city_{ct} + \alpha_2 X_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (1)$$

ESG_{it} The subscripts i, c, t indicate the enterprise, the city of the enterprise and the year respectively. The explained variable is the ESG performance score of listed company i in the first year t, and the data source is CSI ESG evaluation system with the value range is 1 to 9. The higher the value indicates the better ESG performance of the enterprise; the core explanatory variable is the digital economy development level of c where the listed company is located, and the specific structure is as shown above. Therefore, for the core pending estimation parameters in this paper. In addition, the set of control variables at the enterprise level is set up as described below. $Digit_city_{ct}$ by γ_t, μ_i They are year fixed effect and individual fixed effect. ε_{it} For the random disturbance term of the model. Finally, all statistical inferences in this paper employ heteroscedastic robust criterion error.

(5) Control variables and their definitions

In order to reduce the endogenous bias caused by the problem of missing variables, this paper further controls a series of control variables. The detailed variables are shown in Table 1, and the specific descriptive statistical characteristics of each variable are shown in Table 2.

Table 1. The variable types, names, and detailed definitions

type of variable	Variable name	Letters indicate	Variable definition description
explained variable	Enterprise ESG performance	ESG	According to the ESG performance scores of listed companies in the same year released by the ESG third-party evaluation agency
Core explanatory variables	Digital economy development	Digit_city	The level of digital economy development in the region where the enterprise is located
Enterprise control variables	scale	Size	Total ln (total assets of the enterprise at the end of the year)
	asset-liability ratio	Leverage	The asset-liability ratio of the enterprise in the current year
	enterprise age	Age	Enterprise listing years
	Business performance	ROA	Enterprise return on assets of the year
	cash ratio	Cash	Corporate cash ratio for the year
	Board independence	Indratio	The proportion of independent directors of the enterprise in that year
	Equity concentration	Top1	Enterprise in that year the largest shareholder shareholding ratio
	Enterprise ownership	SOE	Virtual variable: If the enterprise belongs to a state-owned enterprise, it is assigned 1, otherwise 0
	Loss status	Loss	Virtual variable: Virtual variable: if the enterprise belongs to a state-owned enterprise, the value is 1, otherwise 0

Table 2. Descriptive statistics

	sample capacity	mean	standard deviation	least value	median	crest value
ESG	30634	6.475	1.084	1	6	9
Digit city	23930	0.288	0.196	0.019	0.232	0.881
Size	32578	22.081	1.292	19.35	21.893	26.43
Leverage	32578	0.421	0.208	0.027	0.414	0.936
Age	32578	9.477	7.258	0	8	27
ROA	32578	0.433	0.461	-.581	0.346	3.037
Indratio	32578	38.91	9.948	0	37.5	66.667
Top1	32578	0.348	0.149	0.082	0.328	0.758
SOE	32578	0.358	0.479	0	0	1
Loss	32578	0.04	0.197	0	0	1

(6) Collinearity test between variables

Before the empirical regression analysis, the results of the correlation between the main study variables are also analyzed, and the correlation test results of the core explanatory variables and control variables are shown in Table 3. As can be seen from the correlation coefficient matrix in Table 3, the correlation coefficient between the core explanatory variable and each control variable is not large, so there will be no systematic bias in the paper due to the statistical inference caused by the high collinear problem.

Table 3. The matrix of the correlation coefficient among the variables

	Digit_city	Size	Leverage	Age	ROA	Indratio	Top1	SOE	Loss
Digit_city	1								
Size	0.02*	1							
Leverage	-0.02*	0.53*	1						
Age	-0.06*	0.39*	0.38*	1					
ROA	-0.04*	-0.01	0.09*	-0.02*	1				
Indratio	-0.00	-0.06*	-0.03*	-0.07*	0.17*	1			
Top1	0.02*	0.20*	0.06*	-0.06*	0.10*	0.05*	1		
SOE	-0.05*	0.38*	0.30*	0.46*	0.10*	-0.03*	0.23*	1	
Loss	0.01*	-0.02*	0.10*	0.07*	-0.25*	-0.10*	-0.09*	-0.05*	1

4. Empirical results

(1) Basic empirical results

Table 4 shows the benchmark stepwise regression results of formula (1) of this paper, and the explained variables are the next ESG performance score of the enterprise. Column (1) does not control any variables; column (1) adds the bidirectional fixed effect of industry and year. Column (3) Further consideration of various control variables at the enterprise level. The benchmark regression results from Table 4 indicate that for all the core explanatory variables in all columns, the Digit _ city estimated coefficient is significantly positive at at least 5% of the statistical level. This result shows that the development of regional digital economy significantly promotes the ESG performance of enterprises. This conclusion is highly robust under the control of various dimensions.

Table 4. Benchmark stepwise regression results

	(1)	(2)	(3)
explained variable	F.ESG	F.ESG	F.ESG
Digit_city	0.193*** (0.038)	0.093** (0.038)	0.116*** (0.033)
Size			0.339*** (0.006)
Leverage			-0.931*** (0.042)
Age			-0.002* (0.001)
ROA			0.077*** (0.019)
Indratio			0.003*** (0.001)
Top1			0.090* (0.048)
SOE			0.436*** (0.018)
Loss			-0.712*** (0.057)
Constant	6.454*** (0.013)	6.483*** (0.013)	-0.927*** (0.134)
Industry FE	No	Yes	Yes
Year FE	No	Yes	Yes
Observations	23,361	23,361	23,361
R-squared	0.001	0.087	0.250

Note: The observed value is at the enterprise level.***, **, * Is significant at 1%, 5%, and 10%, respectively. Numerical heteroscedasticity is a robust standard error in parentheses."Yes" represents controls for this fixed effect and "No" represents controls not for this fixed effect.

(2) Robustness test

To verify the robustness of the core results, a robustness test is needed. Due to the significant differences between economic and social factors in different cities, the variation factors at the city level may be important missing variables under the analytical framework of this paper. Therefore, this paper further considers the important characteristics of cities to reduce the endogenous bias caused by the problem of missing variables. This article has about the control of city level factors include: economic development (urban per capita GDP of natural logarithm form, $\ln\text{perGDP}$), at the end of the total population (People, the city at the total population of natural logarithm), the total amount of foreign direct investment (FDI), and local government fiscal spending ($\ln\text{fin}$), above the city level data are from the calendar year China city statistical yearbook.

The results in Table 5 indicate that, after considering the various development factors of the above cities, the ESG performance of the core explanatory variable Digit_city is significantly positive at 1%, that is, the results in this paper are very robust.

Table 5. Considers the important characteristics at the city level

	(1)	(2)	(3)	(4)
explained variable	F.ESG	F.ESG	F.ESG	F.ESG
Digit_city	0.537*** (0.079)	0.510*** (0.087)	0.500*** (0.089)	0.592*** (0.114)
$\ln\text{perGDP}$	-0.019 (0.026)	-0.018 (0.026)	-0.033 (0.037)	-0.016 (0.039)
People		0.009 (0.015)	-0.004 (0.024)	0.038 (0.040)
FDI			0.005 (0.011)	0.007 (0.012)
$\ln\text{fin}$				-0.039 (0.031)
Size	0.312*** (0.008)	0.314*** (0.008)	0.312*** (0.009)	0.312*** (0.009)
Leverage	-0.938*** (0.053)	-0.938*** (0.054)	-0.937*** (0.057)	-0.939*** (0.057)
Age	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)
ROA	0.110*** (0.026)	0.108*** (0.026)	0.114*** (0.027)	0.113*** (0.027)
Indratio	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
Top1	0.136** (0.062)	0.127** (0.062)	0.114* (0.066)	0.114* (0.066)
SOE	0.510*** (0.023)	0.510*** (0.024)	0.507*** (0.025)	0.508*** (0.025)
Loss	-0.751*** (0.070)	-0.730*** (0.072)	-0.720*** (0.082)	-0.720*** (0.082)
Constant	-0.338 (0.341)	-0.431 (0.354)	-0.209 (0.449)	-0.093 (0.461)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	14,040	13,874	12,406	12,403
R-squared	0.271	0.271	0.267	0.267

(3) Endogenous discussion

Although this paper uses a bidirectional fixed-effect model to estimate the enterprise industry characteristics that do not change at any time, some potential unobservable characteristics and

measurement errors will still produce endogenous problems and thus affect the estimation results. Based on this, this paper uses the average iv of the development level of the digital economy in other cities in the province where the enterprise is located as the tool variable of the digital economy development in the city where the enterprise is located. Firstly, the tool variable meets the correlation: the digital economy development of the city within a province has a high correlation; secondly, the tool variable also meets the exogenous correlation. The development level of digital economy in other cities in one province is difficult to directly affect the decision-making and ESG performance of the enterprise.

The estimation results of the tool variables are shown in Table 6: where column (1) is the estimation results of the first stage, iv is positively correlated with the development level of the digital economy in the city where the enterprise is located Digit _ city at 1%, in line with expectations. The F test also showed no weak instrumental variable problem. Column (2) is the estimated result of the second stage, which is still significantly positive. Therefore, the core results of this paper remain even after considering potential endogeneity problems.

Table 6. For instrumental variable estimates

	(1)	(2)
explained variable	Digit_city	F.ESG
	First Stage	Second Stage
iv	0.978***	
	(0.008)	
Size	-0.001**	0.339***
	(0.001)	(0.006)
Leverage	0.027***	-0.926***
	(0.005)	(0.042)
Age	-0.000	-0.002*
	(0.000)	(0.001)
ROA	-0.003	0.077***
	(0.002)	(0.019)
Indratio	0.000**	0.003***
	(0.000)	(0.001)
Top1	0.032***	0.084*
	(0.006)	(0.049)
SOE	-0.003	0.438***
	(0.002)	(0.018)
Loss	0.004	-0.715***
	(0.004)	(0.057)
Digit_city		0.249***
		(0.042)
F statistics	1.6e+04	
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	23,930	23,361
R-squared	0.655	0.178

(4) Discussion of regulatory effect and heterogeneity

According to the Guidelines for Environmental Information Disclosure of Listed Companies issued by the Ministry of Environmental Protection in 2010, this paper classifies 16 seriously polluting industries, including petrochemical, coal, paper, mining, textile, leather, gold and thermal power, as heavy polluting industries.

Table 7. Analysis of the moderating effects

	(1)	(2)
explained variable	F.ESG	F.ESG
wuran		0.044 (0.060)
Digit_city	-0.072* (0.039)	0.126*** (0.034)
c.SOE#c.Digit_city	0.665*** (0.072)	
c.wuran#c.Digit_city		-0.589*** (0.199)
Size	0.333*** (0.007)	0.340*** (0.006)
Leverage	-0.900*** (0.042)	-0.937*** (0.042)
Age	-0.002** (0.001)	-0.002* (0.001)
ROA	0.078*** (0.019)	0.079*** (0.019)
Inratio	0.003*** (0.001)	0.003*** (0.001)
Top1	0.060 (0.049)	0.095** (0.048)
SOE	0.258*** (0.027)	0.435*** (0.018)
Loss	-0.711*** (0.057)	-0.712*** (0.057)
Constant	-0.754*** (0.136)	-0.952*** (0.134)
Observations	23,361	23,361
R-squared	0.253	0.251

Table 8. Of regional heterogeneity

	(1)	(2)	(3)
explained variable	F.ESG	F.ESG	F.ESG
	east	middle part	the west area
Digit_city	-0.055 (0.038)	-0.029 (0.282)	0.708*** (0.221)
Size	0.339*** (0.008)	0.351*** (0.019)	0.275*** (0.018)
Leverage	-0.806*** (0.051)	-1.141*** (0.123)	-0.886*** (0.105)
Age	-0.001 (0.001)	-0.009** (0.003)	0.000 (0.003)
ROA	0.013 (0.023)	0.067 (0.050)	0.324*** (0.056)
Indratio	0.003*** (0.001)	0.003 (0.002)	0.002 (0.002)
Top1	0.297*** (0.057)	-0.101 (0.151)	-0.515*** (0.132)
SOE	0.474*** (0.023)	0.429*** (0.047)	0.557*** (0.046)
Loss	-0.726*** (0.069)	-0.590*** (0.146)	-0.685*** (0.158)
Constant	-0.961*** (0.161)	-1.006** (0.399)	0.289 (0.389)
Observations	16,237	3,125	2,957
R-squared	0.286	0.185	0.251

5. Mechanism analysis

Why can the regional digital economy development significantly improve the ESG performance of enterprises? In order to verify the influence mechanism, the paper sets the following mediation effect model for analysis:

$$Z_{it} = \gamma_0 + \gamma_1 \text{Digit_city}_{ct} + \gamma_2 X_{it} + \gamma_t + \mu_i + \varepsilon_{ict} \quad (2)$$

$$\text{ESG}_{ict+1} = \delta_0 + \delta_1 \text{Digit_city}_{ct} + \rho Z_{it} + \delta_2 X_{it} + \gamma_t + \mu_i + \varepsilon_{ict} \quad (3)$$

Where, Z_{it} is the mediation variable. Equation (2) is the first step of the mediation effect model, mainly examining the influence of the core explanatory variables on the mediation variables; Equation (3) is the second step of the mediation effect model. To examine the effect of mediation variables on the core explained variables. $\gamma_1 \rho$ If the model is both significant in Equation (2) and Equation (3), a mediation is mediation. According to the previous literature combing and theoretical analysis, this paper will discuss the mechanism from the following two aspects.

(1) Green innovation performance

This paper adopts the number of green patent application measure green technology innovation, because the patent application cycle is long, from the patent application to the final authorization usually takes two years, which leads to patent authorization data has large lag, considering the patent technology during the application may affect the enterprise performance, this paper adopts green patent application data identification enterprise green innovation performance.

The data source of the number of green patent applications filed by listed enterprises is the China Research Data Service Platform (CNRDS) Green Patent Research Database (Green Patent Research Database, GPRD). The database is a professional database developed by combining Chinese patent data and the green patent classification number standard published by the World Intellectual Property Office. Referring to the construction method of green patent application index, the index is divided

into three categories: number of all green patent applications, number of green invention patent applications (Ingrninv) and number of green utility model patent applications, among which the innovation of green invention patent is higher than that of green utility model patents. Therefore, this paper analyzes the number of green patent applications of listed enterprises by adding 1 logarithmic processing, and then constructs the green innovation performance variable lnGP.

Table 9 shows the mechanism analysis of enterprise green innovation performance. All columns control for all control variables and year, industry fixed effects. Column (1) The explained variable is lnGP, and it can be seen that the estimated coefficient of the core explanatory variable Digit _ city is 0.266, and the statistical level of 1% is significantly positive, indicating that the development of regional digital economy can significantly promote the performance of green innovation. To further look at the estimated results of column (2), the lnGP estimation coefficient is 0.08, which is also significantly positive at the 1% level, indicating that enterprise green innovation can boost ESG performance. Therefore, the development of digital economy in the region where the enterprise is located helps the performance of green innovation, and then promotes the intermediary path of enterprise ESG can be verified.

Table 9. Mechanism Analysis 1: Green innovation performance of enterprises

	(1)	(2)
explained variable	lnGP	ESG
lnGP		0.080*** (0.010)
Digit_city	0.266*** (0.025)	0.114*** (0.032)
Size	0.145*** (0.006)	0.314*** (0.006)
Leverage	0.065*** (0.023)	-0.856*** (0.040)
Age	-0.011*** (0.001)	0.000 (0.001)
ROA	0.042*** (0.011)	0.050*** (0.018)
Inratio	0.000 (0.000)	0.002*** (0.001)
Top1	-0.211*** (0.032)	-0.004 (0.047)
SOE	0.063*** (0.011)	0.369*** (0.018)
Loss	-0.040* (0.023)	-0.362*** (0.046)
Constant	-2.925*** (0.133)	-0.368*** (0.133)
Observations	23,930	23,490
R-squared	0.113	0.245

(2) Production efficiency

This paper uses the total factor productivity of an enterprise as a measure of production efficiency. In the measurement of total factor productivity, the most widely used OP method proposed by Olley and Pakes (1996) and the LP method proposed by Levinsohn and Petrin (2003). The former uses the current investment of the enterprise as the proxy variable of unobservable productivity impact, while the latter uses the intermediate input index of the enterprise as the proxy variable. In order to make

the results more credible, this paper adopts the enterprise TFP of LP measure used for mechanism analysis.

Table 10 shows the mechanism analysis of the green innovation performance of enterprises. As can be seen from column (1), the estimated coefficient of the core explanatory variable Digit _ city is 0.106, and the statistical level of 1% is significantly positive, indicating that the development of regional digital economy can significantly promote the TFP of enterprises. Further looking at the estimates of column (2), the TFP _ lp estimated coefficient is also significantly positive at the level of 1%, respectively, indicating that enterprise TFP can significantly improve ESG performance. Therefore, this mediation path is also verified.

Table 10. Mechanism Analysis ii: Enterprise production efficiency

	(1)	(2)
explained variable	TFP_lp	ESG
TFP_lp		0.046*** (0.016)
Digit_city	0.106*** (0.013)	0.131*** (0.032)
Size	0.732*** (0.003)	0.291*** (0.014)
Leverage	0.289*** (0.018)	-0.860*** (0.040)
Age	-0.003*** (0.001)	-0.000 (0.001)
ROA	1.182*** (0.010)	-0.001 (0.026)
Inratio	0.000 (0.000)	0.002*** (0.001)
Top1	0.096*** (0.019)	-0.026 (0.047)
SOE	-0.021*** (0.007)	0.376*** (0.018)
Loss	-0.037 (0.028)	-0.366*** (0.046)
Constant	-7.366*** (0.060)	-0.236 (0.179)
Observations	23,869	23,430
R-squared	0.884	0.242

6. Conclusions and suggestions

The development of digital economy has brought about digital innovation, digital finance, and industrial structure optimization, and has actively and effectively promoted the ESG performance of enterprises. This paper selects the panel of a-share listed companies in 2008-2020 as the original sample to empirically test the effect and mechanism of digital transformation on the ESG performance of enterprises under the background of digital economy. The empirical test results show that the digital transformation of enterprises has a significant effect on the performance of enterprise ESG, and the conclusion is still stable and reliable after a series of endogenous processing and robustness tests.

Based on the above studies, this paper also makes the following suggestions:

First, digital management helps enterprises to improve the quality of ESG information disclosure. Enterprises should cultivate market-oriented professional institutions to help enterprises build ESG

digital system, and strengthen the training of ESG management personnel, so as to realize the automation of ESG information collection and calculation, reduce manual pressure and avoid manual errors in data accounting. At the same time, digital management can monitor and track the performance of enterprise ESG in real time, realize the continuous monitoring of ESG management, and improve the accuracy and timeliness of enterprise ESG information disclosure.

Second, we will promote green transformation and sustainable development. In the era of digital economy, enterprises should actively promote green transformation and sustainable development to achieve coordinated economic, social and environmental development. Enterprises can realize green production and sustainable development by introducing the environmental protection industry, optimizing the industrial structure and improving the efficiency of resource utilization.

Third, to strengthen the practice and performance of corporate social responsibility. Enterprises should strengthen the practice and performance of social responsibility, not only pay attention to financial performance, but also measure enterprise value from the perspective of environment, society and governance. Enterprises should actively fulfill their social responsibilities, promote sustainable development, pay attention to employee rights and interests and environmental issues, and achieve a sustainable business development model.

Fourth, work together with the stakeholders to promote ESG development. Enterprises should work with stakeholders to promote ESG development and establish good cooperative relations. Enterprises should pay attention to the needs and opinions of stakeholders, actively participate in social public welfare undertakings, and improve their social image and reputation. At the same time, enterprises should cooperate with governments, industry associations and other institutions to jointly promote the policy formulation and implementation of ESG development.

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