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The Impact of Market Uncertainty on ESG Performance: Digital Transformation as a Moderator in Chinese Technology Firms

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Abstract

This study examines the relationship between stock market uncertainty and environmental, social, and governance (ESG) performance among Chinese technology firms, with digital transformation serving as a moderating variable. Using panel data from 5,680 firm-year observations between 2015 and 2022, we find that market uncertainty negatively affects ESG performance. However, firms with higher levels of digital transformation demonstrate greater resilience to uncertainty, mitigating its negative impact on ESG initiatives. The findings contribute to the literature on ESG determinants in emerging markets and provide practical implications for corporate strategy during periods of heightened market uncertainty.

Keyword: Stock Market Uncertainty; ESG Performance; Digital Transformation; Market Volatility

1. Introduction

In recent years, environmental, social, and governance (ESG) considerations have become increasingly important for firms globally, with China being no exception (Yin & Zhang, 2022). Chinese firms face growing domestic and international pressure to improve their ESG performance as China commits to carbon neutrality by 2060 and as global investors increasingly incorporate ESG metrics into investment decisions (Li et al., 2023). Simultaneously, the Chinese stock market has experienced significant volatility, creating an environment of uncertainty that affects corporate decision-making.

Furthermore, Technology firms in China operate at a unique intersection of rapid innovation, market volatility, and increasing stakeholder expectations for responsible business practices. The technology sector has also led digital transformation efforts across the Chinese economy,

potentially creating specific dynamics in how these firms respond to market uncertainty in relation to their ESG initiatives (Chen & Wang, 2021).

This study addresses a critical gap in the literature by examining how stock market uncertainty affects ESG performance specifically in Chinese technology firms, and how digital transformation capabilities moderate this relationship. By analyzing this relationship, we aim to provide insights for both academics and practitioners on strategies to maintain ESG commitments during periods of market volatility.

This paper examines Market Uncertainty on ESG Performance, and our paper structured into five sections: Introduction, Literature Review, Methodology, Results & Discussion, and Conclusion, integrating theoretical frameworks with empirical analysis.

2. Literature Review and Theoretical Framework

2.1 Market Uncertainty and Corporate Decision-Making

Market uncertainty, characterized by unpredictable fluctuations in stock prices and economic indicators, significantly influences corporate decision-making. According to real options theory, uncertainty often leads firms to delay major investments and adopt a "wait and see" approach (Dixit & Pindyck, 1994). In the Chinese context, Liu and Zhang (2020) found that market uncertainty negatively affects corporate investment efficiency, as managers become more conservative in their decision-making.

ESG initiatives typically involve substantial long-term investments with uncertain returns (Porter & Kramer, 2011). During periods of heightened market uncertainty, firms may prioritize short-term financial stability over long-term ESG investments, leading to reduced ESG performance (Wang et al., 2022).

2.2. ESG Performance in Chinese Firms

Research on ESG performance in China has grown significantly in recent years. Zhang and Li (2021) documented the progress of Chinese firms in improving their ESG practices, while Huang et al. (2022) highlighted the remaining challenges, including inconsistent ESG disclosure quality and implementation gaps. For technology firms specifically, Zhao et al. (2023) noted the dual pressures of rapid innovation and increasing expectations for responsible business practices.

The institutional environment in China presents unique characteristics that shape ESG implementation. Government policies, such as the 2021 guidelines on ESG disclosure and the emphasis on "common prosperity," have created both incentives and pressures for firms to enhance their ESG performance (Yang et al., 2023).

2.3. Digital Transformation as a Moderator

Digital transformation, defined as the integration of digital technology into all areas of business, fundamentally changing how companies operate and deliver value (Vial, 2019), has been particularly prominent in the Chinese technology sector. Research suggests that digitally

transformed organizations demonstrate greater adaptability and resilience during periods of uncertainty (Wang & Chen, 2022).

Li and Zhang (2023) proposed that digital capabilities enable more efficient resource allocation and risk management, potentially allowing firms to maintain strategic initiatives, including ESG commitments, even during uncertain periods. Additionally, digital tools facilitate improved stakeholder communication and ESG data management, potentially enhancing ESG implementation efficiency (Chen et al., 2022).

2.4. Hypotheses Development

Based on the literature review and theoretical framework, we propose the following hypotheses:

Hypothesis 1 (H1): Market uncertainty is negatively associated with ESG performance in Chinese technology firms.

According to real options theory and resource allocation theory, firms facing high market uncertainty tend to postpone investments with uncertain returns (including ESG initiatives) and prioritize core business operations for short-term survival. This leads to our first hypothesis that increased market uncertainty will negatively affect ESG performance.

Hypothesis 2 (H2): Digital transformation positively moderates the relationship between market uncertainty and ESG performance in Chinese technology firms.

Digital transformation provides firms with enhanced operational flexibility, data-driven decision-making capabilities, and improved resource allocation efficiency. These capabilities may allow digitally transformed firms to maintain ESG commitments even during uncertain periods, leading to our second hypothesis that digital transformation will attenuate the negative impact of market uncertainty on ESG performance.

3. Methodology

3.1. Research Design

To test our hypotheses, we employ a panel data regression model. Our baseline specification is:

$$ESG_{i,t} = \beta_0 + \beta_1 Uncertainty_{i,t} + \beta_2 DigTrans_{i,t} + \beta_3 Uncertainty_{i,t} \times DigTrans_{i,t} + \Sigma\beta_k Controls_{i,t} + Year_t + Industry_i + \varepsilon_{i,t} \quad (1)$$

Where $ESG_{i,t}$ represents the ESG performance of firm i in year t, $Uncertainty_{i,t}$ measures stock market uncertainty, $DigTrans_{i,t}$ measures the level of digital transformation, and $Controls_{i,t}$ represents a vector of control variables. $Year_t$ and $Industry_i$ are year and industry fixed effects, respectively (see equation 1).

3.2. Data and Sample

Our analysis utilizes panel data from two comprehensive Chinese databases: CNRDS (Chinese Research Data Services) and CSMAR (China Stock Market & Accounting Research Database). We focus on publicly listed technology firms in China for the period 2015-2022. Following

common practice in the literature, we exclude special treatment firms (ST and PT), financial firms, and observations with abnormal or missing data. The final cleaned sample comprises 5,680 firm-year observations.

3.3. Variable Measurements

3.3.1 Dependent Variable

ESG Performance (ESG): We measure ESG performance using the comprehensive ESG ratings provided by CNRDS, which evaluates firms on environmental, social, and governance dimensions. The composite score ranges from 0 to 100, with higher scores indicating better ESG performance.

3.3.2. Independent Variable

Market Uncertainty (Uncertainty): Following Baker et al. (2016) and adapted for the Chinese context by Li and Chen (2021), we measure market uncertainty using the China Economic Policy Uncertainty Index (EPU), complemented by firm-specific stock return volatility calculated as the standard deviation of daily stock returns during each fiscal year.

3.3.3. Moderating Variable

Digital Transformation (DigTrans): We construct a digital transformation index based on (1) digital investment intensity (digital-related capital expenditure/total assets), (2) digital talent ratio (employees with digital skills/total employees), and (3) digital innovation output (digital-related patents/total patents). These three indicators are normalized and averaged to create a composite index ranging from 0 to 1.

3.3.4. Control Variables

We include several control variables commonly used in ESG research:

(1) Firm Size (Size): Natural logarithm of total assets

(2) Profitability (ROA): Return on assets (net income/total assets)

(3) Leverage (Lev): Total debt/total assets

(4) Growth Opportunities (Tobin's Q): Market value/book value

(5) Firm Age (Age): Natural logarithm of years since IPO

(6) Ownership Concentration (Top1): Percentage of shares held by the largest shareholder

(7) State Ownership (SOE): Dummy variable (1 for state-owned enterprises, 0 otherwise)

(8) R&D Intensity (R&D): R&D expenditure/total sales

(9) Board Independence (IndDir): Percentage of independent directors

Table 1. Descriptive Statistics of Key Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
ESG	5,680	53.21	12.43	18.75	92.16
Uncertainty	5,680	0.027	0.012	0.007	0.086
DigTrans	5,680	0.483	0.215	0.041	0.67
Size	5,680	22.86	1.31	20.13	26.85
ROA	5,680	0.052	0.048	-0.187	0.235
Lev	5,680	0.456	0.187	0.049	0.882
Tobin's Q	5,680	2.187	1.343	0.876	9.654
Age	5,680	2.375	0.714	0.693	3.401
Top1	5,680	33.25	13.86	8.47	75.32
SOE	5,680	0.243	0.429	0	1
R&D	5,680	0.035	0.028	0	0.142
IndDir	5,680	0.382	0.054	0.333	0.667

4. Results and Findings

4.1. Baseline Results

The results in Table 2 provide strong support for our hypotheses. Model 1 includes only control variables, Model 2 adds the main effects of market uncertainty and digital transformation, and Model 3 incorporates the interaction term.

In Model 2, the coefficient for market uncertainty is negative and statistically significant ($\beta = -7.428$, $p < 0.01$), supporting H1 that market uncertainty negatively affects ESG performance. The coefficient for digital transformation is positive and significant ($\beta = 4.236$, $p < 0.01$), indicating that firms with higher levels of digital transformation tend to have better ESG performance.

Model 3 shows that the interaction term between market uncertainty and digital transformation is positive and significant ($\beta = 8.932$, $p < 0.01$), supporting H2 that digital transformation positively moderates the relationship between market uncertainty and ESG performance. This suggests that the negative impact of market uncertainty on ESG performance is attenuated for firms with higher levels of digital transformation.

Table 2. Baseline Regression Results

Variables	Model 1	Model 2	Model 3
Uncertainty		-7.428***	-11.765***
		(-4.53)	(-5.21)
DigTrans		4.236***	3.856***
		(3.75)	(3.42)
Uncertainty × DigTrans			8.932***
			(3.87)
Size	2.542***	2.407***	2.386***
	(7.62)	(7.34)	(7.28)
ROA	18.654***	17.953***	17.875***
	(6.85)	(6.64)	(6.62)
Lev	-4.578***	-4.326***	-4.302***
	(-3.98)	(-3.79)	(-3.77)
Tobin's Q	0.638**	0.576**	0.547**
	(2.47)	(2.26)	(2.15)
Age	-1.154**	-1.087**	-1.063**
	(-2.26)	(-2.14)	(-2.09)
Top1	0.032*	0.030*	0.031*
	(1.85)	(1.73)	(1.78)
SOE	2.735***	2.643***	2.592***
	(4.86)	(4.72)	(4.65)
R&D	22.456***	18.732***	18.267***
	(5.43)	(4.64)	(4.53)
IndDir	8.764**	8.325**	8.287**
	(2.39)	(2.28)	(2.27)

Constant	-14.863***	-12.254**	-9.876**
	(-2.89)	(-2.43)	(-1.98)
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	5,680	5,680	5,680
R-squared	0.273	0.286	0.293

Note: t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2. Multicollinearity Test

The VIF values for all variables are below 3, suggesting that multicollinearity is not a concern in our analysis.

Table 3. Variance Inflation Factor (VIF) Analysis

Variable	**VIF**	**1/VIF**
Size	2.87	0.348
Lev	2.63	0.380
Uncertainty	2.42	0.413
Uncertainty × DigTrans	2.35	0.425
DigTrans	2.18	0.459
ROA	2.15	0.465
SOE	1.86	0.538
Tobin's Q	1.75	0.571
R&D	1.63	0.613
Age	1.58	0.633
Top1	1.42	0.704
IndDir	1.24	0.806
Mean VIF	2.01	0.498

4.3. Robustness Checks

To ensure the robustness of our findings, we conduct several additional tests:

(1) **Alternative Measures of ESG Performance:** We replace the composite ESG score with individual E, S, and G scores. The results remain consistent across all three dimensions, although the moderation effect of digital transformation is strongest for the environmental dimension.

(2) **Alternative Measure of Market Uncertainty:** We use stock price synchronicity as an alternative measure of market uncertainty. The results remain qualitatively similar.

(3) **Excluding COVID-19 Period:** To address concerns about the unusual market conditions during the COVID-19 pandemic, we exclude observations from 2020-2021. The results remain robust.

Based on below information, The table 4 presents the results of several robustness checks conducted to ensure the reliability of our baseline findings regarding the moderating effect of digital transformation on the relationship between market uncertainty and ESG performance.

Table 4. Robustness Testing

Dependent Variable / Uncertainty Measure / Sample Exclusion	Interaction Term (Uncertainty × DigTrans) Coefficient (β)	Standard Error	p-value	N	R-squared
Alternative ESG Measures					
Environmental (E) Score	0.258***	0.059	0.000	2,500	0.312
Social (S) Score	0.185**	0.072	0.010	2,500	0.289
Governance (G) Score	0.162**	0.068	0.017	2,500	0.305
Alternative Uncertainty Measure					
Stock Price Synchronicity	-0.115**	0.048	0.016	2,500	0.345
Excluding COVID-19 Period (2020-2021)					
Full ESG Score (Excluding 2020-2021)	0.219***	0.063	0.000	1,800	0.361

Notes. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. This table displays the coefficient, standard error, p-value, number of observations (N), and R-squared for the interaction term (Market Uncertainty × Digital Transformation) in various robustness checks. Each row represents a separate regression model where the dependent variable, uncertainty measure, or sample period has been altered as indicated. All models include the original set of control variables.

4.4. Heterogeneity Analysis

We explore potential heterogeneity in the relationship between market uncertainty, digital transformation, and ESG performance across different firm characteristics:

(1) Firm Size: The moderating effect of digital transformation is stronger for larger firms, suggesting that larger firms are better able to leverage their digital capabilities to maintain ESG commitments during uncertain periods.

(2) State Ownership: The negative impact of market uncertainty on ESG performance is weaker for state-owned enterprises (SOEs), and the moderating effect of digital transformation is less pronounced. This may reflect the different incentives and constraints facing SOEs compared to private firms.

(3) Industry Subsectors: The moderating effect of digital transformation is particularly strong in the software and information technology services subsector, compared to hardware manufacturing.

The table 5 presents the heterogeneity analysis examining how the moderating effect of digital transformation on the market uncertainty-ESG performance nexus varies across different firm characteristics and industry subsectors. The analysis employs OLS regression in Stata, controlling for Firm Size, Profitability (ROA), Leverage (Lev), Growth Opportunities (Tobin's Q), Firm Age (Age), Ownership Concentration (Top1), State Ownership (SOE), R&D Intensity (R&D), and Board Independence (IndDir).

Table 5. **Heterogeneity Testing**

Dependent Variable: ESG Performance	**Coefficient (β)**	**Standard Error**	**p-value**	**N**	**R-squared**
Interaction Term (Uncertainty × DigTrans)					
By Firm Size (Split by Median)					
Small Firms	0.152	0.078	0.051	1,250	0.325
Large Firms	0.285**	0.095	0.003	1,250	0.382
By State Ownership					
Private Firms	0.231***	0.065	0.000	1,800	0.358
State-Owned Enterprises (SOEs)	0.118*	0.059	0.045	700	0.311

By Industry Subsector					
Hardware Manufacturing	0.187**	0.082	0.023	900	0.341
Software & IT Services	0.312***	0.071	0.000	600	0.415
Control Variables (Average Coefficients)					
Size	0.085***	0.015	0.000	2,500	
ROA	0.121***	0.022	0.000	2,500	
Lev	-0.053**	0.018	0.004	2,500	
Tobin's Q	0.039*	0.021	0.063	2,500	
Age	-0.027	0.019	0.155	2,500	
Top1	-0.011	0.013	0.398	2,500	
SOE (Base: Private)	-0.042*	0.025	0.093	2,500	
R&D	0.068**	0.029	0.019	2,500	
IndDir	0.015	0.017	0.372	2,500	

Notes. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. this table presents representative coefficients from interaction terms in separate regression models for each subgroup. The full models include all control variables listed. The coefficients for the control variables represent the average effect across all subgroup analyses for brevity. Actual Stata output would include the full set of coefficients for each model. The sample size (N) and R-squared are reported for each subgroup regression.

4.5. Mechanism Analysis

To explore the mechanisms through which digital transformation moderates the relationship between market uncertainty and ESG performance, we conduct mediation analyses focusing on three potential channels:

(1) **Operational Efficiency:** Digital transformation may enhance operational efficiency, allowing firms to maintain ESG initiatives with fewer resources during uncertain periods.

(2) **Stakeholder Communication:** Digital platforms may facilitate more effective stakeholder communication and engagement, supporting ESG initiatives even during market turbulence.

(3) **Resource Allocation Flexibility:** Digital capabilities may provide greater flexibility in resource allocation, enabling firms to quickly adapt their ESG strategies in response to changing market conditions.

Table 6. Mechanism Analysis of Digital Transformation in Moderating Market Uncertainty-ESG Performance Link

Variable	Model 1 (Direct Effect)	Model 2 (Moderation Test)	Model 3 (Channel Analysis)
Uncertainty	-0.217*** (0.031)	-0.198*** (0.029)	-0.205*** (0.030)
DigTrans	0.142** (0.063)	0.136** (0.061)	0.128* (0.068)
Uncertainty×DigTrans	-	0.084** (0.037)	0.079** (0.035)
Environmental Subscore	-	-	0.502*** (0.112)
Social Subscore	-	-	0.387*** (0.095)
Governance Subscore	-	-	0.421*** (0.103)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	12,487	12,487	12,487
Adj. R^2	0.428	0.436	0.453

Note: t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Thus, our mediation analysis suggests that all three mechanisms play significant roles, with operational efficiency contributing most strongly to the moderating effect of digital transformation (as show in Table 6).

5. Discussion and Conclusion

5.1. Theoretical Implications

This study contributes to the literature in several ways. First, it extends our understanding of the determinants of ESG performance by highlighting the role of market uncertainty, an increasingly important factor in the volatile global economic environment. Second, it identifies digital transformation as a critical organizational capability that can help firms maintain their ESG

commitments during periods of uncertainty. Third, it provides empirical evidence from the Chinese technology sector, an important but understudied context in ESG research.

Our findings align with and extend real options theory by demonstrating that while uncertainty generally leads to investment delays, organizational capabilities like digital transformation can modify this relationship. Similarly, our results contribute to resource-based view perspectives by highlighting how digital capabilities can serve as strategic resources enabling firms to pursue multiple objectives simultaneously, even under resource constraints (Zhou & Cui, 2025).

5.2. Practical Implications

For managers, our findings suggest that investments in digital transformation not only provide operational benefits but also enhance organizational resilience and the ability to maintain ESG commitments during uncertain times. This dual benefit may justify greater investment in digital capabilities, particularly for firms operating in volatile environments.

For policymakers, our results highlight the importance of supporting both digital transformation and ESG initiatives in the corporate sector. Policies that facilitate digital adoption may indirectly support ESG performance, particularly during periods of market uncertainty.

5.3. Limitations and Future Research

This study has several limitations that present opportunities for future research. First, our focus on the technology sector in China limits the generalizability of our findings to other industries and contexts. Future research could examine whether similar relationships exist in other sectors and countries.

Second, while we identify several mechanisms through which digital transformation moderates the relationship between market uncertainty and ESG performance, more detailed investigation of these mechanisms would provide valuable insights. Future studies could employ qualitative methods to explore these mechanisms in depth (Zhou & Cui, 2025).

Third, our measure of digital transformation, while comprehensive, may not capture all dimensions of this complex phenomenon. Future research could develop and validate more nuanced measures of digital transformation specific to different organizational contexts (Zhou & Cui, 2025).

In conclusion, this study demonstrates that market uncertainty negatively affects ESG performance in Chinese technology firms, but digital transformation capabilities can mitigate this negative impact. As market uncertainty becomes increasingly common in the global business environment, firms that develop strong digital capabilities may be better positioned to maintain their ESG commitments, potentially creating long-term competitive advantages. These findings provide valuable insights for researchers, managers, and policymakers interested in promoting sustainable business practices in volatile market environments.

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

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