How does the digital economy empower corporate ESG? Evidence from China

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Abstract: Based on the realistic background of corporate digitalization and green development, this paper explored how the digital economy can empower corporate Environmental, Social, and Corporate Governance (ESG). Taking A-share listed companies from 2011 to 2021 as a research sample, this paper used methods such as mediation effect analysis, moderating effect analysis, and endogenous testing. This paper found that the digital economy could drive the improvement of corporate ESG performance significantly, especially for the environmental and social aspects. The improvement effect is more obvious for companies with heavily pollution and green financial environments. The results of the mechanism showed that the empowerment of the digital economy to corporate ESG could be achieved through two paths: Easing financing constraints and promoting green economic development. The results showed that the digital economy could achieve deep integration with corporate environmental governance, social responsibility, and internal governance. Moreover, the digital economy could improve the level of corporate ESG through policy support and have inspirational meaning for the empowerment of the digital economy to corporate ESG.

Keywords: Digital economy; ESG; Financing constraint; Green finance

1. Introduction

In recent years, the concept of Environmental, Social, and Corporate Governance (ESG) has aroused widespread attention and discussion around the world. Many countries and regions have also introduced relevant ESG policies and regulations to promote the healthy development of ESG. In this context, international ESG investment is also gradually emerging. Until 2020, the global ESG investment scale has reached 35.30 trillion US dollars, which has exceeded one-third of the total global asset management scale[1]. To comply with the trend of ESG and low-carbon development, China has put forward the "dual carbon" goal, which has produced profound changes and impacts on China's social governance, enterprise development, and industrial transformation. Concepts such as "environmental protection", "green development" and "sustainable development" are gradually becoming important considerations in the industrial layout and investment strategy of enterprises. Among them, the ESG concept covering the three major factors of the environment, Social, and Governance provides a basic follow-up and development direction for enterprises. The core focus of ESG is the performance of the environment, society, and governance of the enterprise, considering the economic, social, and ecological benefits of the enterprise itself. ESG can effectively promote the enterprise to undertake the responsibility of low-carbon development and green practice behavior in the capital and financial market. In April 2022, the China Securities Regulatory Commission issued the "Guidelines for Investor Relations Management of Listed Companies (2022)", which included "company's environmental, social and governance information (ESG)" in the communication content of investor relationship management for the first time. In terms of ESG funds, according to the "2022 China ESG Development White Paper" issued by Caixin Think Tank, the management scale of China's ESG public offering funds in 2022 will be close to 300 billion Chinese Yuan, an increase of nearly 50 billion yuan compared with the same period last year[2]. In terms of information disclosure, the ESG report disclosure rate of listed companies has also continued to increase. According to Wind data, by the end of August 2022, the disclosure rate of independent CSR/ESG reports of A-share listed companies will exceed 30%. At the same time, China's ESG subject ratings are also constantly improving. The dimensions of domestic mainstream ESG rating indicators are continuously subdivided, the coverage of rating

categories is also expanding, and the ESG evaluation system is constantly improving. From the current point of view, China's ESG concept and related content started relatively late, but it has developed rapidly in recent years and has gradually become a new trend leading to the development of enterprises and a new direction of investment supervision. As a fast-growing emerging economic form, the digital economy is continuously promoting enterprise transformation with its digital, intelligent, and networked characteristics. And the digital economy also has a profound impact on the environment, society, and governance of enterprises. Therefore, it is an important research question of how the digital economy can empower corporate ESG.

With knowledge and information as the content and digitalization as the carrier, the digital economy plays a huge role in empowering the transformation and upgrading of traditional industries, solving the pain points and difficulties of the real economy, and cultivating new industries, formats, and models. Goldfard and Tucker (2019) suggested that digital technologies reduced the cost of data use and processing, which in turn reduced five different economic costs[3]. Therefore, the emergence and development of the digital economy provide a smoother growth path for enterprises, promote the high-quality transformation of enterprises, and can help enterprises achieve more complete internal governance, ecological governance, and social responsibility management. From a global perspective, the overall development of the global digital economy showed an upward trend, and the average score of the TIMG Index (Global Digital Economy Development Index) increased from 45.33 in 2013 to 57.01 in 2021, an increase of 26%, providing strong support for world economic recovery and industrial digital transformation in various countries[4]. In the 14th Five-Year Plan for the Development of the Digital Economy issued by the State Council, China has clarified the guiding ideology and relevant measures to promote the healthy development of the digital economy. At the same time, according to the "Research Report on the Development of China's Digital Economy" released by the China Academy of Information and Communications Technology in April 2023, China's digital economy is achieving high-quality development. In 2022, the scale of China's digital economy reached 50.2 trillion yuan, a year-on-year nominal increase of 10.3%, which has been significantly higher than the nominal growth rate of GDP in the same period for 11 consecutive years, and the proportion of the digital economy in GDP reached 41.5%[5]. Thus, the digital economy is playing a more prominent role in the Chinese economic system and industrial layout.

Regarding the research on the digital economy, scholars have conducted empirical research and theoretical analysis on the internal mechanism, influence path, and development trend of the digital economy. According to the existing literature, researchers believe that digital technology can help enterprises achieve innovative development and gain a competitive advantage (Burgonov et al., 2022)[6]. Chen (2022) argues that the digital economy can reduce market friction and improve market efficiency[7]. Li et al. (2022) believe that the digital economy has a positive role in promoting enterprise innovation and digital transformation[8]. Li et al. (2023) discuss the impact of digital economy on enterprise innovation from the perspective of financing constraints[9]. Peng et al. (2023) believe that the digital economy can improve the investment efficiency of enterprises by curbing excessive investment[10]. Xu et al. (2022) believe that the organic integration of digital economy and enterprise management effectively improves the efficiency of business administration[11]. Wu and Zeng et al. (2022) believe that for enterprises with a digital economy as the core, increased R&D investment and good internal governance can improve corporate performance[12]. Most of the current literature focuses on the economic value and management value of the digital economy for enterprises. However, as a development concept of emerging enterprises, the ESG concept and its performance have not been widely studied and mentioned.

Under the trend of continuous expansion of ESG concepts, scholars have also made many useful explorations on ESG-related content. Broadstock et al. (2021) argue that high ESG portfolios generally perform better and that ESG performance can mitigate risks during financial crises[13]. Bruna et al. (2022) and Gao et al. (2022) believe that good ESG performance has a contributing effect on the financial performance of listed companies[14-15]. Gao et al. (2023) found from the

perspective of enterprise life cycle theory that ESG can significantly improve the performance of enterprises at various life cycle stages[16]. Fatemi et al. (2018) believe that excellent ESG performance can improve corporate value, but disclosing ESG information will have a negative impact on corporate value[17]. At the same time, the literature has found that ESG performance has a significant positive impact on enterprise value and company market value (Wu et al., 2022; Zhou et al., 2022; Carnini Pulino et al., 2022)[18-20]. Lou et al. (2023) found that ESG can increase enterprises' business credit by alleviating information asymmetry, improving operational efficiency, and reducing risks, thereby increasing enterprises' access to trade credit[21].Ge et al. (2022) believe that ESG performance is conducive to promoting the high-quality development of enterprises[22]. Accordingly, through a transmission path different from traditional methods, good ESG performance has a positive impact on corporate performance, corporate financing conditions, and high-quality development. Moreover, ESG has strong practical significance for enterprise innovation drive, value appreciation, and green transformation.

Many scholars have also conducted some research on the digital economy, corporate environmental governance, social responsibility management, and internal governance. For example, Deng et al. (2022) propose that China's digital economy has significantly promoted the growth of green total factor productivity in China's manufacturing industry[23]. Li et al. (2022) and Ning (2022) believe that the digital economy has a role in promoting the green innovation of listed enterprises in China[24-25]. Zhou et al. (2022) believe that the digital economy can significantly improve the level of sustainable development of enterprises[26]. However, prior studies pay less attention to the exploration of the digital economy and corporate ESG.

Accordingly, this paper take A-share listed companies from 2011 to 2021 as a research sample. Using non-equilibrium panel data, moderation effect test, mediation effect test, and endogenous test, we explore how the digital economy empowers enterprise ESG. Compared with previous literature, the main contributions are: (1) broadening the scope of existing theoretical research on ESG, exploring the factors driving ESG efficiency improvement based on the actual data of listed companies and digital economy development indicators, and providing a reference for finding relevant effective mechanisms. (2) This research provides another perspective on the impact path of the digital economy on enterprises and enriches the objects of the driving role of the digital economy. Meanwhile, this paper emphasizes the non-economic utility of the digital economy, and promotes the sustainable and high-quality development of enterprises. (3) Through the two aspects of financing constraints and green economic environment, this paper examine the role of the digital economy on corporate ESG and explain the transmission mechanism of the empowerment role, which provides a reference for corporate reform governance.

2. Theoretical hypotheses

2.1 Digital economy and corporate ESG performance

As an important role in promoting the digitization of all elements of enterprises, intelligent production methods, and production efficiency, the digital economy takes massive data resources and modern information networks as its core elements. In recent years, the rapid development of the digital economy has put forward higher requirements and more possibilities for the environmental governance, social responsibility, and internal governance of enterprises at all levels. The rapid development of the digital economy has had a profound impact on the operation and sustainable development of enterprises. First, the digital economy offers companies more opportunities to improve their environmental performance. According to existing research (Vidmar, 2019), the digital economy can provide support for enterprises to create a greener and low-carbon business model, and promote the green transformation and sustainable development of enterprises[27]. For example, the growth of the digital economy has enabled businesses to better monitor and manage their environmental impact. Through the Internet of Things and big data analysis, companies can monitor environmental indicators such as energy consumption, waste discharge, and water resource

utilization in real-time. Meanwhile, companies can greatly improve energy efficiency, reduce pollution and waste, and promote carbon neutrality. Moreover, the digital economy has also promoted the promotion of remote work, helping companies and employees reduce carbon emissions and waste of resources. In addition, the development of the digital economy has also increased the demand for paperless enterprises, promoting the development and application of clean energy, improving the energy efficiency of enterprises, thereby improving their environmental performance, and achieving a win-win situation of economic and ecological benefits. Second, the digital economy has increased the feasibility of corporate participation in social responsibility. According to relevant literature research (Malaquias et al., 2016), the development of digital technology has opened up new channels for enterprises to participate in society and has formed positive guidance for enterprises to undertake economic responsibility, legal responsibility, ethical responsibility, and discretionary responsibility[28]. At the same time, the digital characteristics of the digital economy enable business activities to use digital channels (e.g., social media, online platforms, and mobile applications) to communicate more directly and extensively with consumers, employees, and social organizations while retaining their economic attributes. This enables companies to better understand social concerns and consumer needs, and adjust and improve products and services promptly based on their feedback, thus generating good social impact. Finally, in terms of corporate governance, the research of Kong and Liu (2023) believes that digital technology can help companies improve internal control efficiency and social responsibility performance[29]. Based on the own attributes of the digital economy, the economic activities of enterprises will be stored and processed intelligently, to reflect the actual development status of enterprises. The results can help enterprises understand the internal resource flow and output of the enterprise, promote the rational allocation of internal resources, and optimize the internal governance structure of the enterprise. Based on the above analysis, this paper proposes the following hypotheses:

H1: The development of the digital economy has a role in promoting the ESG performance of enterprises.

2.2 Corporate pollution control, digital economy and ESG performance

Along with the proposal and in-depth development of China's strategic goal of "carbon peaking and carbon neutrality", China's State Council clearly stated in the Action Plan for Peaking Carbon Emissions before 2030 to promote the green transformation of heavily polluting industries and enterprises and build a complete green supply chain, industrial chain, and green innovation system. In this context, China first improves the access mechanism and the access conditions for heavily polluting projects, and curbs the blind development of high-pollution and high-energy-consuming industries. Second, China has implemented the elimination mechanism, strengthened the treatment of the source of pollution in enterprises, strictly implemented the requirements for the elimination of backward production capacity, and implemented rectification and elimination of enterprises with serious pollution and waste. Therefore, in the face of increasingly stringent environmental protection policies, heavy-polluting enterprises will further realize the importance of promoting energy conservation and emission reduction and the necessity of implementing green and low-carbon transformation. Therefore, this paper believes that heavy polluting enterprises will increase their spending on environmental protection governance and internal structure optimization, accelerate the elimination of high-pollution backward production capacity, improve the level of refined environmental governance, and promote the achievement of various environmental governance and pollution control indicators according to the current new national standards. Under such circumstances, the capital expansion, structural upgrading, and information processing brought by the digital economy to heavy-polluting enterprises will greatly promote the process of low-carbon and green heavy-polluting enterprises. At the same time, according to Su and Tian (2023), using carbon trading methods, heavy-polluting enterprises can achieve better ESG performance by easing financing constraints and increasing R&D investment[30]. This is because the starting level of ESG performance of heavy polluting enterprises is low and the development

potential is large. Meanwhile, heavy polluting enterprises also have an urgent need to meet environmental compliance. Based on this, this paper proposes the following assumptions:

H2: Compared with non-heavy polluting enterprises, the driving effect of the digital economy on the ESG performance of heavily polluting enterprises is more significant.

2.3 Green finance, digital economy and ESG performance

Green finance is an emerging economic form that provides relevant financial services for enterprises with environmental remediation, climate mitigation, and resource conservation as the core. As China's ecological civilization construction continues to advance, China is also constantly building and improving its green financial system to cope with potential crises and challenges. Through green finance, enterprises can enjoy more innovative financial products, such as green funds, green futures, and green bonds, to improve the level of green development. Meanwhile, they can also supplement and improve their digital economy with the help of green finance to create a more complete enterprise economic form. In the existing literature, Zheng et al. (2022) and Lei et al. (2021) believe that the improvement of green credit level is conducive to promoting the high-quality development of the green economy[31-32]. At the same time, high-quality development areas of the green economy have "spillover effect", which can drive the development of green economy in surrounding areas. It can be seen that in a good green financial system and environment, enterprises will have more green development opportunities and enjoy more policy preferences. This will encourage enterprises to incorporate green finance into the framework of investment activities, not only achieve low-carbon operation in actual operation, but also establish a green concept in strategy, and promote the improvement of corporate ESG level from both practical and strategic levels. Based on this, this paper makes the following assumptions:

H3: Compared with enterprises with good non-green financial environments, the driving role of the digital economy on the ESG performance of enterprises with excellent green financial environments is more significant.

3. Research design

3.1 Model setting

To measure the impact of the digital economy on the ESG performance of enterprises, this paper adopts a two-way fixed-effect model to control individual effects and time effects, and constructs the model as follows:

$$\text{ESG\_pengbo}_{it} = \alpha + \beta Dig - economy_{it} + \gamma X_{it} + \tau i + \upsilon t + \varepsilon_{it}$$

In this model, i represents the enterprise, t represents the year, ESG_pengboit represents the ESG performance of i enterprise in t year, Dig-economyit represents the digital economy development status of the city where i enterprise is located in t year, Xit represents the control variable at the enterprise level, τ represents the time fixed effect, υ represents the individual fixed effect, εit is the random disturbance term, α is the constant term, and β is the model estimation parameter. Among them, the core focus parameter of this paper is β, if the β is significantly positive, it indicates that the digital economy has a positive driving effect on the improvement of the ESG performance of enterprises.

3.2 Description of variables and data

3.2.1 Data sources

This paper selects all A-share listed companies from 2011 to 2021 as research samples and screens the samples: first, the listed companies of ST and *ST are excluded; second, the continuous variables are shrunk at the level of 1% and 99%; third, the listed companies with missing data are excluded; and fourth, the listed companies whose industries are financial industry are excluded, and finally a total of 8120 valid observations are obtained. The data on corporate ESG performance in this article comes from the Bloomberg ESG Index compiled by Bloomberg, and the digital financial

index comes from the Peking University Digital Financial Inclusion Index compiled by the Peking University Digital Finance Research Center. Data for control variables, mediation variables, and heterogeneity analyses came from CSMAR, Wind, provincial and municipal statistical yearbooks, and environmental status bulletins.

3.2.2 Dependent variables

At present, ESG, as an emerging and important development concept, has a variety of evaluation systems and scoring methods. This paper refers to Fang et al. (2023) on digitalization and enterprise ESG performance and uses Bloomberg ESG Score (ESG_pengbo) to measure the ESG performance of enterprises[33]. The index includes the performance and performance of enterprises in three aspects: Environmental, Social, and Governance, and includes 10 secondary indicators and 35 third-level indicators, covering resource use, pollution treatment, supply management, governance mechanism, and other aspects.

3.2.3 Core independent variables

The core independent variable of this paper is digital finance (Dig-economy), which is measured by the Peking University Digital Financial Inclusion Index released by the research group of the Peking University Digital Finance Research Center[34]. Relying on Ant Group's massive data on digital inclusive finance, the index constructs a digital inclusive financial index system from three dimensions: the breadth of digital financial coverage, the depth of use of digital finance, and the digitalization of inclusive finance, with 33 specific indicators. The selection of this core explanatory variable refers to Yang et al. (2022) research on digital finance and corporate ESG performance, but to improve the accuracy of data research and the credibility of the research conclusions, this paper chooses to use a more accurate 2011-2021 municipal digital inclusive financial index to measure the core explanatory variable Dig-economy[35].

3.2.4 Mediators

The mediators covered in this article are the Financing Constraint (KZ) and the Green Economy Development Index (GD). Drawing on the research of Kaplan and Zingales (1997), this paper uses the KZ index to reflect the financing constraints of enterprises, and the larger the KZ index, the greater the degree of financing constraints on enterprises[36]. Referring to Ran Shasha et al. (2023) "How to Construct a Statistical Framework for Green Finance", this paper constructs a green economic development index (GD), which is aggregated and standardized by green investment, green fund, and green equity[37]. Among them, green investment is expressed as the proportion of environmental pollution control investment to GDP, the green fund is expressed as the total market value of the green fund as the proportion of the total market value of all funds, and green equity is expressed as the proportion of carbon trading, energy uses right trading, and emission right trading to the total market transaction volume of the equity market, and the data range is from 2011 to 2021.

3.2.5 Control variables

Referring to the relevant literature in the field of digital economy (Fang et al., 2023), a total of 9 control variables are selected, including enterprise size (size), enterprise debt level (Lev), enterprise profitability (ROA), enterprise inventory ratio (INV), enterprise fixed assets proportion (FIXED), Tobin Q value (TobinQ), company establishment age (FirmAge), enterprise two-position integration rate (dual), and equity concentration (Top5).

3.2.6 Descriptive statistics

The average ESG score of enterprises is 28.08, the minimum value is 6.198, the maximum value is 68.92, and the standard deviation is 9.346. The overall ESG score is good, but there are still large gaps between enterprises, and ESG scores fluctuate greatly. The average value of the city-level digital financial inclusion financial index is 229.6, the minimum value is 41.91, and the maximum value is 359.7, which shows that the inclusive effect of the digital economy is significant, but the

differences between cities are obvious, and the degree of benefit of each city is uneven. The average value of the breadth of municipal digital financial coverage, the depth of municipal digital financial coverage, and the degree of digitalization of inclusive finance are not much different, which shows that digital finance has achieved coordinated development in horizontal, vertical, and digital aspects.

Table1: Descriptive statistical results for primary variables

Types of variables	Names of variables	Variable description	(1) N	(2) mean	(3) sd	(4) min	(5) max
Dependent variables	ESG_pengbo	Bloomberg ESG Index	8,120	28.08	9.346	6.198	68.92
Independent variables	Dig-economy	Peking University Digital Financial Inclusion Index (2011-2021), is a municipal digital financial inclusion index	8,120	229.6	62.51	41.91	359.7
	Dig-economy1	Peking University Digital Financial Inclusion Index (2011-2021), Municipal Digital Finance Coverage Depth Index	8,120	224.3	65.99	25.44	354.3
	Dig-economy2	Peking University Digital Financial Inclusion Index (2011-2021) , Digitalization of Municipal Financial	8,120	241.5	72.98	19.20	581.2
Mediators	KZ	Financing constraints index	7,829	1.001	2.385	-11.34	10.84
	GD	Green economic development index: composed of green investment, green fund and green rights and interests of prefecture-level cities	8,117	0.103	0.0349	0.0135	0.223

Control variables	Size	The logarithm of the total assets of the enterprise	8,120	23.16	1.288	19.55	26.43
	Lev	Total liabilities/total assets	8,120	0.478	0.200	0.0349	0.925
	ROA	Net Profit/Average Balance of Total Assets	8,120	0.0483	0.0650	-0.398	0.254
	INV	The ratio of net inventory to total assets	8,054	0.153	0.150	0	0.772
	FIXED	Ratio of net fixed assets to total assets	8,120	0.223	0.176	0.00150	0.725
	TobinQ	(tradable market value + number of non-tradable shares × net assets per share + book value of liabilities) / total assets	7,993	1.989	1.443	0.802	17.73
	FirmAge	ln (current year - year of incorporation +1)	8,120	2.936	0.333	1.386	3.611
	dual	If the chairman and general manager are the same person = 1, otherwise = 0	8,120	0.211	0.408	0	1
	Top5	Number of shares held by the top five shareholders / total number of shares	8,120	0.550	0.161	0.185	0.892

4. Empirical research

4.1 Baseline Results

In this paper, the two-way fixed-effect model in the panel data model is used to maintain the temporal fixed effect and individual fixed effect, and the benchmark regression results are shown in Table 2. In the regression result column (1), the regression coefficient of the core explanatory variable Dig-economy is 0.051, which is significantly positive at the level of 1%. After adding the control variable, the regression coefficient of the core explanatory variable Dig-economy is 0.047,

which is still significantly positive at the level of 1%, and the regression result is shown in column (2). It can be seen that there is a significant positive correlation between the digital economy and corporate ESG performance, assuming that H1 is true. To further explore the driving logic of the digital economy on corporate ESG performance, this paper adds the impact of the digital economy on three ESG indicators (Environmental, Social, and Governance), and the regression results are shown in columns (2),(3), and (4). It can be seen from the results that the digital economy has a significant role in promoting the three first-level indicators of ESG, among which the effect on environmental governance and responsibility is the most prominent. Referring to Li et al. (2022) on digital finance and green innovation, it can be argued that compared with Social and Governance, enterprises' investment in the environment can not only reduce corporate resource loss, promote energy conservation and emission reduction, but also promote green innovation and green transformation of enterprises to a certain extent. Therefore, for strategic reasons, companies are more willing to increase the proportion of investment in the environmental aspect of ESG performance, to obtain better E performance output.

Table 2: Baseline results: Impact of the digital economy on ESG performance

VARIABLES	(1) ESG_pengbo	(2) ESG_pengbo	(3) E_pengbo	(4) S_pengbo	(5) G_pengbo
Dig-economy	0.051***	0.047***	0.065***	0.043***	0.031*
	(3.96)	(3.70)	(2.64)	(3.34)	(1.88)
Size		1.278***	2.184***	1.742***	-0.022
		(6.07)	(5.47)	(7.68)	(-0.08)
Lev		-2.536***	-5.144***	-2.008**	-1.259
		(-3.27)	(-3.41)	(-2.45)	(-1.10)
ROA		3.014***	4.896**	1.949	1.672
		(2.60)	(2.09)	(1.55)	(1.02)
INV		3.750***	6.654***	3.855***	0.812
		(3.39)	(2.80)	(3.58)	(0.52)
FirmAge		3.543**	5.071	0.443	2.543
		(2.27)	(1.64)	(0.25)	(1.19)
Dual		-0.192	0.378	-0.383*	-0.610**
		(-0.83)	(0.77)	(-1.77)	(-2.09)
Top5		4.244***	4.889**	1.427	6.625***
		(3.38)	(2.20)	(1.09)	(3.96)
Observations	8,120	8,054	7,953	8,027	8,054
R-squared	1,308	0.737	0.359	0.283	0.824
Number of stkcd	0.728	1,305	1,290	1,302	1,305
Company FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
r2_a	0.728	0.737	0.358	0.281	0.824
F	515.4	334.7	52.85	38.17	818.9

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Robustness tests

4.2.1 Substitution variables

To ensure the robustness of the results, this paper uses the city-level digital financial coverage depth index (Dig-economy1) and the city-level digital financial inclusion degree (Dig-economy2) in the Peking University digital financial inclusion index to compare the original The explanatory variable is replaced by the city-level digital financial inclusion index (Dig-economy). Among them, the depth of digital financial use is mainly measured from the actual use of digital financial services, including the use of financial services, the total amount of actual use, and the use of active indicators. The degree of digitalization of inclusive finance is measured by the convenience of digital financial services, cost and interest rates, and the degree of credit. As shown in columns (1) and (2) of Table 5, the regression coefficients of the digital economy after replacing variables are all significantly positive at the 1% level, indicating the robustness of the digital economy's driving effect on corporate ESG performance.

Table 3: Regressions with alternative measures of the digital economy

VARIABLES	(1) ESG_pengbo	(2) ESG_pengbo
Dig-economy1	0.025***	
	(2.91)	
Dig-economy2		0.012***
		(3.29)
Size	1.295***	1.296***
	(6.13)	(6.11)
Lev	-2.538***	-2.546***
	(-3.28)	(-3.28)
ROA	2.969**	3.006**
	(2.56)	(2.58)
INV	3.688***	3.758***
	(3.31)	(3.41)
FirmAge	3.662**	3.560**
	(2.35)	(2.26)
Dual	-0.204	-0.196
	(-0.87)	(-0.84)
Top5	4.249***	4.217***
	(3.38)	(3.35)
Constant	-26.617***	-25.194***
	(-4.19)	(-3.95)
Observations	8,054	8,054
R-squared	0.737	0.737
Number of stkcd	1,305	1,305
Company FE	YES	YES
Year FE	YES	YES
r2_a	0.736	0.736
F	333.5	335.7

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2Endogeneity test

Since the research in this paper may have measurement errors and omission of explanatory variables, which may lead to endogeneity problems, this paper uses the instrumental variable method to test and selects the logarithm of the digital economy patent authorization of the prefecture-level city where the company is located as an instrumental variable. As shown in Table 6, column (1) shows that the coefficient of the level of digital economy development is significantly positive, indicating that the development of the digital economy has a significant driving effect on the ESG performance of enterprises. Column (2) shows that there is a significant positive correlation between the number of digital economy patent authorizations and the development of the digital economy. At the same time, there is no direct correlation between the number of digital economy patent authorizations and corporate ESG performance, which is in line with the exogenous nature of instrumental variables. It can be seen that the selection of the instrumental variable meets the needs of the research. Column (3) shows the regression results using the logarithm of digital economy patent authorization as an instrumental variable, which shows that the positive driving effect of digital economy (Dig-economy) on corporate ESG performance is still significant at the 1% level is positive. According to the above analysis, it can be seen that the results of this paper are robust.

Table 4: Regression results of instrumental variables

VARIABLES	(1) ESG_pengbo	(2) Dig-economy	(3) ESG_pengbo
Dig-economy	0.047***		
	(3.70)		
Tech		3.492***	
		(3.99)	
Dig-economy			0.1192***
			(19.9309)
Size	1.278***	0.905***	1.0103***
	(6.07)	(2.77)	(6.1588)
Lev	-2.536***	0.003	-1.8243***
	(-3.27)	(0.00)	(-2.7634)
ROA	3.014***	-6.479***	5.7574***
	(2.60)	(-3.16)	(5.3461)
INV	3.750***	-1.292	4.1915***
	(3.39)	(-0.75)	(4.6504)
FirmAge	3.543**	2.681	-7.9693***
	(2.27)	(1.24)	(-3.7627)
Dual	-0.192	-0.116	-0.1479
	(-0.83)	(-0.42)	(-0.7955)
Top5	4.244***	0.897	3.7068***
	(3.38)	(0.50)	(3.9489)
Observations	8,054	8,044	7,987
Company FE	YES	YES	YES
Year FE	YES	YES	YES
r2_a	0.737	0.993	0.6914

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Mediating Effect

Referring to the studies of Kaplan and Zingales (1997) and Ouyang and Lu (2022), this paper uses two intermediary variables, the KZ index, and the green economy development index, to study the two driving paths that the digital economy promotes the improvement of corporate ESG performance[36][38]. At the same time, to make the data more stable and narrow the data gap, this paper performs logarithmic processing on the explanatory variable Dig-economy in the mediation effect test and then performs regression analysis. It can be seen from column (1) of Table 4 that there is a significant negative correlation between financing constraints and the degree of digital economy development at the level of 5%, that is, the development of digital economy can alleviate corporate financing constraints. The alleviation of corporate financing constraints can further bring capital injection to companies, promote companies to optimize resource allocation, increase green development expenditures, and thereby improve their ESG performance. It can be seen from column (2) of Table 4 that there is a significant positive correlation between the green economy development index and the degree of digital economy development at the 5% level. The openness, inclusiveness, and inclusiveness of the digital economy are essentially consistent with the concept of green development. Therefore, the development of the digital economy will also drive the development of the green economy to a certain extent and give birth to more green economic forms. A good green economy can also enable companies to conduct more green transactions and enjoy more green rights and interests, thereby promoting the green transformation of companies and the optimization of governance models, and ultimately helping companies achieve growth in ESG performance.

Table 5: Mediating effect analysis

VARIABLES	(1) KZ	(2) GD
In Dig-economy	-2.090**	0.017**
	(-2.50)	(2.27)
Size	0.181**	0.001
	(2.20)	(0.86)
INV	5.281***	-0.003
	(11.02)	(-0.58)
FIXED	4.332***	-0.010***
	(9.86)	(-2.92)
Dual	0.018	-0.001*
	(0.20)	(-1.67)
TobinQ	0.280***	0.000
	(9.64)	(0.27)
FirmAge	2.199***	0.004
	(3.93)	(0.80)
Constant	-1.033	-0.006
	(-0.23)	(-0.15)
Observations	7,765	7,925
R-squared	0.175	0.139
Number of stkcd	1,289	1,304
Company FE	YES	YES
Year FE	YES	YES
r2_a	0.174	0.137
F	49.18	52.91

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4.4 Heterogeneity

4.4.1Enterprise Pollution Control

In hypothesis H2, this paper believes that compared with non-heavy polluting companies, the digital economy has a more obvious driving effect on the ESG performance of heavily polluting companies, that is, the degree of environmental protection of the company itself will affect the company's ESG performance. Based on this, this paper divides all sample enterprises into heavily polluting enterprises and non-heavy polluting enterprises according to the CSMAR database and the Ministry of Ecology and Environment's "Environmental Protection Inspection Industry Classification Management List of Listed Companies". Heavy polluting enterprises are assigned a value of 0 (Pollution=0). To test which company's ESG performance is more driven by the digital economy, this paper constructs an interaction term of Dig-economy×Pollution and conducts regression analysis. As shown in column (2) of Table 3, the estimated coefficient of the interaction item is significantly positive at the 1% level, which shows that the digital economy has a better driving effect on the ESG performance of heavily polluting companies than non-heavy polluting companies. The hypothesis H2 is established. This may be because the development of the digital economy has promoted the digital innovation of high-polluting enterprises, reduced resource consumption and pollution emissions of enterprises, and improved the performance of high-polluting enterprises at the environmental level. The development of the digital economy has also eased the financing constraints of high-polluting companies, enabling high-polluting companies to raise funds through financing channels, investing more resources in environmental protection, social responsibility, and internal governance, thereby greatly improving the foundation of comparative Weak ESG performance.

4.4.2Green financial environment

In hypothesis H3, this paper believes that compared with non-green financial environment excellent enterprises, the driving effect of the digital economy on the ESG performance of enterprises with excellent green financial environment is more obvious. Based on this, this paper refers to Liu and He's (2021) research on green finance, as well as provincial and municipal statistical yearbooks, environmental status bulletins, and other documents, and uses the green financial development index of prefecture-level cities to measure whether the green financial environment of enterprises is good[39]. The green financial development index of prefecture-level cities is composed of seven aspects green credit, green investment, green insurance, green bonds, green support, green funds, and green rights and interests of the prefecture-level city. The entropy method is used to measure and standardize the results. If the green financial index of the prefecture-level city where the enterprise is located is higher than the average value of all prefecture-level cities, it is said that the green financial environment is good, and the value is 1 (Green_economy=1); otherwise, the green financial environment is good, and the value is 0 (Green_economy=0). So this paper constructs the interaction term of Dig-economy×Green_economy and conducts regression analysis. As shown in column (3) of Table 3, the estimated coefficient of the interaction term is significantly positive at the 5% level, which shows that the digital economy has a better driving effect on enterprises with a good green financial environment than those with a non-green financial environment, verifying the establishment of hypothesis H3. This may be because enterprises with a good green financial environment are more likely to have access to financial products including green bonds, green funds, and green credit, which can meet the capital needs of enterprises for green technology innovation, thereby promoting the green development of enterprises. Moreover, green finance, as an emerging financial form, is generally rooted in areas with a high degree of digitalization and developed financial industries, which provides a very convenient transmission path for the digital economy to drive the ESG performance of companies, thereby better driving the ESG performance of companies in the region.

Table 6 Heterogeneity analysis

VARIABLES	(1) ESG_pengbo	(2) ESG_pengbo	(3) ESG_pengbo
Dig-economy	0.047***		
	(3.70)		
Dig-economy×Pollution		0.010***	
		(4.18)	
Dig-economy×Green_economy			0.041**
			(2.56)
Size	1.278***	1.369***	1.194***
	(6.07)	(6.47)	(5.24)
Lev	-2.536***	-2.290***	-2.259**
	(-3.27)	(-3.00)	(-2.56)
ROA	3.014***	1.992*	4.081***
	(2.60)	(1.72)	(3.10)
INV	3.750***	3.538***	3.874***
	(3.39)	(3.27)	(3.25)
FirmAge	3.543**	4.126***	3.215**
	(2.27)	(2.65)	(2.05)
Dual	-0.192	-0.228	0.045
	(-0.83)	(-0.98)	(0.19)
Top5	4.244***	4.279***	4.776***
	(3.38)	(3.45)	(3.36)
Constant	-27.499***	-27.953***	-25.059***
	(-4.32)	(-4.39)	(-3.74)
Observations	8,054	8,054	6,322
R-squared	0.737	0.738	0.741
Number of stkcd	1,305	1,305	1,080
Company FE	YES	YES	YES
Year FE	YES	YES	YES
r2_a	0.737	0.738	0.740
F	334.7	339.1	261.3

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

Based on the two mainstream development trends of Chinese society, the digital economy and ESG, this paper takes China's A-share listed companies from 2011 to 2021 as a research sample to explore the driving logic of the digital economy for corporate ESG performance. The research found that: first, the development of the digital economy has a significant positive driving effect on the ESG performance of enterprises, and the promotion effect on the two aspects of enterprise Environment and Social is more significant. Second, the digital economy has a more significant effect on improving the ESG performance of heavily polluting companies and companies with a good green financial environment in cities, showing the determination of relevant companies to carry out green transformation and systematic governance. Third, this paper finds that the digital economy can improve corporate ESG performance through two channels: easing corporate financing constraints and promoting green economic development. The research in this paper has

beneficially explored the possible path of the digital economy driving ESG performance, strengthened the connection between the digital economy and corporate ESG performance, enriched the theoretical framework of the two, and has certain practical significance.

The practical contribution and policy implications of the conclusions of this paper are as follows: First, enterprises should realize the coordinated development of digitalization and low-carbonization. Through digitalization to empower green, using the digital economy to empower the green economy, and integrating digitalization strategies into all levels of corporate ESG responsibility fulfillment, enterprises could use digital means to realize the management and control of corporate energy resources, pollution source control, social responsibility, and internal structure optimization, etc., to promote the coordinated development of the company in the three aspects of environment, society, and governance, thereby improving the company's ESG performance. Second, the government should vigorously promote the development of the digital economy and improve the digital infrastructure. Meanwhile, the government could promote the deep integration of the digital economy with the industrial chain, the financial sector, and ecological governance. Moreover, the government can provide technical support for the green transformation of enterprises and give full play to the driving force of the digital economy for the improvement of ESG performance effect. Third, the government should strengthen the ESG strategic layout and introduce targeted assistance policies, provide active guidance and development suggestions for heavily polluting enterprises, and promote heavily polluting enterprises to realize green organization through digitalization, so the government can achieve the win-win economic effect, ecological benefit, and social benefit. Fourth, the government should focus on building a higher-level green financial system and formulate financing policies related to corporate ESG. Meantime, the government could create an open and transparent financing environment to ensure that funds are put in place to meet corporate financing needs.

Author contribution

The authors of this paper were involved in: (a) theoretical research and design; (b) data analysis and interpretation; (c) drafting the article and revising the core of the article; (d) approval of the final version.

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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