Impact of Industry Digitization on ESG Performance – An Empirical Analysis Based on Industry Perspective

Han Lin[1, *, #], Zheyi Liu[1, #], Jingwei Sun[2, #]

[1]College of Mathematics and Computer Science, Shantou University, Shantou, China, 515063

[2]School of Business Liu Guojun School of Management, Changzhou University, Changzhou, China, 213100

*Corresponding author:21hlin3@stu.edu.cn

#These authors contributed equally.

Abstract. This research seeks to investigate the influence of industrial digitalization on environmental, social responsibility, and corporate governance (ESG) outcomes. Through the utilization of a panel data model, the study demonstrates that the industrial digitalization index exerts a notable positive effect on corporate ESG performance, with this impact displaying a gradual augmentation in recent periods. The findings elucidate the correlation between industrial digitalization and ESG performance, underscoring the significance of corporate ESG ratings. Furthermore, the study contributes to the scholarly discourse on the industrial digitization process and the determinants of ESG performance, shedding light on the repercussions of digitalization advancement on industry ESG through an industry-centric lens.

Keywords: industrial digitization, ESG, digital economy, financing constraints, largest shareholder shareholdings.

1. Introduction

Fueled by the contemporary advancements in science and technology and the ongoing industrial revolution, the process of digital transformation has become increasingly crucial in enhancing the competitiveness of nations and fostering innovative growth opportunities. The rapid evolution of science and technology has led to the maturation of digital technology, which is now being widely adopted in various sectors such as industry and daily life. Consequently, many industries are gradually undergoing digital transformation in response to the pervasive trend of digitalization.

In pursuit of achieving high-quality economic and social development objectives, countries worldwide are placing a growing emphasis on enterprises' Environmental, Social, and Governance (ESG) performance alongside their digital development efforts (Hu et al., 2023). Environmental, social and governance(ESG), as a measure of sustainable development of enterprises, has received more and more attention from the international community and enterprises themselves.

In this paper, the influence of industrial digitization on ESG rating indices in digital economy is studied. According to the research directions and progress in recent years, the literature which is highly relevant to this topic can be summarized as follows.

2. Research progress of digital development affecting ESG rating indices.

Various studies indicate that the digitization of industries and businesses can have a beneficial effect on Environmental, Social, and Governance (ESG) performance. An analysis of heterogeneity reveals that this impact is particularly pronounced in non-state-owned enterprises. This includes notable enhancements in ESG performance through the utilization of artificial intelligence and big data technologies (Zhang & Chen, 2023). Based on corporate digitization, Using the benchmark regression model, Hu et al. (2023) posits that the digitalization of businesses has the potential to enhance Environmental, Social, and Governance (ESG) performance. They argue that the enhancement of corporate value and the reduction of financial limitations represent favorable economic outcomes resulting from the impact of digital transformation on ESG performance. Gao et

al. (2022) employed the concept of intangible capital to describe the contemporary state of digital transformation within businesses, and investigated the correlation between decision-making processes related to digital transformation and the impact on enterprises' ESG scores in the presence of financial constraints. The decision-making regarding capital allocation enhances the performance of the enterprise, consequently influencing its ESG score.

Most scholars believe that industrial digitization positively contributes to ESG rating indicators, including some scholars who analyze the impact of digitization on the industry and the mechanism of the enterprise. Zeng et.al. (2022) show that increasing total factor productivity is a potential mechanism for digitization to improve the financial performance of the enterprise through mechanism testing. Liu et al. (2022) find that enterprise digitization can promote internal resource synergy, enhance R&D investment, and optimize workforce quality by means of mechanism analysis. The study revealed that the process of enterprise digitalization has the potential to enhance workforce quality through the facilitation of internal resource collaboration, increased focus on research and development investments, and the optimization of workforce capabilities.

3. Research and analysis of the effects of digital development in industry.

In recent years, there has been rapid growth in the digital economy, with industrial digitization progress having a notable positive impact on various other facets. **For industrial digitization, the most direct impact is to promote the upgrading of economic and industrial structure.** Some literature studies surface that since 2013, in the context of the digital economy landscape, the process of industrial digitization has become a power source for the continuous upgrading of China's industrial structure, and based on theories such as gray correlation entropy, it is found that the digitization process lays a solid foundation for the upgrading of China's economic and industrial structure (Chen & Yang, 2021).

Some of the literature suggests that industrial digitalization progress has a positive contribution to the governance aspects of enterprise dimensions in the industry. Based on empirical studies of data from A-share listed companies, the digitization process significantly improves the economic efficiency and expands the economic scale of real enterprises (He & Liu, 2019). Qi et al. (2020) argued that, in the context of the digital economy, industrial digitization promotes the transformation of corporate goals and the change of the governance structure, as well as promotes the change of enterprise management modes (including, but not limited to, the organizational structure, the R&D mode, marketing mode, etc.) change. It is also found that industrial digital transformation significantly improves the level of specialization and division of labor of Chinese listed enterprises, and improves the management efficiency and total factor productivity of enterprises (Yuan et al., 2021).

Part of the literature analyzes the impact of industrial digitization on environmental effects. Cui et.al (2022) estimated regional eco-efficiency based on China's provincial digital development index (CDI) using non-radial data envelope analysis model and panel data regression model and panel vector autoregression model. Data shows that in recent years, both digital and financial development have improved the ecologicalefficiency of China region.

4. Theoretical mechanisms

4.1. Industrial digital transformation and corporate ESG performance

Among the existing studies, the vast majority of articles hold the attitude that digital transformation will be positive for corporate ESG performance. Wang et al. (2022) developed a database detailing the attributes of corporate digital transformation, with the potential to enhance the ESG accountability outcomes of publicly traded firms. This database was created using a dataset comprising 314 A-listed companies evaluated for ESG criteria by the Shanghai Composite Index between 2016 and 2021. This paper analyzes the digital transformation of enterprises from different angles and draws similar

conclusions. While environmental, social and governance (ESG) practices of enterprises have externalities, there is the issue of inadequate inputs: enterprises' investments in ESR can waste resources, increase additional expenditures, impose burdens on enterprises and harm their shareholders' interests; at the same time, due to resource constraints, backward technology, and asymmetric information, many enterprises have insufficient capacity for ESG performance and too high costs, and Therefore their ESG incentives are insufficient (Hu et al.,2023). However, the white-hot development of global digital technology has led to more companies have participated in the digital transformation process, and have upgraded and transformed their corporate structure, business management model, etc. using digital technology, and in the process of upgrading and transforming, directly or indirectly participated in or increased their investment between environmental and social responsibility aspects. On the one hand, green innovation can be achieved through digital strategies, which can lead to stronger corporate reputation and social recognition, enabling manufacturing companies to improve ESG performance (Maaloul, A. et al., 2023);The widespread adoption of digital technologies has led to significant improvements in both internal and external information sharing, enhanced efficiency in resource management, and has the potential to expedite the integration of environmental data with research and development efforts. This trend is motivating businesses to pursue more environmentally friendly practices and to boost their commitments to environmental and social responsibility through increased investments. Companies are also encouraged to engage in more green innovation activities (Zhao et al., 2023), which in turn further improves corporate governance and indirectly improves the social benefits of enterprises. In addition, digital transformation lays the foundation for enterprises' green technology innovation capability, and the continuous enhancement of enterprises' green technology reduces green production costs (Zhong et al., 2023), and the remote supervision and remote control of production through the corresponding green technology leads to non-polluting or low-polluting production, which reduces the production emissions of enterprises and reduces the pollution to the environment, and further enhances the ESG performance of enterprises. performance. And the digital behavior of the overall industry will inevitably bring the digital adjustment of each enterprise in the downstream of the industry. Hence, this study puts forward the following hypothesis:

H1: Digital transformation of industries can improve corporate ESG performance.

4.2. Industrial digital transformation and corporate ESG performance

4.2.1 Digital Transformation, Financing Constraints and Corporate ESG Performance

Firms are often subject to various constraints in the financing process that affect their ability and cost of accessing capital. Firms' own financial position and risk level are important factors that restrict financing. It is often difficult for the enterprise with poor financial situation to meet the financing needs through long-term debt financing or equity financing, and it has to pay higher financing costs. By contrast, digital transformation can facilitate technological innovation and specialization of enterprises, establish risk control and surveillance systems, and incorporate more information into risk assessment systems to reduce information asymmetry, thus achieving accurate matching between investors and financiers and increasing the probability of successful financing (Teng & Ma, 2020). Moreover, digital transformation can lead to the development of digital finance, which in turn can provide enterprises with diversified sources of financing. Enterprises have the opportunity to secure funding not solely through traditional banking institutions, but also through alternative financing channels tailored specifically for FinTech firms, thereby alleviating their financial limitations. (Ning & Zhang, 2023). When the enterprise's financing constraints are satisfied, the enterprise will have enough funds for further production, so that it can devote some of its resources to the use and development of green technologies and reduce the pollution emissions of the enterprise; at the same time, the enterprise can allocate funds rationally to maintain the effective management of the enterprise. Therefore, this paper proposes the hypothesis:

H2: Digital transformation can help ESG performance by easing financing constraints.

4.2.2 Digital Transformation, Equity Concentration and Corporate ESG Performance

In contemporary scholarly works, while there is a limited number of publications addressing the correlation between digital transformation and equity concentration, existing evidence suggests that digital transformation does influence equity concentration. Furthermore, the environmental, social, and governance implications of equity concentration can differ across various enterprises with distinct equity frameworks. Equity concentration may lead to conflicts of interest, dominant owners may prioritize their economic interests over the sustainability of the firm (Wen et al., 2023), and decisions within the team may be controlled by the largest shareholder, which may to some extent hinder research and development and innovation of the firm, thereby inhibiting its environmental, social and governance performance. Managers can utilize digital tools to enhance their understanding of the digital environment, recognize potential digital prospects, enhance operational effectiveness, and incorporate digital assets. (Wang et al., 2023), which in part improves management's decision-making ability, indirectly facilitates financing, dilutes equity and weakens decision-making power of the first largest shareholder. On the basis of the above assumptions, it can be seen that easing financing constraints can contribute to corporate environmental, social and governance. Therefore, this paper proposes the following hypotheses.

H3: Digital transformation can dampen equity concentration and reduce the proportion of shares held by the largest shareholder, which in turn contributes to firms' ESG performance.

5. Research design

5.1. Data sources and sample selection

In order to explore the impact of industrial digitization on ESG performance from an industry-based perspective, this paper chooses 2009-2021 as the research interval and selects A-share listed companies from 2009-2021 as the research sample, the explanatory variable is ESG index, denoted as ESG score, and the data is obtained from Wind database.

This paper follows the following steps to process the raw data: 1. Remove the samples of listed companies whose data contain outliers, 2. Remove the listed companies with serious missing data . Divide the overall age of market entry (Year of Market) by 365, and unitize the number of days into years to avoid too large a difference between this indicator and other indicators.

5.2. Model construction

This paper explores the relationship between ESG and digitization by constructing the following benchmark regression equation model:

$$ESG = \beta_0 + \beta_1 \cdot Dig + \sum_i \beta_i \cdot Con_i + \varepsilon \quad (1)$$

Where ε denotes the randomized perturbation term.

ESG Denotes the explanatory variable ESG index, this paper refers to the data of Huazheng ESG rating system as the explanatory variable of this paper. Dig Denotes the explanatory variable digitization index, with reference to Wu (2021), the digitization index is quantified through the analysis of word frequency across five dimensions, namely artificial intelligence technology, big data technology, cloud computing technology, blockchain technology, and the utilization of digital technology. Considering that in addition to the impact of digitization on ESG, there are still other variables that will have a certain impact on the ESG index, this paper adds "corporate indebtedness" and "proportion of independent directors" according to Hu (2022) and others, "two positions", "revenue growth rate", "age of entry" and "board size". control variables, in the model, the Con_i denotes different control variables. β_0 denotes other effects that can have an impact on ESG performance but are not mentioned in this paper. β_1 and β_i denote the effects of digitization index and different control variables on ESG performance, respectively.

As in Table 1, a table of variable definitions for this paper:

Table 1: Definition of variables

data type	variable name	notation	Data indicators
explanatory variable	ESG index	Esg score	The CSI ESG quarterly ratings are assigned a score of 1-9 and are averaged.
explanatory variable	Digitization index a/b	Digital a/b	Referring to Wu (2021), the digitization index reflects usage in five areas: artificial intelligence (AI), big data, cloud computing technology, blockchain technology, and digital applications.
control variable	Enterprise debt ratio	debtratio	Total enterprise liabilities/total enterprise assets
	Proportion of independent directors	iddrate	Ratio of independent directors to total number of directors
	two jobs in one	Two to one	1 for the combination of the positions of chairman and general manager, otherwise 0
	Revenue growth rate	income12	Ratio of current period's operating income to previous period's operating income
	entry age	Year of market	Days on market/365
	Board size	dsscale	Logarithm of the number of directors
Mechanism variables	Financing constraints	sa	
	Shareholding ratio of the largest shareholder	maxros	Shareholding ratio of the largest shareholder

5.3. Descriptive statistical analysis

Table 2 presents statistical measurements of the main variables of the sample firms. Taking the corporate ESG performance variable (Esg score) and the corporate independent director ratio variable (iddrate) as an example, the mean value of the corporate ESG performance variable is 8.327 with a standard deviation of 11.061, which indicates that there is a large difference in the ESG index among the sample firms; the mean value of the corporate independent director ratio variable is 0.379 with a standard deviation of 0.065, which indicates that there is a small difference in the independent director ratio among the sample firms. The average independent director ratio variable of enterprises is 0.379 and the standard deviation is 0.065, indicating that the proportion of independent directors in the sample enterprises was not very different. Descriptive statistics for the remaining indicators are presented in the table below.

Table 2: Descriptive statistics results of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Esg score	24099	8.327	11.061	0	64.115
Digital a	24099	11.999	31.609	0	547
income12	23886	5.503	391.624	-10.924	59412.551
debtratio	24099	43.814	29.771	-19.47	1883.753
iddrate	24099	0.379	0.065	0.167	0.8
Two to one	24099	0.271	0.444	0	1
maxros	24099	31.145	16.96	-87.391	99
dsscale	24099	9.433	2.488	0	27
Year of market	24099	10.809	7.272	0	30.058

6. Empirical analysis

6.1. Baseline regression results:

To investigate the influence of various factors on Environmental, Social, and Governance (ESG) levels within organizations, a model was constructed utilizing the multivariate linear regression approach, as detailed in Table 3. The results of the regression analysis revealed that, apart from the proportion of dual job roles within the organization, the estimated coefficients associated with enterprise digitalization level A, enterprise debt ratio, and other variables were found to be statistically significant at the 1% confidence level. This indicates a positive relationship between these factors and the level of ESG within the enterprise. Conversely, the regression coefficients for the proportion of dual job roles within the organization were found to be significantly negative at the 1% confidence level, suggesting an inverse relationship between this variable and the ESG level within the organization.

Table 3: Baseline regression results

esgscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	0.01	0.002	4.84	0	0.006	0.014
income12	0	0	0.12	0.903	0	0
debtratio	0.029	0.002	11.72	0	0.024	0.034
iddrate	7.584	1.058	7.17	0	5.51	9.657
Two to one	-1.511	0.157	-9.64	0	-1.818	-1.203
maxros	0.083	0.004	20.80	0	0.075	0.09
dsscale	0.753	0.028	26.82	0	0.698	0.808
Year of market	0.349	0.01	35.28	0	0.33	0.369
Constant	-8.954	0.553	-16.18	0	-10.039	-7.87

6.2. Robustness test:

6.2.1. Variable substitution

Firm digitization level index replacement, this paper refers to (Skare M, 2023) replaces digitization index A with digitization index B. The effect of digitization level on firms' ESG level is further examined. The results in the regression analysis are still supported, indicating that the findings of this paper are highly robust.

Table 4: Alternative digitization index A robustness test results

esgscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital b	0.006	0.001	5.97	0	0.004	0.008
income12	0	0	0.13	0.895	0	0
debtratio	0.029	0.002	11.77	0	0.024	0.034
iddrate	7.468	1.058	7.06	0	5.394	9.542
Two to one	-1.524	0.157	-9.72	0	-1.831	-1.217
maxros	0.083	0.004	20.92	0	0.075	0.091
dsscale	0.754	0.028	26.86	0	0.699	0.809
Year of market	0.352	0.01	35.46	0	0.332	0.371
Constant	-9.062	0.554	-16.36	0	-10.148	-7.976

This paper regresses the age of entry into the market with the ESG index of the sample firms again after shrinking the tail at the 2.5% level, and concludes that the age of entry into the market is significantly and positively correlated with the ESG index of the firms at the 1% confidence level, with a regression estimation coefficient of 0.4254963, which validates the results in the regression analysis and is robust.

Table 5: Results of robustness tests for alternative entry ages

esgscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	0.011	0.002	5.11	0	0.007	0.015
income12	0	0	0.14	0.89	0	0
debtratio	0.026	0.002	10.65	0	0.021	0.031
iddrate	7.66	1.052	7.28	0	5.598	9.722
Two to one	-1.397	0.156	-8.96	0	-1.702	-1.091
maxros	0.082	0.004	20.90	0	0.075	0.09
dsscale	0.735	0.028	26.31	0	0.68	0.79
age	0.384	0.01	39.07	0	0.364	0.403
Constant	-9.331	0.551	-16.95	0	-10.41	-8.251

6.3. Heterogeneity test

Considering the important influence of industry digitization index scale on ESG performance, this paper further divides the industry digitization index interval of sample enterprises into [0,20] and the whole level, and tests the heterogeneity of lower industry digitization level from the whole digital level. As indicated in Table 7, the regression analysis reveals a statistically significant positive relationship between the lower industrial digitization level and the environmental, social, and governance (ESG) performance of both individual companies and the industry as a whole at a 1% confidence level. This finding further supports the notion that the industry digitization index has a notable positive influence on ESG performance. Notably, the regression coefficients for the [0,20] range are higher compared to those for the overall industry digitization level, suggesting that lower levels of industry digitization may play a more substantial role in enhancing the ESG performance of enterprises.

Table 6: Results of [0,20] industry digitization level heterogeneity test

ESGscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	0.204	0.015	13.54	0	0.174	0.233
income12	0	0	0.54	0.586	0	0
debtratio	0.015	0.003	5.55	0	0.01	0.02
iddrate	7.403	1.346	5.50	0	4.765	10.041
Two to one	-1.922	0.203	-9.49	0	-2.319	-1.525
maxros	0.087	0.005	18.08	0	0.077	0.096
dsscale	0.75	0.036	21.11	0	0.68	0.819
Year of market	0.287	0.012	23.35	0	0.263	0.311
Constant	-9.81	0.712	-13.77	0	-11.206	-8.414

Table 7: Regression results of industry digitization level in the overall interval

esgscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	0.01	0.002	4.84	0	0.006	0.014
income12	0	0	0.12	.903	0	0
debtratio	0.029	0.002	11.72	0	0.024	0.034
iddrate	7.584	1.058	7.17	0	5.51	9.657
Two to one	-1.511	0.157	-9.64	0	-1.818	-1.203
maxros	0.083	0.004	20.80	0	0.075	0.09
dsscale	0.753	0.028	26.82	0	0.698	0.808
Year of market	0.349	0.01	35.28	0	0.33	0.369
Constant	-8.954	0.553	-16.18	0	-10.039	-7.87

6.4. Mechanism testing

6.4.1 Analysis of the mechanism of financing constraint variables

Industry digitization is not only helpful for industry digitization transformation, but also affects enterprise ESG level. An intermediary function exists that connects digital finance with the environmental, social, and governance (ESG) performance of enterprises. (Zhao et al.,2023). In this paper, sa index variables affecting enterprise ESG level are added to the path of industrial digitization to explore its mechanism. The table illustrates that the regression coefficient for the level of enterprise digitization is a statistically significant negative value at a confidence level of less than 1%. This indicates that enterprise digitization plays a role in alleviating financing constraints. At 1%, the regression estimation coefficient of Sa index is significantly positive, and the higher the sa index, the higher the CSR level. In simpler terms, enhancing the digitalization level of an enterprise leads to a decrease in the extent of financial constraints faced by the enterprise. Conversely, a certain level of financial constraint within an enterprise can actually support the enhancement of the enterprise's Environmental, Social, and Governance (ESG) performance.

Table 8: Results of analytical tests of financing constraint mechanisms

sa	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	-0.0001403	0	-3.08	0.002	0	0
Constant	-3.763	0.002	-1706.59	0	-3.767	-3.758

Table 9: Results of Analytical Tests of Financing Constraint Mechanisms

esgscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
sa	3.517	0.238	14.79	0	3.051	3.983
Constant	21.57	0.898	24.01	0	19.81	23.331

6.4.2 Analysis of the mechanism of shareholding ratio of the largest shareholders

Equity financing and debt financing serve as intermediaries in facilitating the sustainable growth of businesses and augmenting the overall value of enterprises. (Lin,2023), so this paper selects the maximum shareholder shareholding ratio as a possible mechanism variable for mechanism analysis. From the table below, the enterprise digitization index is significantly negative to the maximum shareholder shareholding ratio at 1% confidence level, which indicates that the increase in the level of enterprise digitization may bring about a decrease in the maximum shareholder shareholding ratio. The shareholding ratio of the enterprise's largest shareholder is significantly positive to the enterprise's ESG level at the 1% confidence level, indicating that the increase in the shareholding ratio of the enterprise's largest shareholder may be helpful for the improvement of the enterprise's ESG level. That is, in the path of enterprises to improve ESG level, the digitization level should be controlled at a low level and the largest shareholder shareholding ratio at a relatively high level.

Table 10: Results of analyzing and testing the mechanism of the largest shareholder's shareholding ratio

maxros	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Digital a	-0.052	0.003	-15.01	0	-0.058	-0.045
Constant	31.765	0.116	273.08	0	31.537	31.993

Table 11: Results of analyzing and testing the mechanism of the largest shareholder's shareholding ratio

Esg score	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
maxros	0.076	0.004	18.20	0	0.068	0.084
Constant	5.961	0.148	40.28	0	5.671	6.251

7. Conclusions

In today's green development landscape, Environmental, Social, and Governance (ESG) criteria are increasingly valued as a measure of enterprises' overall development level. In this paper, A-share listed companies from 2009 to 2021 were selected as research samples. The effects of industrial digitalization on ESG are discussed by fitting data with a multivariate statistical analysis model. Empirical results show that the higher the degree of enterprise digitization, the higher the level of ESG, and the stronger the contribution of digitization to ESG. The conclusions of the robustness test are still valid. In addition to the digital level, variables such as the company's debt ratio, the percentage of independent directors, the proportion of the largest shareholder, the size of the company's board, and the age at which the company enters the market all have a positive effect on promoting ESG. Secondly, lower levels of digitization lead to a greater contribution to the ESG (Environmental, Social, and Governance) performance of the enterprise. Third, the level of enterprise digitization directly reduces the extent of enterprise financing constraints. On the other hand, a certain level of enterprise financing constraints is conducive to enhancing the enterprise's ESG performance. At the same time, increasing the ownership stake of the largest shareholder in an enterprise can enhance the ESG (Environmental, Social, and Governance) performance of the enterprise, with the ownership stake of the largest shareholder being maintained at a relatively high level.

8. Policy Implications

According to the findings presented above, this study suggests the following policy recommendations: First, in order to ensure the smooth implementation of ESG indicators in the course of sustainable development, enterprises should actively promote digital development. While this creates ESG value for the company, it also improves the company's production model and creates more value. Furthermore, it is imperative for businesses to carefully consider the extent to which financial constraints are being suppressed in order to enhance the ownership stake of major shareholders. Although digitization can directly or indirectly enhance these factors and thus improve ESG levels, adjusting the strategy directly from these influences will result in faster and more efficient ESG gains.

There are still some research limitations in this paper, for example, this paper is mainly based on word frequency to construct the digitization index, which may have a certain degree of subjectivity. Future research can adopt a more objective and systematic index system to construct the digitization index; ESG rating standards are not uniform, this paper selected the rating data of a rating agency, future research can comprehensively consider the ratings of multiple rating agencies to more fully reflect the ESG performance of enterprises. Meanwhile, this paper does not examine the moderating effect of relevant policies on the relationship between digitization and ESG; future research can add policy variables to assess the effect of different policies.

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