Journal of Infrastructure, Policy and Development 2024, 8(8), 7239.
https://doi.org/10.24294/jipd.v8i8.7239

Article

An empirical research on ESG, digital transformation and firm value in China

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CITATION

Li K, Sutunyarak C. (2024). An empirical research on ESG, digital transformation and firm value in China. Journal of Infrastructure, Policy and Development. 8(8): 7239. https://doi.org/10.24294/jipd.v8i8.7239

ARTICLE INFO

Received: 19 June 2024
Accepted: 9 August 2024
Available online: 21 August 2024

Abstract: Sustainable development has emerged as a global imperative, with the rapid adoption of the Environmental, Social, and Governance (ESG) framework reflecting this trend. In the context of digital transformation, this study aims to investigate the impact of ESG performance on corporate value, while also examining the moderating and mediating roles of digital transformation and green innovation within this relationship. Utilizing annual data from A-share listed companies on the Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) spanning the years 2018 to 2022, this research encompasses a total of 17,940 observations. Given China's commitment to sustainable, high-quality development, this study underscores the critical importance of advancing ESG principles alongside corporate digital transformation. Empirical analysis reveals that ESG performance significantly enhances firm value, with digital transformation serving as a positive moderator that amplifies the impact of ESG performance on firm value primarily through the enhancement of firms' green technology innovation capabilities. These findings contribute to a deeper understanding of the interaction between ESG initiatives and firm value, particularly amidst ongoing digital advancements. Consequently, this paper recommends that governments enhance corporate ESG performance through a combination of incentive and penalty mechanisms, establish a comprehensive ESG rating system, and optimize the policy framework for digital transformation. Moreover, enterprises should foster awareness of green innovation, refine their governance structures, accelerate digital transformation efforts, and promote the application of digital technologies and information sharing across various domains to achieve sustainable development and enhance competitiveness.

Keywords: ESG; digital transformation; enterprise value
JEL Classification: M14; O32; G38

1. Introduction

Globally, environmental, social and governance (ESG) performance has gradually become a core indicator of corporate sustainability, especially in the context of China's economic transformation and high-quality development, and the impact of a company's ESG performance on its value has become increasingly important. With the acceleration of corporate digital transformation, it is particularly urgent and necessary to study the relationship between ESG performance and corporate value, as well as the moderating and mediating roles of digital transformation, green innovation and financing constraints in this relationship. This not only helps firms develop effective strategies to meet the challenges of sustainable development, but also provides an important theoretical basis for policy makers.

The uniqueness of this study is that it combines the effects of digital transformation and green innovation on the relationship between ESG performance and firm value (Gao et al., 2023), filling a gap in the existing literature. Although studies have examined the impact of ESG performance on firm value, few studies have considered both digital transformation and green innovation as moderating and mediating variables. Therefore, this study provides a new perspective by highlighting how firms can enhance their ESG performance through green technology innovation in the digitalization process, thereby further increasing firm value.

In addition, the empirical analysis of this paper shows that ESG performance significantly enhances firm value, consistent with existing research that companies that actively engage in ESG practices and digital transformation reforms can improve their ability to address internal issues, reduce external risk levels, and achieve sustainable development (Niu et al., 2022). However, this study also finds that digital transformation further amplifies this impact by enhancing firms' green technology innovation capabilities and proactively adjusting their ESG performance. This finding is different from related studies in other regions, especially in terms of the specific mechanisms of the impact of digital transformation on corporate sustainability. With the rapid development of new technologies, such as big data and artificial intelligence, the importance of digital transformation has become more prominent as firms address environmental and social challenges. Therefore, understanding these dynamic relationships is important for promoting corporate practices in digital transformation and sustainable development.

2. Literature review and hypotheses

The existing literature mostly supports the positive correlation between ESG disclosure and firms' financial performance. Khan (2022) emphasizes the importance of firm characteristics for ESG disclosure, and Xue et al. (2022) demonstrates that higher ESG disclosure can attract stakeholder investment. Deng et al. (2023) confirms the positive relationship between ESG ratings and total factor productivity, while Wang et al. (2022) suggests that the fulfillment of ESG responsibilities enhances firm value. Therefore, this paper proposes Hypothesis 1.

H1: ESG performance contributes positively to firm value.

Digital transformation is defined by Gong and Ribiere (2021) as the creation of new value through digital technology that triggers a fundamental change in form, function, or structure. Fitzgerald et al. (2014) describe it as the adoption of digital technologies to improve operational efficiency and automate processes, covering aspects such as social media, mobile devices, and data analytics. Solis et al. (2014), Matt and Hess (2015), Warner and Wäger (2019), Wang et al. (2020), and Siachou et al. (2021), on the other hand, view digital transformation as a strategic, long-term shift that transcends functional boundaries, whereby digital innovations can reshape the organization and thus increase firm value. In addition, research has shown that digital transformation can provide organizations with new growth opportunities and strengthen their capabilities in terms of sustainability. By implementing digital technologies, organizations can more effectively monitor and manage their environmental, social and governance (ESG) performance, thereby increasing their

overall value. Digital transformation enables companies to collect and analyze ESG data more effectively, thereby improving ESG performance and increasing corporate value. Digital transformation enhances communication and transparency, promotes investor trust and customer loyalty, and ultimately increases enterprise value (Yang, 2024). Digital transformation drives innovation, productivity, and ESG risk management, enhances firms' attractiveness in the expanding ESG investment landscape, and promotes sustainable corporate growth and long-term value creation (Matytsin, 2022). Therefore, this paper proposes hypothesis 2.

H2: Digital transformation has a moderating role between ESG performance and enterprise value.

Examining the relevant literature finds that the enhancing role of ESG performance in corporate green innovation is stronger in green patents, state-owned enterprises, and non-polluting industries (Wu et al., 2024). Digitization significantly improves efficiency, especially in manufacturing, real estate, and utilities (Chen et al., 2022), leading to a differential impact on firm value. High-carbon firms (He and Chen, 2023) are more likely to benefit from digital transformation under government regulation of decarbonization policies, which may lead to additional return on equity (Wen et al., 2020). The study defines high-carbon firms as those operating in one of the eight high-polluting industries (petrochemicals, chemicals, construction, steel, nonferrous metals, paper, electricity, and air transport) (Ba et al., 2018), whereas the other firms are considered low-carbon firms (Wang and Xia, 2024). This analysis categorizes companies based on carbon emissions, which positively affects the value of high-carbon companies over low-carbon companies (Wang and Xia, 2024).

ESG priorities vary by industry, with energy and manufacturing industries focusing more on environmental issues, while technology and financial industries focus on social and governance aspects. Industry-specific factors, including business models, resource utilization, and governance practices, shape the relationship between ESG performance and firm value. In addition, the regulatory environment and investors' varying levels of attention to ESG issues also have an impact on firm performance (Ray, 2023).

Green inventions and innovations enable firms to gain competitive advantage, meet consumer needs, and increase market share and profits (Juniati et al., 2019). These initiatives promote efficient use of energy and resources, cost reduction, and resource efficiency. Stakeholder recognition of ESG performance and green innovation further enhances the reputation and brand image of the company and attracts the attention of investors and partners. Green energy innovations help companies develop new markets, meet sustainability needs, expand market share, and increase corporate value. However, these innovations require strong internal management and governance mechanisms to promote innovation, address environmental challenges, and improve ESG governance scores to enhance overall corporate value (Lu, 2023). Based on the above analysis, this paper proposes Hypothesis 3 as well as Hypothesis 4:

H3: ESG performance can promote firms' green invention and innovation.

H4: Firms' green inventions and innovations mediate between ESG performance and firm value.

3. Method

3.1. Sample and data

This study chooses the A-share listed businesses' annual data on China's Shanghai Stock Exchange (SSE) as well as Shenzhen Stock Exchange (SZSE) from 2018 to 2022 as the initial sample, as well as proceeds as follows: remove ST, *ST samples and the financial industry Sample; remove missing samples of financial data; remove industries with less than 5 companies; shrink nonstop variables (on the 1% and 99% quantiles), and lastly obtain 17,940 observations. The financial figures in this research come from CSMAR as well as WIND databases of Guotaian database. The industry classification standard is "Industry Classification Guidelines for Listed Companies". The final sample of this research includes the annual unbalanced panel data of observations from 2018 to 2022.

The Shanghai as well as Shenzhen A-share markets are one of the major stock markets in China, with an enormous market size, contains many listed companies. Consequently, the figures of the Shanghai as well as Shenzhen A-share markets can replicate the general circumstances of China's domestic economy as well as the action of the capital market. Most of Shanghai and Shenzhen A-share listed corporations are famous leading companies in China, contains archetypal industry representatives and leading companies in China. Their economic and operating situations, market presentation and extra figures can replicate the existing macroeconomic condition and industrial structure in China. Some large Shanghai as well as Shenzhen A-share listed companies have become strong competitors in the international market. Therefore, using the figures of Shanghai as well as Shenzhen A-share listed companies for this study is representative and helpful for further analysis of this study.

3.2. Variable definition

3.2.1. Dependent variables

Tobin's Q is the ratio of a company's market value to its intrinsic value. That is to say, the market value of a firm divided by the replacement cost of its assets. It benefits to determine whether a company is overpriced or underpriced.

In the existing literature, most scholars use Tobin's Q value for quantification. Referring to the authoritative practice, Tobin's Q value is used as the proxy variable of business value.

Firm value. The key measures of firm value in the current literature are the return on assets (ROA), return on net assets (RONA), as well as TobinQ value (TobinQ). Since the Tobin Q value is a business' market indicator, the return on assets (ROA) as well as return on net assets (RONA) are corporate financial indicators, this study based on combination the financial indicator system of the DuPont analysis and referring to associated studies, chooses the return on assets (ROA) as an evaluation indicator of industrial enterprise presentation and chooses the return on net assets (RONA) as an alternative indicator of enterprise presentation for robustness testing.

3.2.2. Independent variable

This research's central explanatory variable is ESG performance of enterprises, which is measured by ESG rating of China Securities Index. The ESG evaluation

statistics of Sino Securities has the characteristics of being close to the Chinese market, wide coverage and high timeliness. At present, this index has been widely known and applied by the industry and academia. In terms of data update, the ESG index of China Securities adopts the mixture of quarterly periodic evaluation and dynamic tracking for data adjustment, and divides enterprise ESG into 9 levels, which are C, CC, CCC, B, BB, BBB, A, AA and AAA.

3.2.3. Moderating variables

Digital transformation, which means varying the way enterprises create value for clients through current technology as well as communication resources, is the regulatory variable of this study. This research uses the natural logarithm of the sum of five dimensions of word frequency in the text information of the company's annual report as the Digit metric for enterprise digital transformation. The term frequency related to enterprise digital transformation is classified into "artificial intelligence technology", "big data technology", "cloud computing technology", "blockchain technology" and "digital technology application", and the word frequency number of characteristic words under various categories is calculated and summed up, and the logarithmic processing is carried out to obtain the quantitative index of enterprise digital transformation.

3.2.4. Intermediary variable

This paper investigates the motivational mechanisms through which Environmental, Social, and Governance (ESG) factors influence enterprise value, employing the quantity of green patent grants as a metric for assessing corporate green innovation. The findings indicate that Research and Development (R&D) investment positively affects green innovation performance, while ESG performance contributes to an increase in the number of green patents. Furthermore, ESG performance moderates the relationship between R&D investment and green innovation performance (Xu et al., 2021).

ESG performance significantly impacts an organization's green innovation by alleviating pressure on funding entities, aligning stakeholders' perceptions regarding environmental protection, and fostering employees' organizational identity, all of which influence the organization's capacity for green innovation (Wu et al., 2024). Grounded in stakeholder theory, the results demonstrate that ESG practices substantially enhance green innovation. However, a non-significant moderating effect of innovative orientation was observed in the relationship between ESG practices and green innovation. Additionally, the findings confirm the presence of a negative moderating effect between ESG practices and green innovation (Mukhtar et al., 2023).

3.2.5. Control variables

According to Zhao and Cai (2023); Whelan (2021), Lan and Zhou (2024), this study uses control variables such as Enterprise scale (Size), Debt-to-Asset Ratio (Lev), Return on Total Assets Ratio (ROA), Enterprise growth (Growth), Ownership concentration (Top10), Board Independence (Indep), Whether the chairman is also the general manager (Dual), Year dummy (year), and Industry dummy variable (ind). And so on as control variables. The main variable definition **Table 1** is shown below:

Table 1. Variable selection.

Variable name	Variable name	Variable symbol	Variable definition
Dependent variable	Firm value	TobinQ	The Tobin Q value is a corporate market indicator, download from CSMAR
Independent variable	ESG performance	ESG	China Securities ESG score
Moderating Variables	Enterprise digital transformation	lnDE	The natural logarithm of the digital word frequency + 1
Intermediary variable	Enterprise green invention and innovation	lnGR	Number of green patent applications + the natural logarithm of 1
Control variable	Enterprise scale	Size	The natural logarithm of total assets
	Debt-to-Asset Ratio	Lev	Total liabilities/total assets
	Return on Total Assets Ratio	ROA	Net profit/total assets
	Enterprise growth	Growth	(Current operating income-previous year operating income)/Previous year operating income
	Ownership concentration	Top10	Number of shares held by the largest shareholder/total number of shares
	Board Independence	Indep	Number of independent directors/Number of board members
	Whether the chairman is also the general manager	Dual	The combination of general manager and chairman is 1, otherwise it is 0
	Year dummy	year	Year dummy
	Industry dummy variable	ind	Industry dummy variable

Based on the above theoretical analysis, the following four models were constructed. Model (1) tested that ESG performance helps to increase enterprise value, which was used to prove research hypothesis H1. model (2) tested that digital transformation has a moderating effect on the relationship between ESG performance and enterprise value, which was used to test research hypothesis H2. model (3) was used to test that ESG performance can promote green invention and innovation of enterprises, which was used to test research hypothesis H3. model (4) was used to test whether corporate green invention and innovation has a mediating effect on ESG performance and firm value. It is used to test research hypothesis H4.

$$\mathrm{TobinQ_{it}} = \alpha_0 + \alpha_1 \mathrm{ESG_{it}} + \mathrm{CV} + \sum \mathrm{year} + \sum \mathrm{ind} + \varepsilon_{it} \quad (1)$$

$$\mathrm{TobinQ_{it}} = \alpha_0 + \alpha_1 \mathrm{ESG_{it}} + \alpha_2 \mathrm{lnDE_{it}} + \alpha_3 \mathrm{lnDE_{it}} * \mathrm{ESG_{it}} + \mathrm{CV} + \sum \mathrm{year} + \sum \mathrm{ind} + \varepsilon_{it} \quad (2)$$

$$\mathrm{lnGR_{it}} = \alpha_0 + \alpha_1 \mathrm{ESG_{it}} + \mathrm{CV} + \sum \mathrm{year} + \sum \mathrm{ind} + \varepsilon_{it} \quad (3)$$

$$\mathrm{TobinQ_{it}} = \alpha_0 + \alpha_1 \mathrm{ESG_{it}} + \alpha_2 \mathrm{lnGR_{it}} + \mathrm{CV} + \sum \mathrm{year} + \sum \mathrm{ind} + \varepsilon_{it} \quad (4)$$

4. Results

By eliminating the missing figures, this research selects the statistics of all A-share listed initiatives, and uses the data samples of 17,973 enterprises from 2018 to 2022 to get 17,940 observations. Since the differential model, that is, the multi-period did model, is estimated in this paper, Parallel trend test is needed to verify that there is no significant difference among the experimental group as well as the control group,

and then descriptive statistics are carried out to appreciate the condition of the research figures in this study. The association among variables is preliminarily understood through correlation analysis, and the model is estimated, the association between variables is verified, and the adjustment effect analysis is carried out. To find out whether digital transformation, green technology innovation and ESG have a regulating effect between two variables, and then to replace the explained variables, change the research sample interval, and take the explanatory variables with a lag of one stage as the instrumental variables to perform the robustness test, and finally to find the research decision of this research.

As can be seen from **Table 2**, the amount of numerical samples is 17,940, representative that all missing values have been removed. TobinQ's mean figure is 1.930627, 1.227196 is standard deviation, 0.850434 is the minimum figure of TobinQ, and the maximum figure is 7.892484. The fluctuation range of data is general, and the degree of fluctuation of data is general. The mean number of TobinQ is much higher than the minimum value, the mean figure of ESG is 5.998313, the mean number of lnDE is 1.820132, the mean figure of lnGR is 0.468104 and the mean value of KZ is 0.951393.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
TobinQ	17,940	1.930627	1.227196	0.850434	7.892484
ESG	17,940	5.998313	0.778659	4.37	8.25
lnDE	17,940	1.820132	1.419138	0	5.141664
lnGR	17,940	0.468104	0.869019	0	3.7612
Size	17,940	22.37365	1.297004	19.97484	26.06271
Lev	17,940	0.424498	0.198952	0.059551	0.888276
ROA	17,940	0.03467	0.071286	−0.21042	0.208869
Growth	17,940	0.132873	0.343002	−0.51555	1.895583
Top1	17,940	0.326091	0.144683	0.080566	0.739844
Indep	17,940	0.379698	0.053987	0.333333	0.571429
Dual	17,940	0.315217	0.464615	0	1

Note: Variable definitions are given in **Table 1**.

As can be observed from **Table 3**, the figure of correlation coefficients among TobinQ, ESG and InDE were 0.0784, 0.0469, and −0.0455, respectively, which passed the correlation test at the significance level of 1%. However, since the influence of year and industry was not controlled, the consequences obtained were only the mathematical connection between the two variables. It does not signify the last regression result, since the adjustment effect needs to be verified by interaction terms, and the correlation coefficient is only a preliminary look at the relationship between variables, which cannot characterize the ending conclusion. Consequently, it needs to be verified in subsequent regressors. The absolute value of the correlation coefficient between explanatory variables or control variables is minor than 0.8. However, this is a preliminary judgment, which needs to be additional verified by VIF test.

Table 3. Correlation analysis.

Variables	TobinQ	ESG	lnDE	lnGR	Size	Lev	ROA	Growth	Top1	Indep	Dual
TobinQ	1.0000	-	-	-	-	-	-	-	-	-	-
ESG	0.0784***	1.0000	-	-	-	-	-	-	-	-	-
lnDE	0.0469***	0.1137***	1.0000	-	-	-	-	-	-	-	-
lnGR	−0.0455***	0.1639***	0.1457***	1.0000	-	-	-	-	-	-	-
Size	−0.3308***	0.0927***	0.0214***	0.2273***	1.0000	-	-	-	-	-	-
Lev	−0.2542***	−0.1492***	−0.0161**	0.1208***	0.4721***	1.0000	-	-	-	-	-
ROA	0.2058***	0.1696***	−0.0698***	0.0509***	0.0571***	−0.3582***	1.0000	-	-	-	-
Growth	0.1303***	0.0558***	−0.0401***	0.0249***	0.0554***	0.0160**	0.3277***	1.0000	-	-	-
Top1	−0.1026***	0.0321***	−0.1095***	0.0243***	0.1849***	0.0137*	0.1728***	0.0111	1.0000	-	-
Indep	0.0434***	0.0279***	0.0543***	0.0070	−0.0221***	−0.0022	−0.0163**	−0.0062	0.0402***	1.0000	-
Dual	0.0980***	0.0051	0.0861***	−0.0202***	−0.1861***	−0.1138***	0.0213***	0.0288***	−0.0537***	0.1138***	1.0000

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

In order to more accurately exclude the interference of multicollinearity, this paper further carried out the variance inflation factor (VIF) test, and the results obtained are shown in **Table 4**. The VIF value of each variable is around 1, so the interference of multicollinearity can be excluded, i.e., there are no multicollinearities among the variables selected in this paper, and regression analyses can continue to be carried out.

Table 4. VIF Test.

Variable	VIF	1/VIF
Lev	1.68	0.595725
Size	1.5	0.666637
ROA	1.46	0.683447
Growth	1.15	0.866106
Top1	1.07	0.933104
ESG	1.07	0.935722
Dual	1.05	0.949835
Indep	1.02	0.982957
Mean VIF	1.25	

In order to test that ESG performance helps to increase the value of firms, this paper conducts regression tests to control for the year effect and industry effect on the explained variables to obtain the findings of this study. **Table 5** shows the regression results, with regression 1 and 2 indicating the case of adding and not adding control variables, respectively. When no control variables are added, the coefficient of ESG effect on TobinQ is positive 0.0199 and significant at 10% level. When control variables are added, the regression coefficient is positive 0.0629 and significant at 1% level and the goodness of fit is better than the goodness of fit without adding control variables. The F-test value is 169.6772. The control variables Size, Lev, ROA, Growth,

TOP1, INDEP and Dual all have a significant effect on TobinQ. Hypothesis 1 is acceptable.

Table 5. Test result of ESG performance contributes to enterprise value.

	(1)	**(2)**
Variables	**TobinQ**	**TobinQ**
ESG	0.0199*	0.0629***
	(1.7012)	(5.5904)
Size		−0.3022***
		(−38.0701)
Lev		−0.0002
		(−0.0042)
ROA		3.5167***
		(25.4225)
Growth		0.2556***
		(9.9228)
Top1		−0.4638***
		(−7.8530)
Indep		0.7247***
		(4.8135)
Dual		0.0240
		(1.3450)
Constant	1.6118***	7.8176***
	(15.0420)	(41.0677)
Observations	17,940	17,940
R-squared	0.1023	0.2327
F	81.6592	169.6772

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

To test that digital transformation has a moderating effect on the relationship between ESG performance and firm value. **Table 6** shows the regression results in the second column, the combined effect of the independent and dependent variables on the mediator variable is analyzed after adding the control variables. The effect of ESG on TobinQ is positive 0.0599 and significant at the 1% level, which indicates that ESG performance contributes positively to the firm's green innovation and inventiveness. Therefore, Hypothesis 2 is acceptable.

Table 6. Test result of moderating effect.

	(1)	**(2)**
Variables	**TobinQ**	**TobinQ**
ESG	0.0224*	0.0599***
	(1.9054)	(5.3054)

Table 6. (*Continued*).

	(1)	(2)
Variables	**TobinQ**	**TobinQ**
lnDE	−0.0344***	0.0048
	(−4.6597)	(0.6893)
c_lnDEc_ESG	0.0432***	0.0402***
	(4.9157)	(4.9377)
Size		−0.3029***
		(−37.9043)
Lev		0.0025
		(0.0467)
ROA		3.5205***
		(25.4510)
Growth		0.2572***
		(9.9869)
Top1		−0.4563***
		(−7.7229)
Indep		0.7170***
		(4.7626)
Dual		0.0230
		(1.2830)
Constant	1.6161***	7.8297***
	(15.0982)	(40.9284)
Observations	17,940	17,940
R-squared	0.1045	0.2337
F	77.4222	160.6428

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

To test that ESG performance can promote firms' green inventions and innovations. Firms' green inventions and innovations mediate ESG performance. The results are shown in **Table 7**. First, the first column explores the effect of ESG on the intermediate variable, lnGR. r-squared is 0.1649, with a goodness of fit of 16.49%, and the f-test value is 110.5190, which indicates that the whole model has a high probability of passing the test of significance. the system of the effect of ESG on lnGR1 is positive 0.0981, which is significant at the 1% level. Secondly, in the result of the second column, the influence system of ESG on TobinQ is positive 0.0599, which is significant at 1% level. And by soble test, it is found that lnGR has strong mediating effect between ESG and TobinQ. This suggests that ESG performance can encourage green creation and innovation in firms, which in turn affects firm performance. Therefore, Hypotheses 3 and 4 are acceptable.

Table 7. Test result the performance of ESG promote the green invention and innovation.

	(1)	(2)
Variables	**lnGR1**	**TobinQ**
ESG	0.0981***	0.0599***
	(14.3721)	(5.2938)
lnGR1		0.0306**
		(2.4863)
Size	0.1464***	−0.3066***
	(30.3919)	(−37.6807)
Lev	0.1767***	−0.0056
	(5.3741)	(−0.1039)
ROA	0.3669***	3.5054***
	(4.3696)	(25.3315)
Growth	−0.0561***	0.2574***
	(−3.5901)	(9.9873)
Top1	0.0425	−0.4651***
	(1.1859)	(−7.8758)
Indep	0.0796	0.7222***
	(0.8708)	(4.7979)
Dual	0.0146	0.0236
	(1.3460)	(1.3202)
Observations	17,940	17,940
R-squared	0.1649	0.2329
F	110.5190	164.7704
Soble	2.4500[0.0143]	

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

Endogeneity can be due to a variety of reasons, and in this paper it could be due to the interaction between the independent variable ESG and the dependent variable TobinQ, so there is a problem of endogeneity due to bidirectional causality. Using the independent variables lagged by one stage as instrumental variables, as shown in the results in **Table 8**, the first column below shows the results of the first stage and the second column shows the results of the second stage, both of them have a significance of 1 percent, which means that they pass the endogeneity test and the results are stable.

Table 8. Endogeneity analysis.

	First Stage	Second Stage
Variables	**ESG**	**TobinQ**
L.ESG	0.7379***	
	(125.1358)	
ESG		0.0685***
		(3.7574)

Table 8. (*Continued*).

	First Stage	**Second Stage**
Variables	**ESG**	**TobinQ**
lnGR	0.0286***	0.0147
	(5.3020)	(1.1856)
Size	0.0479***	0.3222***
	(11.2070)	(32.4368)
Lev	0.1608***	0.1117*
	(5.5893)	(1.6916)
ROA	0.3998***	4.0458***
	(5.4095)	(23.9338)
Growth	0.0110	0.2231***
	(0.7903)	(7.0096)
Top1	0.0969***	0.2842***
	(3.0884)	(3.9642)
Indep	0.1893**	0.9286***
	(2.3952)	(5.1472)
Dual	0.0033	0.0474**
	(0.3489)	(2.1914)
Constant	0.3167***	8.5129***
	(3.0708)	(36.0293)
Year Effect	YES	YES
Ind Effect	YES	YES
Observations	13364	13364
R-squared	0.6171	0.2330
F	671.4154	125.9575
K-P rk LM statistic	3117.47	
C-D Wald F statistic	15658.96	
K-P rk Wald F statistic	12664.01	

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

In this study, the relationship between the core independent variable and dependent variable was verified through multiple robustness tests. The results are shown in the results of **Table 9**, the first method removes the research data in 2020, i.e., changing the sample interval; The second method uses the robustness test with one stage lag, which can effectively prevent the effect of endogeneity; and the third method uses the change estimation method. The double fixed-effects model controlling for year effects and industry effects in the benchmark regression is changed to a double fixed-effects model controlling for year and individual to see if the results change. When removing the 2020 data, the coefficient of the ESG effect on TobinQ is a positive 0.2811 and significant at the 1% level. When lagging the single-period independent variable, the coefficient of ESG on TobinQ is positive 0.5690 and significant at the 1% level. When changing the estimation method, the coefficient of

ESG on TobinQ is positive 0.2811 and significant at the 5% level. All the three robustness tests pass and the results are non-randomized and more feasible.

Table 9. Robustness test.

	Remove 2020	**Lagged one-period explanatory variables**	**Changing the estimation method**
Variables	**ENE**	**ENE**	**ENE**
INTV	0.4047***		0.2811**
	(5.2732)		(2.2702)
L.INTV		0.5690***	
		(4.3970)	
Size	0.0058***	0.0053***	0.0107***
	(10.6474)	(8.9642)	(8.1887)
Lev	0.0905***	0.0918***	0.0867***
	(26.6502)	(24.8721)	(15.3731)
ROA	0.0814***	0.0707***	0.0313***
	(7.9145)	(6.7334)	(2.6579)
Growth	0.0001	0.0006	0.0007
	(0.0609)	(0.3284)	(0.4963)
Board	0.0020	0.0016	0.0009
	(0.7266)	(0.5584)	(0.2127)
Dual	0.0057***	0.0056***	0.0025
	(4.6324)	(4.3617)	(1.4406)
Top1	0.0000	0.0000	0.0000
	(0.6855)	(0.1925)	(0.3616)
FirmAge	0.0069***	0.0070***	0.0203**
	(3.8805)	(3.5793)	(2.3891)
Constant	0.0726***	0.1079***	0.0068
	(5.7280)	(7.8630)	(0.2027)
Year effect	Controls	Control	Control
Industry effects	Control	Control	Not in control
Individual effect	Not controlled	Not in control	Control
Observations	23066	22702	28804
R-squared	0.4588	0.4197	0.3799
Number of id	3907	3907	3907

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

Heterogeneity analysis as shown in **Table 10** below was done to see whether the impact of independent variable on the dependent variable will vary with the selection of different samples. The samples are divided into manufacturing and non-manufacturing industries according to the nature of enterprises in the industry to understand whether there is a significant difference in the impact of the two groups of explanatory variables. The impact coefficient of ESG on TobinQ in non-manufacturing department is 0.1234, which passes the significance level of 1%; the impact coefficient

of manufacturing industry is 0.0356, which passes the significance level of 5%; the impact coefficient of non-manufacturing industry is higher, i.e., the non-manufacturing industry ESG value has a more pronounced positive impact on the firm's TobinQ.

Table10. Heterogeneity analysis.

	Manufacturing	**Non-manufacturing**
Variables	**TobinQ**	**TobinQ**
ESG	0.0356**	0.1234***
	(2.4201)	(7.4428)
Size	0.2719***	0.3593***
	(25.7173)	(31.6205)
Lev	0.2201***	0.3737***
	(3.0206)	(4.9381)
ROA	4.1137***	1.9788***
	(22.4974)	(9.8650)
Growth	0.3271***	0.1361***
	(9.3362)	(3.8412)
Top1	0.5555***	0.2166**
	(7.1311)	(2.5215)
Indep	0.5434***	1.1450***
	(2.8031)	(5.0448)
Dual	0.0279	0.0206
	(1.2491)	(0.7158)
Constant	7.4009***	8.4924***
	(30.9118)	(33.8881)
Year Effect	YES	YES
Ind Effect	YES	YES
Observations	11827	6113
R-squared	0.1875	0.3406
F	181.7273	112.2306

Note: ***, **, * indicates a significant relationship at the significance level of 0.01, 0.05, 0.1, respectively.

5. Discussion

Currently, there is an increasing global focus on sustainable development, and the widespread adoption of ESG (environmental, social, governance) frameworks is a reflection of this trend. Although many studies have explored the impact of ESG on firm performance, systematic research on how ESG affects firm value in the context of digital transformation and green innovation is still relatively lacking. This study fills this research gap by introducing two important variables, digital transformation and green innovation.

With the rapid development of technology and changes in the policy environment, digital transformation of enterprises has become particularly important. As the second

largest economy in the world, China has made significant commitments to sustainable and high-quality development in recent years. This study utilizes data from the critical period of 2018 to 2022 to capture the latest developments in Chinese companies' policy-driven digital transformation and ESG practices, and is therefore highly time-sensitive.

Innovative aspects of this research. First, this study innovatively considers digital transformation as a moderating variable of ESG performance affecting firm value, and analyzes how it can amplify the role of ESG by enhancing firms' green technology innovation capabilities. Second, the data are extensive and representative. Utilizing a large sample of data (a total of 17,940 observations) from A-share companies listed on China's Shanghai Stock Exchange and Shenzhen Stock Exchange provides a solid statistical foundation for the study's conclusions. Finally, the empirical analysis of this paper has a new perspective, revealing the mediating role of green innovation in the relationship between ESG and corporate value through empirical analysis, providing a more detailed explanation of the mechanism, and expanding the theoretical horizon in the field of ESG.

The findings of this study provide compelling evidence regarding the role of Environmental, Social, and Governance (ESG) performance in enhancing corporate value. Hypothesis 1 substantiates that robust ESG performance contributes positively to enterprise value, aligning with the growing body of literature that emphasizes the importance of sustainable practices in driving financial performance. This clearly supports the works of Whelan et al. (2021), and Aydoğmuş et al. (2022). This relationship underscores the necessity for organizations to integrate ESG considerations into their strategic frameworks, thereby fostering a culture of sustainability that resonates with stakeholders and enhances overall corporate reputation.

Moreover, Hypothesis 2 reveals that digital transformation serves as a significant moderator in the relationship between ESG performance and corporate value. This finding highlights the critical role of technological advancement in amplifying the benefits derived from ESG initiatives. By leveraging digital tools and platforms, organizations can enhance their operational efficiency and innovation capabilities, thereby improving their ESG performance. This, in turn, positively influences corporate value, suggesting that enterprises undergoing digital transformation are better positioned to realize the full potential of their ESG efforts. The views here in this article agree with the literature of Zhao and Cai (2023).

Hypothesis 3 further confirms that ESG performance facilitates green invention and innovation within organizations. This finding aligns with contemporary notions that view ESG as a catalyst for innovative practices, particularly in the realm of sustainable technologies. The integration of environmental considerations into the innovation process not only fosters creativity but also encourages the development of solutions that address pressing societal challenges, thus reinforcing the value proposition of enterprises committed to sustainable development. The views here in this article are consistent with the literature in Garcia et al. (2018).

Additionally, Hypothesis 4 establishes that green invention and innovation mediate the relationship between ESG performance and corporate value. This mediation effect emphasizes the importance of tangible outcomes arising from ESG

initiatives, suggesting that the adoption of sustainable practices leads to innovative solutions that directly enhance corporate value. Consequently, organizations should prioritize the cultivation of an innovative culture that aligns with their ESG goals, facilitating a cycle of continuous improvement and value creation. The views here in this paper are consistent with the literature of Garcia (2018), Lan and Zhou (2024), Lian et al. (2023) and Long et al. (2023).

In conclusion, the evidence presented in this study underscores the multifaceted role of ESG performance in driving corporate value, with digital transformation acting as a pivotal enabler of this relationship. The integration of ESG principles not only fosters green innovation but also contributes to the overall financial health of organizations. Future research should continue to explore the intricate dynamics between ESG performance, innovation, and corporate value, particularly in the context of emerging technologies and evolving market conditions.

6. Conclusions

This study utilizes annual data from A-share listed companies on China's Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) spanning the years 2018 to 2022, comprising a final sample of unbalanced panel data observations within this period. The findings of this study reveal several key insights into the relationship between Environmental, Social, and Governance (ESG) performance and corporate value. First, strong ESG performance is shown to significantly enhance corporate value. Additionally, digital transformation plays a crucial moderating role in this relationship, amplifying the positive effects of ESG initiatives on firm value. Furthermore, the research indicates a positive correlation between ESG performance and the promotion of green invention and innovation within enterprises. Notably, corporate green invention and innovation serve as mediators in the relationship between ESG performance and corporate value, suggesting that effective ESG initiatives not only foster innovation but also contribute to increased value creation.

This paper recommends that authorities incentivize ESG improvements through rewards such as increased bank credit and tax reductions, alongside establishing a robust ESG rating system for corporate accountability. Additionally, creating a conducive environment for digital transformation involves enhancing big data platforms and reducing taxes. Enterprises should focus on energy conservation, green innovation, and refining governance structures while accelerating digital transformation across all functions. It is important to acknowledge the limitations of this study. The relatively small sample size and the restricted geographical focus may affect the generalizability of the findings.

In addition to this, ESG numerical evaluation indicators are constantly changing, and this dynamic nature may pose some limitations to this study. As CSR standards and regulations evolve, ESG evaluation metrics are constantly being updated and adjusted. This variability complicates long-term data comparisons and trend analysis, as historical data may not be fully compatible with current standards. Definitions and weighting settings of ESG metrics may vary across institutions and rating agencies, further adding to the difficulty of the study. Subsequent studies should need to fully consider these variations and differences when conducting ESG-related analyses to

avoid bias or misinterpretation of conclusions due to indicator inconsistency. And these limitations can be extended by combining more diverse sample sets and exploring additional geographic contexts.

Author contributions: Conceptualization, KL and CS; methodology, KL; software, KL; validation, KL; formal analysis, CS; investigation, KL; resources, KL; data curation, KL; writing—original draft preparation, KL; writing—review and editing, KL and CS; visualization, KL; supervision, CS; project administration, KL. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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