

# The Influence of Corporate Digital Advancement on the ESG Achievement of Heavy-Polluting Enterprises

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**Abstract.** The analysis of the association across corporate digital advancement and business ESG outcomes holds significant influences for businesses aiming to adopt sustainable development principles and achieve exceptional results, particularly in this age of swift advancements in the electronic economy and the pursuit of low-carbon practices. This paper employs a sample of enterprises registered on the A-share stock market in Shenzhen as well as Shanghai, covering the period from 2017 to 2021 as the sample to conduct research. Python crawler technology is employed to assess the extent of corporate digital transformation and investigate its influence on organizational ESG achievement. The empirical evidence indicates that the adoption of digital transformation has a noteworthy and favorable influence on the ESG achievement of organizations. The findings of the mechanism test indicate that the implementation of corporate digital evolution has a favorable influence on the ESG achievement of organizations operating in heavy-polluting industries. This objective is accomplished through the implementation of measures aimed at reducing environmental pollution, consequently, this leads to an improvement in their overall ESG achievement. The analysis of heterogeneity demonstrates that the influence of digital evolution on enhancing ESG achievement is especially significant for organizations that are not nationalized businesses and have a lower number of independent directors. This study aims to further investigate the microeconomic implications of enterprise digital transformation. This study presents empirical evidence and suggests strategies for enterprises to improve their ESG achievement within the framework of the digital economy era.

**Keywords:** Digital Advancement; ESG Achievement; Heavy-Polluting Enterprises.

## 1. Introduction

The global economy is being propelled forward by the digital economy, which is spearheaded by advancements in technologies for instance the Internet of Things, big data, cloud computing, and artificial intelligence. This new wave of technological innovation is driving significant changes. Based on the findings presented in the Investigation Report on the Advancement of Chinese Electronic Economy, it is anticipated that the digital economy of China will attain a significant valuation of 50.2 trillion yuan by the year 2022, constituting nearly 41.5 percent of the nation's GDP. The profound integration involving the digital marketplace and the physical industry has emerged as a significant avenue for achieving the high-caliber advancement of the national economy. The electronic economy notably contributes to the advancement of industrial entities. The utilization of digital technology by microenterprises plays a crucial role in facilitating their systematic functioning and sustainable growth, thereby contributing significantly to the overall economic development of the nation. This emphasis on digital technology adoption is essential for achieving a high standard of Chinese-style modernization and is increasingly recognized as a prevailing direction for enterprise transformation. The digital transformation of businesses comprises two fundamental dimensions: the micro conversion, which entails the seamless integration of digital innovations and growth in manufacturing, and the macro transformation, which signifies the transition of firms from conventional manufacturing processes to digital systems [1]. The extensive amalgamation of digital innovation and corporate production and administration has led to the proliferation of the business model that revolves around digital platforms. This integration has also facilitated the establishment of decision-making and management systems that rely on data analysis. By leveraging digital technology, enterprises have been able to achieve a rational allocation of resources, enhance

production and operational efficiency, and reduce operational and management costs [2]. However, the implementation and utilization of the big data information platform facilitate the transcending of conventional temporal and spatial constraints in the market and transactions. It also significantly diminishes the expenses associated with information identification, resolves the issue of information asymmetry among stakeholders, guarantees the veracity and comprehensiveness of information, enhances information transparency, effectively mitigates the moral hazard and adverse selection predicaments faced by enterprises, and further advances the achievement of enterprises' high-quality development [3].

In recent times, there has emerged an increasing emphasis on ESG investment and its performance. This focus has been observed among various stakeholders, including governments, market participants, investors, and the academic community. The heightened attention towards ESG investment is particularly notable in relation to the "dual-carbon" aim. ESG, an acronym for environmental, social, and governance, holds substantial importance as a manifestation of internal motivations and external assessments in corporate environments. External investors have the capacity to evaluate the investment risk, sustainability, and social responsibility of corporations through their observation of the ESG performance and its respective sub-categories [4]. The incorporation of ESG principles inside business operations, encompassing both internal governance and external monitoring, has the potential to enhance corporate innovation by fostering a proactive mindset. Additionally, this approach can attract greater investor attention and generate good market signals, thereby enhancing the investor "anchoring effect". Specifically, it facilitates the advancement of corporate innovation through enhancing the accessibility and variety of capital, hence alleviating constraints associated with corporate funding. Previous research has demonstrated that favorable ESG performance has the potential to improve overall corporate performance [5] and increase the value of enterprises [6], while also effectively mitigating the expenses associated with corporate debt [7]. In the contemporary period marked by a focus on innovation-driven high-quality development, it is imperative for organizations to augment their ESG performance. The aforementioned imperative arises from the necessity for businesses to adhere to their social obligations, realize their societal value, and bolster the qualitative advancement of the national economy.

The present study centers on the selection of A-share registered corporations in the Shanghai as well as Shenzhen securities exchanges, specifically focusing on the period spanning from 2017 to 2021, which serves as the research sample. The aim of this study is to conduct an experimental study on the effect of digital evolution on the ESG achievement of enterprises. Additionally, the study seeks to gain insights into the underlying mechanisms that drive this influence. The empirical evidence suggests that the fulfillment of enterprise digital evolution has the capacity to improve the ESG performance of enterprises through a range of methods. Firstly, it can promote the adoption and implementation of ecological technology innovations, leading to reduced environmental impact. Additionally, it can address information asymmetry and transaction costs, resulting in improved efficiency in resource utilization. Secondly, corporate digital evolution can contribute to the advancement of intelligence and intensification in the manufacturing and operational management of heavily polluting companies. By leveraging digital techniques, these enterprises can effectively reduce their environmental footprint by incorporating green and low-carbon technologies into their production processes. Consequently, this leads to a decrease in pollutant emissions and an overall enhancement of the ESG performance of heavily polluted enterprises. In addition, non-state-owned enterprises exhibit a greater inclination to employ corporate digital transformation as a means to enhance corporate governance, in contrast to state-owned enterprises. The inclination mentioned above can be ascribed to the pressure for achievement faced by privately owned businesses, thus amplifying the influence of digital evolution on the ESG achievement of such organizations. Moreover, the existence of autonomous directors, who hold social capital, serves as a deterrent to corporate digital evolution and reduces its influence on corporate ESG achievement. Therefore, when comparing organizations with a greater percentage of independent directors to those with a lower

proportion, it becomes evident that the latter group experiences a more significant influence of corporate digital evolution on their ESG achievement.

The study's main contributions pertain to its extension of research concerning the microeconomic consequences of corporate digital transformation, with a particular emphasis on the influence it has on enterprise ESG performance. Prior studies have established that the adoption of corporate digital transformation leads to enhanced total factor productivity in firms [8]. Moreover, previous research has demonstrated that it facilitates innovation performance [9], improves the effectiveness of internal supervision mechanisms [10], and effectively addresses financial constraints [11], among other advantageous outcomes. Additional research is needed to further explore the influence of corporate digital evolution on ESG achievement. This study seeks to investigate the effects and basic processes of digital evolution on ESG achievement. The objective of this study is to provide empirical information that improves the understanding and identification of the precise economic outcomes arising from corporate digital transformation. The primary aim of this research is to examine the impact and progression of digital evolution on the ESG achievement of organizations with significant pollution levels. The study takes a digital transformation approach and performs an analysis of heterogeneity, including aspects such as the characteristics of firms and the inclusion of independent directors. The aim of this study is to elucidate the theoretical underpinnings as well as the internal and external ramifications of digital transformation within firms that are known for their significant contribution to pollution. Furthermore, the research aims to expand the understanding of the societal and economic impacts of digital transformation within organizations, while simultaneously enhancing their ESG performance and operational procedures.

The subsequent sections of this work are structured in the following manner. In Section 2, we provide a theoretical analysis and outline our study hypothesis. Section 3 provides an overview of the data included in the study as well as the research model employed. The findings of the empirical testing are presented in Section 4. Section 5 provides an account of the outcomes obtained from the testing of the mechanism. Section 6 presents the findings of additional examination. The conclusion is presented in Section 7.

## **2. Theoretical Analysis and Research Hypothesis**

This section presents a comprehensive summary of the theoretical studies and ideas derived from two unique perspectives. The initial viewpoint centers on the connection involving corporate digital transformation and the ESG achievement of corporations. The second approach explores the correlation underlying organizational digital evolution and ESG achievement, with a specific focus on enterprises that have a substantial impact on pollution.

### **2.1. Enterprise Digital Evolution and Corporate ESG Achievement**

In order to attain substantial progress in the digital economy era, enterprises must adopt a fundamental strategy that involves amalgamating digital information technology of the latest iteration with their current production and operational practices. Enterprise digital transformation facilitates the seamless integration of various production factors with digital technology and enhances operational efficiency without altering the fundamental nature and functions of the enterprise. This is achieved by bolstering research and development efforts as well as fostering innovation in the realm of digital technology. Consequently, it overcomes the limitations imposed by traditional production factors and generates additional value, thereby augmenting the overall business performance of the enterprise [12]. Simultaneously, enterprise digital transformation facilitates the empowerment of conventional industries, thereby achieving the efficient amalgamation of digital technology and traditional production and operational processes. This transformation reinforces the connectivity of the supply chain's upstream and downstream segments, enhances both internal and external information exchange, and ultimately enhances the efficacy of resource utilization [13].

The impact of company digital evolution on company ESG achievement is primarily evident in the following areas:

The function of business digital evolution is crucial in promoting innovation inside enterprises, specifically in the domain of green technology invention and implementation. This, in turn, facilitates the integration of environmentally friendly practices into corporate production processes, leading to reduced expenses associated with pollution management and enhanced environmental performance of organizations. Additionally, enterprise digital transformation facilitates the dismantling of both internal and external information barriers. This, in turn, leads to a reduction in information asymmetry and transaction costs, as well as an enhancement in enterprise information transparency. Moreover, it amplifies the pressure for external legitimacy, making it simpler for enterprises to adhere to the constraints and oversight imposed by external regulators and stakeholders. In addition, it serves to alleviate internal agency issues and bias, therefore facilitating the advancement of corporate governance and the more efficient execution of social responsibility. Moreover, the adoption of enterprise digital transformation holds the capacity to augment the efficiency of resource allocation and utilization, enhance corporate decision-making and operational management efficiency, reinforce corporate ESG practices, and mitigate the costs linked to these practices [14].

Based on the preceding analysis, this research article proposes the following hypotheses:

Hypothesis 1: The introduction and integration of digital evolution initiatives yield positive outcomes in terms of organizational ESG achievement.

## **2.2. Corporate Digital Evolution and ESG Achievement of Heavily Polluting Firms**

The fulfillment of digital evolution in organizations has the potential to enhance the intelligence and intensification of production and operations in heavily polluting industries. This, in turn, can lead to a reduction in pollutant emissions and an overall improvement in the environmental performance of such enterprises. Firstly, the company's digital evolution enhances the level of intelligence in the manufacturing and administration of heavily polluting enterprises. The fundamental components of enterprise digital transformation encompass two primary elements: Software technology encompasses intelligent manufacturing information software systems for instance the Internet of Things, big data, cloud computing, and artificial intelligence. On the other hand, hardware technology encompasses various intelligent hardware systems like microprocessor chips, sensors, industrial robots, and PLC controllers. In the production and operation process, enterprises utilize intelligent sensors to collect real-time data on resource consumption, pollutant emissions, and production and operation efficiency. This data is then transmitted to an intelligent software system for analysis, which generates optimal production and operation programs. This integration of intelligent sensors, software systems, and hardware systems such as industrial robots and PLC controllers significantly enhances the information processing capabilities of heavy pollution enterprises. The integration of advanced technologies has resulted in a notable enhancement of intelligence within the manufacturing process, as well as a substantial decrease in pollutant emissions. Consequently, this optimization of production structure has led to improved production efficiency within heavily polluting firms. Furthermore, the implementation of digital transformation in organizations has led to a significant enhancement in the operational efficiency of significantly polluting industries. The profound impact of digital technology on traditional production processes and procedures is primarily evident in its application to various digital scenarios, such as the integration of design and manufacturing, the refinement of production and processing, the management of the entire product life cycle, and the synergy within the supply chain. This utilization of digital technology enables the reduction of industrial emissions by empowering the incorporation of green and low-carbon technologies into the operations of highly polluting enterprises. Additionally, it involves the integration of green and low-carbon technologies, such as desulfurization and decarbonization, into conventional production processes, thereby enhancing the efficiency of fossil fuel utilization and reducing pollutant emissions from the very source [15].

This study proposes the following thesis in light of the aforementioned analysis:

Hypothesis 2: The adoption of corporate digital transformation yields favorable outcomes for the ESG achievement of heavily polluting companies. The aforementioned outcome is attained by mitigating the impact of environmental contamination, resulting in a comprehensive enhancement of ESG performance.

### **3. Research Data and Research Model**

#### **3.1. Sampling and Information Sources**

The expeditious advancement of ESG ratings experienced substantial acceleration, notably following the year 2016. Therefore, this study has chosen to include all publicly registered companies in Shanghai as well as Shenzhen A-shares as the primary investigation sample for the time span from 2017 to 2021. The aim of this study is to conduct an experimental study on the impact of a digitally oriented organization on the ESG achievement of organizations working in industries with high levels of pollution.

The various types of data employed in this study are delineated as follows: The acquisition of data for an organization's digital advancement involves the employment of the Python programming language to extract textual information from the yearly statements of publicly traded corporations. The reports have been obtained from the authoritative websites of both the Shenzhen and Shanghai securities exchanges. The investigation relied on the utilization of the CSMAR database and the Wind database as the main sources of data. The methodology utilized in this study involves the implementation of a sample screening technique, which involves the exclusion of listed organizations operating within the financial industry. More specifically, businesses labeled as ST or ST\* are excluded from the sample, along with those that do not possess crucial features and have been listed for a duration of less than one year. After conducting matching and merging operations on the aforementioned dataset, this study has acquired a total of 17,840 observation samples. To mitigate the potential influence of outliers on the outcomes, the primary continuous variables undergo a 1% winsorization technique.

#### **3.2. Definition and Description of Variables**

##### **3.2.1 Predicted variables**

The predicted variable in this research pertains to the performance of enterprises, specifically in relation to ESG aspects. The researchers employed the ESG performance of wind energy as a proxy variable to serve as a representation of the comprehensive ESG achievement of enterprises. The scale consists of nine levels, which span from bottom to top and are represented as C, CC, CCC, B, BB, BBB, A, AA, and AAA. This research converts the performance within this scale into comparable scores, ranging from 1 to 9. It is essential to note that a higher score indicates a more favorable ESG performance for the respective firm. A positive correlation exists between higher scores and superior ESG performance exhibited by enterprises. Subsequently, the score undergoes a transformation by taking the natural logarithm, thus enhancing the smoothness of the data.

##### **3.2.2 Explanatory variables**

The explanatory variable under consideration is the extent to which firms have undergone digital transformation (referred to as "Digital" in this study). This study utilizes the methodologies employed by Xiao Tusheng et al. [16] and integrates text analysis techniques with Python crawler technology to assess the extent of digital transformation within enterprises. Initially, a compendium of terminologies pertaining to the digitalization of enterprises is compiled. Keywords associated with enterprise digital transformation were extracted from significant policy documents. These keywords underwent Python lexical processing and manual identification. Subsequently, words pertaining to enterprise digital transformation that exhibited a high frequency of occurrence were selected to form a comprehensive dictionary of digital terms. Furthermore, an analysis was performed on the words pertaining to annual reports. In order to facilitate a thorough study, it is advisable to get the yearly

documents of all businesses listed on the A-share market through the official web pages of the Shenzhen as well as Shanghai stock exchanges. The primary objective will be to utilize Python programming to extract the "Management Discussion and Analysis (Hereinafter referred to as MD&A) section" from the aforementioned yearly documents. Following this, text analysis methodologies will be employed to scrutinize the MD&A segment of the yearly documents of each organization. The present investigation will encompass the execution of lexical analysis and the generation of statistical data regarding the frequency of digitized terms inside the MD&A part of the yearly documents. The utilized methodology involves the analysis of text to extract individual words from the MD&A section of the yearly documents of publicly traded corporations. This enables the determination of the frequency of terms associated with digitalization within the MD&A portion of these reports. Ultimately, the construction of a comprehensive statistical framework is of utmost importance in assessing the magnitude of an organization's digital alteration. To assess the extent of digital transformation within micro-firms, we compute the occurrence rate of crucial terms related to business digital alteration. Subsequently, this rate is normalized by dividing it by the length of the MD&A section, which is commonly present in yearly documents.

### 3.2.3 Control variables

In order to guarantee the stability of the examined findings, this study incorporates several control variables, namely magnitude of the company (Size), asset-liability ratio (Lev), return on equity (ROE), capital density (Density), the development of a company (Growth), size of the board of directors (Board), Percentage of independent directors (Indepe), shareholding concentration (Top1), and age of the firm (Age). The primary factors in this study are operationalized and shown in Table 1.

**Table 1.** Definitions of variables

Variable type	variable name	notation	Description of variables
Predicted variables	Corporate ESG achievement	ESG	The Wind database performances were evaluated by assigning a score to each performance, followed by the application of the logarithm of natural numbers to the obtained scores. The calculation involves determining the relative occurrence of terms associated with corporate digitalization by dividing their total word frequency by the length of the Management's Discussion and Analysis (MD&A) section of the yearly document and then multiplying the result by 100.
Explanatory variable	Enterprise digital evolution	Digital	
Control variable	Magnitude of the company	Size	The natural logarithm is used to determine the total assets of the firm.
	Asset-liability ratio	Lev	Total liabilities divided by total assets
	Return on equity	ROE	Net profit divided by net owner's equity
	Capital density	Density	Net fixed assets divided by total assets
	The development of a company	Growth	Operating income growth rate = (current year's main operating income - previous year's main operating income) / previous year's main operating income
	Size of the board of directors	Board	The natural logarithm of the quantity represents the count of board members.
	Percentage of independent directors	Indepe	Number of independent board members divided by all board members
Shareholding concentration	Top1	The largest shareholder's shareholding ratio.	
Age of the firm	Age	the natural logarithm of the company's years in business, plus 1	

### 3.2.4 Modeling

The model is configured as follows to validate the influence of digital transformation on a company's ESG performance:

$$ESG_{it} = \beta_0 + \beta_1 Digital_{it} + \lambda Controls_{it} + \sum Year + \sum Ind + \varepsilon_{it} \quad (1)$$

Where  $ESG_{it}$  denotes firms' ESG performance,  $Digital$  denotes firms' digital transformation level, and  $Controls$  is a control variable. Meanwhile,  $Year$  and  $Ind$  are year and industry virtual variables to control the effects of time and industry on the empirical results. The regression is robust to the standard errors of the model.

## 4. Analysis of the Results of Empirical Tests

### 4.1. Descriptive Statistics

Table 2 presents the statistical data that is descriptive of the primary variables examined in this research.

**Table 2.** Full sample descriptive statistics

Variable	Obs	Mean	Std.	Min	Max.
ESG	17840	1.808	0.115	0.959	2.099
digital	17840	0.420	0.428	0.018	1.469
size	17840	21.708	1.413	18.761	26.428
lev	17840	0.419	0.221	0.021	1.042
roe	17840	0.077	0.169	-0.933	0.485
density	17840	0.160	0.161	0	0.680
growth	17840	0.188	0.664	-0.904	4.799
board	17840	2.147	0.217	1.609	2.708
indepe	17840	0.355	0.089	0	0.571
top1	17840	0.350	0.154	0.085	0.751
age	17840	2.012	0.919	0	3.332

The mean value of ESG (ESG) of firms over the observation time frame of this investigation is 1.808, which translates into a rating of around 6.098, suggesting that the average level of ESG achievement is in the BBB-A range. The standard deviation is 0.115, with a minimum value of 0.959, corresponding to a rating of approximately 2.06, and a high value of 2.099, corresponding to a rating of approximately 8.15, suggesting that ESG performance varies greatly between firms. The average value of the degree of digital evolution (Digital) of companies is 0.42, indicating that on average, 0.42% of the terms in the MD&A section of listed companies' yearly documents are related to digitalization; and the maximum value of 1.469% indicates that a maximum of 1.469% of the terms in the MD&A section of the yearly documents are related to digitalization transformation, indicating that there is a large variation in digitalization transformation among organizations.

### 4.2. Correlation Analysis

Table 3 presents the correlation coefficient matrix pertaining to the primary variables of the model. The correlation coefficient between the explanatory factors of enterprise ESG (ESG) and enterprise digital transformation (Digital) is 0.029, suggesting statistical significance, according to the data shown in Table 3. This finding presents preliminary evidence that enterprise digital evolution has a favorable influence on company ESG.

**Table 3.** The matrix of correlation coefficients

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) ESG	1.000										
(2) digital	0.029*	1.000									
(3) size	0.304*	0.232*	1.000								
(4) lev	0.056*	-0.092*	0.249*	1.000							
(5) roe	0.094*	-0.020*	0.059*	-0.134*	1.000						
(6) density	-0.015	-0.225*	-0.138*	0.045*	-0.023*	1.000					
(7) growth	-0.008	-0.004	0.018*	0.017*	0.149*	-0.027*	1.000				
(8) board	0.141*	-0.140*	0.233*	0.141*	0.043*	0.121*	0.009	1.000			
(9) indepe	-0.001	0.227*	0.143*	-0.042*	0.008	-0.198*	-0.015*	-0.320*	1.000		
(10) top1	0.046*	-0.097*	0.133*	-0.012*	0.130*	0.115*	0.013*	0.026*	0.002	1.000	
(11) age	0.129*	0.039*	0.315*	0.302*	-0.129*	-0.026*	0.004	0.090*	0.003	-0.103*	1.000

\* shows significance at  $p < 0.01$

### 4.3. Basic Regression Model

Table 4 displays the outcomes of the basic regression model (1).

**Table 4.** The results of basic regression

	(1) ESG	(2) ESG	(3) ESG	(4) ESG	(5) ESG	(6) ESG
digital	.009*** (.002)	.008*** (.002)	.009*** (.002)	.01*** (.002)	.009*** (.002)	.009*** (.002)
size		.028*** (.001)	.024*** (.002)		.029*** (.001)	.026*** (.002)
lev		-.039*** (.007)	-.042*** (.007)		-.011 (.007)	-.014* (.008)
roe		.035*** (.006)	.038*** (.007)		.045*** (.007)	.051*** (.007)
density		.009 (.011)	-.001 (.011)		.037*** (.011)	.031*** (.012)
growth			-.004*** (.001)			-.004*** (.001)
board			.036*** (.01)			.031*** (.009)
indepe			.086*** (.033)			.053* (.032)
top1			-.002 (.011)			.014 (.011)
age			.006*** (.002)			.009*** (.002)
Year	N	N	N	Y	Y	Y
Industry	N	N	N	Y	Y	Y
_cons	1.801*** (.003)	1.2*** (.026)	1.154*** (.04)	1.737*** (.01)	1.101*** (.032)	1.066*** (.043)
Observations	17840	17840	17840	17840	17840	17840
R-squared	.001	.1	.091	.085	.17	.175

Standard errors are in parentheses

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Table 4 presents the results of univariate regressions, specifically for variables (1) and (4). The values of the regression coefficients for enterprise digital transformation (referred to as "Digital") are 0.009 and 0.01 respectively. Both coefficients are statistically significant at the 1% confidence level. These findings suggest that corporate digital evolution plays a significant role in facilitating enterprise ESG achievement. After accounting for the variables of year and industry in (3) and (6), the influence of corporate digital evolution on organizational ESG achievement remains statistically significant.

The regression coefficients pertaining to enterprise digital transformation have statistically significant positive effects at a significance level of 1%. This suggests that enterprise digital

transformation has the potential to enhance enterprise ESG performance, hence validating hypothesis H1.

## 5. Mechanism testing

This study provides a more in-depth examination of the moderating influence exerted by major polluters on the correlation between digital evolution and organizational ESG achievement. This paper examines a selection of heavy polluting industries, specifically the 16 types of industries identified in conformity with the Guidelines for Environmental Information Disclosure of Listed Companies, which were publicly solicited by the Ministry of Environmental Protection (MEP) on September 14th, 2010. These industries include cement, iron and steel, electrolytic aluminum, thermal power, metallurgy, coal, building materials, petrochemical industry, chemical industry, papermaking, brewing, fermentation, textile industry, tanning industry, pharmaceutical industry, and mining industry. This study utilizes a set of 16 industry codes obtained from the updated Guidelines for Industry Classification of Listed Enterprises, as issued by the China Securities Regulatory Commission (CSRC) in 2012. Specifically, the selected codes include 06, 08, and 09 in Category B, 13, 17, 19, 22, 25, 26, 27, 28, 30, 31, 32, and 33 in Category C, and 44 in Category D. The specific study focuses on firms within these industries as the subjects of analysis. The variable "Pollute" is introduced to represent the presence or absence of heavy pollution industry among listed enterprises. A value of 1 is assigned to enterprises belonging to the heavy pollution industry, while a value of 0 is assigned to enterprises not belonging to this industry. A test model is constructed, incorporating cross-multiplier terms, to examine the moderating effect of heavy pollution enterprises. The specific model is presented below:

$$ESG_{it} = \beta_0 + \beta_1 Digital_{it} + \beta_2 Pollute + \beta_3 Digital_{it} \times P + \lambda Controls_{it} + \sum Year + \sum Ind + \varepsilon_{it} \quad (2)$$

In this study, the variable *Pollute* is treated as a virtual variable. Specifically, a value of 1 is assigned to the sample of listed firms belonging to the heavy pollution industry, and A value of 0 is allocated to the sample of listed firms that do not belong to the heavy pollution industry.  $Digital_{it} \times P$  represents the cross-multiplier between the virtual variables of enterprise digital transformation and heavy pollution enterprises. The interaction term coefficient,  $\beta_3$ , represents the moderating influence of high-polluting enterprises on the association between corporate digital evolution and the ESG achievement of organizations. After accounting for the influence of time and industry variables, the regression findings are presented in Table 5.

**Table 5.** The moderating effect of heavy polluters: regression results with the introduction of cross-multiplier terms

	(1) ESG Pollute	(2) ESG Non-pollute	(3) ESG ALL sample
digital	.022*** (.005)	.002 (.002)	.003 (.002)
pollute			-.017 (.019)
Digital*P			.022*** (.005)
Controls	Y	Y	Y
Year	Y	Y	Y
Industry	Y	Y	Y
_cons	1.112*** (.08)	1.161*** (.045)	1.071*** (.043)
Observations	5174	12666	17840
R-squared	.117	.101	.176

Standard errors are in parentheses

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

The regression analysis reveals that the cross-multiplier term between the virtual variable representing heavy polluting enterprises and the index measuring enterprises' digital transformation significantly influences the ESG performance of organizations at a statistically significant level of 1%. Moreover, the coefficient associated with this cross-multiplier term is found to be significantly positive. These findings suggest that heavy-polluting enterprises have the ability to positively moderate the association between corporate digital evolution and their ESG achievement. The second hypothesis (H2) proposed in this research has been confirmed. Corporate digital evolution has the potential to greatly enhance the ESG achievement of heavily polluting firms.

In this study, we offer a theoretical and logical elucidation of the mechanism test. Specifically, we explore how the digital transformation of organizations can lead to a reduction in pollutant emissions among substantially polluting enterprises. Consequently, this reduction has a substantial influence on the ESG achievement of these companies. The ongoing advancements in energy innovation and digital transformation within industries characterized by high levels of pollution are increasingly characterized by a profound integration of digital technologies, including blockchain, cloud computing, artificial intelligence, and the Internet of Things. These technologies are playing a pivotal role in expediting their assimilation into heavy pollutant industries. Consequently, heavy polluters are now able to leverage digitalization solutions to develop novel business models tailored to their respective sectors. The industrial production process generates a dataset as a result of digital transformation. To enhance the efficiency of this process, big data, and artificial intelligence techniques are employed to construct a unit model. This model is then optimized to improve the overall production process, leading to the digital management of energy usage and carbon dioxide emissions in key production processes. Consequently, this approach facilitates energy and water conservation, promotes the comprehensive utilization of resources, and encourages cleaner production practices in heavily polluting enterprises. Ultimately, this optimization strategy significantly reduces carbon emissions from pollutants. The enhancement of environmental performance in the context of ESG performance is primarily driven by the mitigation of pollutants and carbon emissions. This, in turn, leads to a substantial increase in the overall ESG performance of organizations.

## 6. Further Research

### 6.1. State-Owned Enterprises

In contrast to non-state-owned enterprises, state-owned enterprises (SOEs) typically face less performance pressure and do not prioritize the maximization of corporate profits. Despite having access to superior digital technology infrastructure, their commitment to enhancing corporate governance (G) in ESG performance is not particularly pronounced. The concept primarily revolves around taking social responsibilities and obligations, while also functioning as a regulatory body for the national economy on behalf of the government. On the other hand, non-state-owned firms face significant pressure to demonstrate strong performance and prioritize the enhancement of corporate governance practices, as well as the maximization of corporate earnings. The adoption and integration of digital innovations have the capacity to augment the efficiency and effectiveness of production and operational procedures within privately owned enterprises. This phenomenon has the potential to result in a decrease in expenses related to manufacturing, enhancing the overall efficiency of production processes and raising the standard of corporate governance. Therefore, the fulfillment of digital evolution has the potential to increase the ESG performance of organizations. The influence of the kind of company on the digital evolution of businesses and the ESG achievement of organizations is documented in columns (1) and (2) of Table 6. The results suggest that the coefficient estimate for the degree of digital transformation in state-owned firms is statistically significant at a significance level of 5% ( $\beta=0.004$ ,  $p<0.05$ ). Likewise, the statistical analysis reveals that the coefficient estimate pertaining to the degree of digital transformation in non-state-owned firms is also deemed statistically significant at a significance level of 5% ( $\beta=0.005$ ,  $p<0.05$ ). Nevertheless, there

are notable distinctions between the digital transformation processes in non-state-owned firms and state-owned enterprises. The size of the estimated coefficient of 0.005 is bigger than that of the estimated coefficient of 0.004 with respect to the digital evolution of state-owned companies. Therefore, the impact of digital evolution on the ESG achievement of privately owned enterprises is significantly greater in comparison to government-owned organizations.

**Table 6.** Heterogeneity test results

	(1) ESG SOE	(2) ESG Non-SOE	(3) ESG Indepe $\geq$ Mean	(4) ESG Indepe $<$ Mean
digital	.004** (.002)	.005** (.002)	.003 (.002)	.006*** (.002)
Controls	Y	Y	Y	Y
Code	Y	Y	Y	Y
Year	Y	Y	Y	Y
Industry	Y	Y	Y	Y
_cons	1.664*** (.078)	1.495*** (.076)	1.608*** (.08)	1.5*** (.096)
Observations	6779	11061	9455	8385
Within R <sup>2</sup>	.044	.074	.061	.065

*Standard errors are in parentheses*

*\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$*

## 6.2. Independent Directors

The excessive dependence of independent directors on external resources and relationship networks can result in organizational inertia. This can lead to a certain level of inertia in the execution of their responsibilities, ultimately perpetuating the status quo. Consequently, they may be reluctant to take on the risks associated with failure during the digital transformation process. This reluctance can weaken their inclination towards adopting new technologies and upgrading business models. Such tendencies are detrimental to the enterprise's progress in digital transformation [17]. Therefore, it is probable that the social capital possessed by independent directors hinders the progression of firms' digital evolution and reduces its influence on the ESG achievement of those organizations. The influence of independent directors on the digital evolution and ESG performance of enterprises is depicted in columns (3) and (4) of Table 6. The results suggest that there is no statistically significant relationship between corporate digital transformation and corporate ESG performance when the fraction of directors who are independent is at or above the average value of 35.5%. When the fraction of independent directors falls below the mean value of 35.5%, a statistically significant association is shown between the extent of corporate digital transformation and the estimated coefficient ( $\beta=0.006$ ,  $p<0.01$ ) at a significance level of 1%. Therefore, the influence of enterprise digital evolution on corporate ESG achievement is more significant in businesses that have fewer independent directors, compared to those with a larger percentage of independent directors.

## 7. Conclusions

This study used an example of A-share listed businesses in Shanghai as well as Shenzhen from 2017 to 2021 to conduct an experimental study on the influence of organizational digital evolution on the ESG achievement of enterprises with high levels of pollution. The results obtained from this investigation can be summarized as follows: Firstly, it is important to note that company digital transformation plays a crucial role in enhancing corporate ESG performance. The digital transformation of non-state-owned firms and companies with a lower number of independent directors has been found to have a more significant impact on driving the improvement of enterprise ESG achievement, as compared to other enterprise features. Secondly, the adoption of enterprise digital transformation has the potential to significantly mitigate the pollutant emissions generated by

heavily polluting enterprises. This, in turn, can enhance the environmental performance of such enterprises and consequently improve their overall ESG performance.

Furthermore, this study is deficient in conducting a stability test in the empirical investigation. Additionally, it has not successfully established a comprehensive lexicon of digital terminology across diverse industries, nor has it formulated indicators for digital transformation in various sectors. In future research endeavors, we intend to address these limitations by conducting thorough investigations and continuously enhancing and refining our research outcomes.

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