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Digital Transformation and Firm Environmental Performance: Does Managerial Overseas Experience Matter?

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Abstract

Digital transformation and firm environmental performance have emerged as central topics in the field of corporate sustainability. However, few publications have explored how managerial characteristics influence this relationship. This paper aims to address this gap by examining the impact of digital transformation on firm environmental performance, with a particular focus on the moderating role of managerial overseas experience. Using a sample of Chinese listed companies from 2011 to 2021, we employ robust econometric models to analyse the effects and variations across firms. Our findings reveal that digital transformation significantly enhances firm environmental performance. This positive impact is more pronounced in non-high-pollution firms compared to high-pollution firms. Furthermore, we identify managerial overseas experience as a critical moderating factor, strengthening the positive relationship between digital transformation and firm environmental performance. This study provides valuable insights for firms pursuing sustainable development strategies through digital transformation, emphasizing the importance of managerial overseas experience in achieving improved environmental outcomes.

Keywords: digital transformation, firm environmental performance, managerial overseas experience, China

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Introduction

As global concerns about environmental sustainability intensify, firms face increasing pressure to address environmental performance while maintaining competitive advantage. Against this backdrop, digital transformation has emerged as a transformative force, enabling firms to innovate, optimize operations, and pursue sustainable development goals [1; 2]. By integrating advanced technologies such as artificial intelligence, big data, cloud computing, and blockchain into their business processes, firms can reduce resource consumption, improve operational efficiency, and enhance transparency, thereby driving significant improvements in environmental outcomes [3]. However, while the literature increasingly acknowledges the role of digitalization in fostering sustainability, the specific mechanisms and contextual factors shaping this relationship remain insufficiently explored.

One critical yet underexamined factor is the role of managerial overseas experience. Managers with international exposure bring unique insights, diverse perspectives, and a global mindset to decision-making, which can influence how firms leverage digital transformation for environmental performance. The Upper Echelons Theory [4] suggests that managerial overseas experience can enhance firms' ability to adopt and implement advanced digital technologies in ways that align with environmental goals. These managers are more likely to recognize the long-term strategic benefits of environmental initiatives, adopt international best practices, and embrace stakeholder-driven sustainability standards [5]. However, empirical evidence on whether and how managerial overseas experience moderates the digital transformation – environmental performance relationship remains scarce.

Furthermore, firms face varying degrees of environmental challenges depending on their industry characteristics. In high-pollution industries, such as manufacturing or energy, firms may prioritize short-term financial gains over long-term environmental improvements, limiting the potential benefits of digital transformation [6]. In contrast, non-high-pollution firms often operate under less intense environmental scrutiny and are better positioned to capitalize on the efficiencies and innovations enabled by digitalization. These industry variations raise important questions about the differential impact of digital transformation on firm environmental performance.

To address these gaps, this study empirically examines the relationship between digital transformation and firm environmental performance, with a particular focus on the moderating role of managerial overseas experience. Using a comprehensive dataset of Chinese listed firms from 2011 to 2021, we reveal that digital transformation significantly enhances firm environmental performance. Notably, this positive effect is more pronounced in non-high-pollution firms compared to high-pollution firms. Furthermore, managerial overseas experience positively moderates this relationship, amplifying the environmental benefits of digital transformation.

This study makes several important contributions to the existing literature. First, it provides robust empirical evidence on the role of digital transformation in improving firm environmental performance, advancing the understanding of how digital technologies drive sustainability outcomes. This adds to the growing body of research emphasizing the strategic importance of digitalization for addressing environmental challenges. Second, our analysis identifies managerial overseas experience as a critical moderating factor, offering fresh insights into the role of leadership characteristics in facilitating the successful implementation of digital strategies for sustainability. By doing so, it highlights the significance of globalized managerial perspectives in shaping environmental outcomes. Third, this study underscores the importance of industry heterogeneity by demonstrating that the positive impact of digital transformation on environmental performance is more evident in non-high-pollution industries. This finding provides a nuanced understanding of the contextual factors influencing the environmental benefits of digitalization, offering valuable implications for industry-specific policy and managerial strategies.

The remainder of this paper is structured as follows. Second section reviews the relevant literature and theoretical foundations, leading to the development of hypotheses. Third section outlines the data, variable construction, and empirical methodology. Fourth section presents the results, including robustness checks, and discusses the findings. Finally, fifth section concludes the study and suggests avenues for future research.

Theoretical Foundations and Hypothesis Development

Resource-Based Theory

The resource-based view (RBV) is a foundational theory in strategic management that emphasizes the role of firm-specific resources and capabilities in achieving and sustaining competitive advantage [7]. According to RBV, resources that are valuable, rare, inimitable, and non-substitutable form the basis for long-term performance and differentiation in competitive markets. These resources can include tangible assets, intangible assets, and organizational capabilities that enable firms to effectively exploit opportunities and mitigate threats in their environments [8].

Within the RBV framework, technological advancements, particularly digital transformation, are increasingly recognized as strategic resources that can unlock operational efficiencies, promote innovation, and address environmental challenges [9]. Digital transformation, defined as the integration of advanced digital technologies – such as big data, artificial intelligence, cloud computing, and blockchain – into firms' operations, equips organizations with dynamic capabilities to optimize resource utilization and improve sustainability outcomes. By enabling firms to transform business processes and manage resources more efficiently, digital transformation serves as a strategic tool to enhance environmental performance, aligning with the core tenets of RBV.

Upper Echelons Theory

The Upper Echelons Theory (UET), introduced by Hambrick and Mason (1984) [4], posits that organizational outcomes – such as strategies, performance, and innovation – are significantly influenced by the demographic and experiential characteristics of top managers. According to UET, managerial decisions are not purely rational but are shaped by cognitive frames, values, and experiences, which arise from factors such as age, education, functional background, and international exposure [10]. These characteristics serve as filters through which managers perceive challenges, evaluate opportunities, and formulate strategies, ultimately determining firm performance and strategic direction.

Among the various managerial traits, overseas experience is increasingly recognized as a key determinant of managerial cognition and decision-making capabilities. Managers with overseas backgrounds are exposed to diverse institutional environments, global best practices, and advanced technologies, which broaden their cognitive scope and enhance their ability to identify strategic opportunities. In the context of digital transformation and environmental performance, managerial overseas experience equips top executives with a global mindset, fostering greater awareness of sustainability imperatives and innovative pathways to achieve environmental goals [11]. Thus, UET provides a robust theoretical lens to understand how managers' international exposure moderates the relationship between corporate digitalization and firm environmental performance.

Hypothesis Development

Direct Effect Hypothesis

RBV provides a strong theoretical foundation for understanding how digital transformation positively influences firm environmental performance. As firms face increasing pressure to achieve environmental sustainability, their ability to leverage unique and strategic resources becomes critical. Digital transformation, as a technological and organizational resource, enhances firms' capabilities to reduce environmental impact through improved operational efficiency, innovation, and resource optimization.

First, digital transformation facilitates efficient resource management, which directly supports environmental sustainability. Advanced digital technologies, such as big data analytics and artificial intelligence, enable firms to monitor and optimize energy consumption, emissions, and resource utilization in real time [12]. By providing granular insights into operational inefficiencies, these technologies empower firms to adopt cleaner production methods and reduce their environmental footprint. For instance, big data analytics allows firms to identify patterns in energy usage, while artificial intelligence optimizes production processes to minimize waste and emissions [13]. Such efficiency gains align with RBV, as firms with superior technological capabilities are better positioned to capitalize on these resources to improve environmental performance.

Second, digital transformation promotes technological innovation, a key driver of sustainable environmental practices. According to RBV, innovation capabilities are critical for firms to develop and sustain competitive advantages in dynamic environments [14]. Digital technologies enable firms to invest in green innovations, such as eco-friendly products, low-carbon technologies, and circular economy practices. Cloud computing, for example, reduces firms' reliance on energy-intensive physical infrastructure by enabling virtualized systems, while blockchain enhances transparency and traceability in supply chains, ensuring compliance with environmental regulations [15]. Firms that leverage these innovative capabilities can gain a first-mover advantage in addressing environmental challenges, further supporting the RBV assertion that strategic resources drive firm-level outcomes.

Third, digital transformation enhances firms' dynamic capabilities, enabling them to respond to external environmental pressures and institutional demands effectively. Firms operating in resource-constrained environments face challenges in balancing economic growth with environmental sustainability. However, digital transformation equips firms with the ability to sense, seize, and transform environmental opportunities by integrating digital solutions into their strategic planning and operations. For example, digital platforms enhance firms' ability to engage with stakeholders, disclose environmental performance, and comply with regulatory requirements, further aligning firm strategies with sustainability goals [16]. According to RBV, such capabilities are essential for firms to adapt to evolving environmental standards and maintain long-term competitiveness. Thus, we propose the following hypothesis:

H1: Digital transformation has a positive and significant effect on firm environmental performance.

Moderating Effect Hypothesis

UET suggests that managers' characteristics, such as overseas experience, influence their ability to perceive and leverage strategic opportunities [17]. In the context of digital transformation, managerial overseas experience provides exposure to international best practices and environmental standards, which can influence how managers guide firms in deploying digital technologies for sustainability purposes. Importantly, while overseas experience may not independently lead to improved environmental performance – especially when misaligned with local operational contexts – it can serve as an important contextual enabler, strengthening the positive effects of digital transformation on firm environmental performance.

First, managers with overseas experience tend to possess a broader cognitive framework, allowing them to better identify and interpret the environmental value of digital transformation. Their familiarity with advanced digital applications – such as AI for emissions forecasting or big data for energy optimization – enhances their ability to amplify the environmental benefits of digital investments [18–21]. In this sense, overseas experience does not act as a direct driver of sustainability, but as a catalyst that enhances the strategic utility of digital tools.

Second, international exposure often brings with it a heightened sensitivity to long-term environmental objectives and stakeholder expectations, especially in jurisdictions with strict environmental regulations [22–24]. Managers with such backgrounds are better positioned to align digital transformation initiatives with emerging regulatory frameworks and sustainability norms, thereby elevating the effectiveness of digital transformation in addressing environmental challenges.

Third, managerial overseas experience enhances firms' dynamic capabilities, which are critical for navigating the complexities of digital transformation and sustainability [25]. Managers with international exposure are adept at sensing, seizing, and transforming opportunities within rapidly changing technological and environmental landscapes. For instance, they are more likely to adopt digital innovations, such as blockchain for supply chain transparency or cloud computing for energy-efficient operations, to improve environmental performance [26]. Their global perspective also facilitates cross-border knowledge transfer and collaboration, enabling firms to integrate cutting-edge digital practices that magnify the ecological value of digital transformation.

All in all, we argue that managerial overseas experience plays a complementary and reinforcing role in the digital transformation – environmental performance relationship, serving as a strategic asset that conditions the success of digital initiatives aimed at sustainability.

H2: Managerial overseas experience positively moderates the relationship between digital transformation and firm environmental performance.

Heterogeneous Effect Hypothesis

RBV posits that firms' competitive advantages are derived from resources and capabilities that are valuable, rare, inimitable, and non-substitutable [27]. Firms with superior capabilities are better positioned to optimize resources and adapt to changing market or institutional demands. Digital transformation, as a strategic resource, enables firms to achieve operational efficiency, optimize resource utilization, and foster environmental innovations, thereby improving firm environmental performance [28]. However, the extent to which digital transformation enhances environmental performance depends on firms' resource flexibility and environmental constraints, which differ significantly between high-pollution and non-high-pollution firms.

First, non-high-pollution firms typically exhibit greater resource flexibility, allowing them to harness the benefits of digital transformation more effectively to improve environmental performance. Digital transformation facilitates precise resource allocation, energy optimization, and waste reduction through technologies such as big data analytics and artificial intelligence [29]. Non-high-pollution firms, facing lower regulatory compliance costs and fewer legacy constraints, can allocate more resources toward integrating digital technologies for proactive environmental management [30]. In contrast, high-pollution firms often divert resources toward mandatory pollution control and regulatory compliance, which limits their ability to leverage digital transformation for innovation and process optimization fully [29–30].

Second, digital transformation provides firms with the capability to pursue green innovation, a critical pathway to environmental performance improvement. Non-high-pollution firms are less burdened by immediate environmental pressures that constrain innovation investments in high-pollution industries [31]. These firms can leverage digital technologies to develop sustainable products, implement cleaner production processes, and adopt circular economy models, aligning with RBV's emphasis on innovation as a source of competitive advantage. By contrast, high-pollution firms often focus on meeting baseline environmental standards, leaving little room for investments in proactive and innovative environmental strategies driven by digital transformation. This leads to the following hypothesis:

H3: The positive impact of digital transformation on firm environmental performance is stronger in non-high-pollution firms than in high-pollution firms.

Methodology

Sample and Data

This study utilizes a comprehensive dataset of 1,316 Chinese A-share listed firms spanning the period from 2011 to 2021. The data for executive characteristics and financial indicators were meticulously extracted from the China Stock Market and Accounting Research (CSMAR) database, while firm environmental performance data were obtained from the Bloomberg database, which is widely recognized for its reliability in ESG-related research.

To ensure the rigour, relevance, and robustness of the dataset, a systematic data preprocessing procedure was employed. First, firms in the financial industry were excluded due to their distinct governance structures and regulatory frameworks, which could introduce bias into the analysis. Second, companies designated as "ST" (Special Treatment) by the China Securities Regulatory Commission (CSRC) – indicating financial distress for two consecutive years – were removed to minimize the influence of severely underperforming firms on the results. Third, firms lacking sufficient financial or accounting information were excluded to preserve the completeness and consistency of the dataset. Fourth, to mitigate the impact of outliers that could distort statistical inferences, all continuous variables were subjected to winsorization at the 1st and 99th percentiles. This technique effectively controls for extreme values while maintaining the integrity of the data distribution. After the above procedures were applied, the final sample comprised 10,593 firm-year observations. The resulting panel is unbalanced due to variations in listing dates and missing values across years. This structure is common in empirical corporate finance studies and allows for the retention of a larger and more representative sample without introducing selection bias.

Variable Measurement and Estimations Techniques

The dependent variable in this study is firm environmental performance, proxied by environmental rating scores from the Bloomberg database. These scores comprehensively evaluate a firm's environmental practices, encompassing aspects such as resource efficiency, carbon emissions, energy consumption, waste management, and environmental disclosures. Derived from publicly available sustainability reports and independent third-party sources, Bloomberg's ratings ensure objectivity and comparability across firms and industries. By reflecting multiple dimensions of environmental performance over time, these standardized scores serve as a robust and dynamic proxy for assessing firms' environmental outcomes [33; 34].

The independent variable in this study is digital transformation, which reflects the extent to which firms adopt and integrate advanced digital technologies into their strategic operations. Digital transformation involves the deployment of technologies such as artificial intelligence (AI), big data (BD), cloud computing (CC), blockchain (BC), and digital technology applications (DTA) to optimize business processes, improve decision-making, and enhance operational efficiency. Given the strategic importance of digital transformation, this study relies on firms' annual reports – particularly the Management Discussion and Analysis (MD&A) sections – as a primary source to capture their engagement with digital initiatives.

To measure digital transformation, we take a textual analysis approach using advanced natural language processing (NLP) techniques. First, the Jieba segmentation tool is used to perform precise word segmentation on Chinese corporate texts. Next, we apply Word2Vec models (CBOW and Skip-Gram) to identify and embed digital transformation-related terms, ensuring that the measure captures both frequent and contextually nuanced keywords. The digital transformation index is constructed by calculating the logarithmic transformation of the frequency of these keywords in each firm's MD&A section. This methodology not only overcomes the limitations of traditional keyword-based approaches but also ensures greater semantic accuracy and robustness, providing a comprehensive and dynamic measure of firms' digital transformation levels.

The moderating variable in this study is managerial overseas experience, which reflects whether a firm's top executives have international work or educational backgrounds. This variable is constructed as a dummy variable (binary indicator): it takes the value 1 if at least one member of the top management team (TMT) – such as the CEO, board chairperson, or other senior executives – has studied or worked overseas, and 0 otherwise.

To control for potential confounding factors that may influence the relationship between digital transformation and firm environmental performance, this study includes a set of control variables widely adopted in the existing literature [35; 38]. Listing age (LA) is measured as the natural logarithm of the number of years since a firm's initial public offering, accounting for firm maturity and experience. Financial leverage (LEV), defined as the ratio of total debt to total assets, reflects a firm's capital structure, as higher debt levels may constrain investments in digital transformation and environmental initiatives. Return on equity (ROE), calculated as net income divided by total shareholders' equity, serves as a proxy for profitability, with financially successful firms being more capable of adopting advanced digital technologies to improve sustainability outcomes. Cash holdings (CH), measured as the ratio of cash and cash equivalents to total assets, capture firm liquidity, which can facilitate or limit resource allocation toward digital transformation and environmental efforts. With regard to corporate governance, board size (BS), measured as the total number of directors on the board, reflects governance capacity and decision-making structure, while the proportion of independent directors (ID) captures board independence and its ability to monitor managerial actions. Ownership concentration (OC), defined as the percentage of shares held by the largest shareholder, indicates the degree of shareholder control, which may influence firms' strategic priorities, including environmental sustainability. Finally, managerial ownership (MO), measured as the percentage of shares held by senior management, aligns managerial interests with shareholders, potentially motivating executives to pursue long-term digitalization and environmental goals.

To test hypothesis H1–H3, we construct the following empirical models:

$$\begin{aligned} FEP_{i,t} &= \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 LA_{i,t} + \alpha_3 LEV_{i,t} + \\ &+ \alpha_4 ROE_{i,t} + \alpha_5 CH_{i,t} + \alpha_6 BS_{i,t} + \alpha_7 ID_{i,t} + \\ &+ \alpha_8 OC_{i,t} + \alpha_9 MO_{i,t} + Year + Firm + \varepsilon, \end{aligned} \tag{1}$$

$$\begin{aligned} FEP_{i,t} &= \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 MOE_{i,t} + \\ &+ \alpha_3 DT_{i,t} * MOE_{i,t} + \alpha_4 LA_{i,t} + \alpha_5 LEV_{i,t} + \\ &+ \alpha_6 ROE_{i,t} + \alpha_7 CH_{i,t} + \alpha_8 BS_{i,t} + \alpha_9 ID_{i,t} + \\ &+ \alpha_{10} OC_{i,t} + \alpha_{11} MO_{i,t} + Year + Firm + \varepsilon. \end{aligned} \tag{2}$$

where α_0 denotes the intercept, and $\alpha_1 - \alpha_{11}$ the coefficients to be estimated. *Year* and *Firm* are dummy variables that control for year and firm fixed effects to account for unobserved, time-invariant firm-specific characteristics that may influence the dependent variable; ε is the error term; i denotes the cross-sectional dimension for firms; and t denotes the time series dimension.

Equation (1) is used to test the direct effect and the heterogeneity effect, while Equation (2) is aimed at examining the moderating role of MOE.

Findings and Discussion

Descriptive Statistics and Correlation Matrix

Table 1 presents the descriptive statistics for the variables used in this study, based on 10,593 firm-year observations, computed using Stata 17. The dependent variable, Firm Environmental Performance (FEP), has a mean value of 8.900, with a relatively large standard deviation of 12.250, indicating significant variation across firms. The values range from 0 to a maximum of 73.815, suggesting that some firms perform exceptionally well in environmental practices while others lag behind.

The key independent variable, Digital Transformation (DT), has a mean of 1.393 and a standard deviation of 1.386, with values ranging from 0 to 6.301, reflecting varying levels of digital technology adoption among firms. The moderating variable, Managerial Overseas Experience (MOE), is a binary indicator with a mean of 0.630, suggesting that 63% of the firms' executives possess overseas backgrounds.

Among the control variables, Listing Age (LA), measured as the logarithmic number of years since listing, shows a mean of 2.478 with a standard deviation of 0.676 and ranges between 0 and 3.367. Leverage (LEV) averages 0.478, reflecting that firms finance 47.8% of their assets with debt, and has a relatively low dispersion (standard deviation of 0.199). Return on Equity (ROE) has a mean value of 0.087 yet displays notable variation, with a standard deviation of 0.128 and extreme values ranging from -0.926 to 0.419, suggesting profitability disparities across firms. Cash Holdings (CH) exhibit a mean of 0.059 and a standard deviation of 0.069, with values ranging between -0.199 and 0.257, indicating varying levels of liquidity among firms. Board Size (BS), expressed as the natural logarithm of the number of board members, has a mean of 2.175 and a low standard deviation of 0.201, with values between 1.609 and 2.708. Independent Directors (ID), measured as the percentage of independent directors on the board, has a mean of 37.534% with notable variation (standard deviation of 5.503) and ranges from 28.570% to 60.000%. Ownership Concentration (OC), defined as the percentage of shares held by the largest shareholder, averages 36.821%, with significant dispersion (standard deviation of 16.104) and a wide range from 8.087% to 75.779%. Finally, Managerial Ownership (MO) has a mean value of 7.079% with substantial variability (standard deviation of 14.884) and ranges from 0 to 70.382%, indicating considerable heterogeneity in managers' equity stakes across firms.

Overall, these statistics reveal substantial variation across firms in terms of environmental performance, digital transformation, managerial characteristics, and governance indicators.

Table 2 presents the results of the Pearson correlation analysis and Variance Inflation Factor (VIF) diagnostics for the key variables in this study. The correlation analysis focuses on the relationships between the independent variable (digital transformation), the moderating variable (managerial overseas experience), and the dependent variable (firm environmental performance). The results show that DT is positively and significantly correlated with FEP ($r = 0.070$, $p < 0.01$), indicating a preliminary positive association between DT and firms' environmental outcomes. Similarly, the moderating variable (MOE) exhibits a significant positive correlation with FEP ($r = 0.108$, $p < 0.01$), suggesting that firms with managers possessing overseas experience tend to achieve better environmental performance. Furthermore, DT and MOE are positively correlated ($r = 0.124$, $p < 0.01$), implying that managerial overseas experience may enhance the effectiveness of digital transformation in improving environmental performance.

Table 1. Descriptive Statistics

Variable	Definition	Obs	Mean	Std. dev.	Min	Max
FEP	Firm Environmental Performance	10.593	8.900	12.250	0.000	73.815
DT	Digital Transformation	10.593	1.393	1.386	0.000	6.301
MOE	Managerial Overseas Experience	10.593	0.630	0.483	0.000	1.000
LA	Listing Age	10.593	2.478	0.676	0.000	3.367
LEV	Leverage	10.593	0.478	0.199	0.032	0.908
ROE	Return on Equity	10.593	0.087	0.128	-0.926	0.419
CH	Cash Holdings	10.593	0.059	0.069	-0.199	0.257
BS	Board Size	10.593	2.175	0.201	1.609	2.708
ID	Independent Directors	10.593	37.534	5.503	28.570	60.000
OC	Ownership Concentration	10.593	36.821	16.104	8.087	75.779
MO	Managerial Ownership	10.593	7.079	14.884	0.000	70.382

Source: calculated by authors.

Table 2. Pearson Correlation and Variance Inflation Factor

	FEP	DT	MOE	LA	LEV	ROE	CH	BS	ID	OC	MO	VIF
FEP	1.000											
DT	0.070***	1.000										1.06
MOE	0.108***	0.124***	1.000									1.04
LA	0.036***	-0.061***	-0.096***	1.000								1.42
LEV	0.046***	-0.082***	-0.022**	0.261***	1.000							1.21
ROE	0.065***	0.026***	0.038***	-0.161***	-0.218***	1.000						1.20
CH	0.108***	0.013	0.025***	-0.088***	-0.251***	0.361***	1.000					1.20
BS	0.037***	-0.094***	0.050***	0.090***	0.123***	-0.014	0.004	1.000				1.34
ID	0.036***	0.054***	0.003	-0.015	-0.000	0.020**	0.019*	-0.454***	1.000			1.28
OC	0.035***	-0.146***	-0.057***	-0.076***	0.085***	0.112***	0.069***	0.023**	0.072***	1.000		1.11
MO	-0.029***	0.133***	0.091***	-0.495***	-0.268***	0.122***	0.073***	-0.186***	0.034***	-0.152***	1.000	1.47

Note: * p < 0.1, ** p < 0.05, *** p < 0.01.

To further assess multicollinearity, VIF values were calculated for all explanatory variables. The results indicate that multicollinearity is not a concern, as all VIF values are well below the critical threshold of 10. Specifically, the VIF values for DT and MOE are 1.06 and 1.04, respectively, suggesting very low collinearity. The highest VIF value, 1.47, is observed for managerial ownership (MO), which remains within acceptable limits. Overall, the combination of correlation and VIF results confirms that the regression models are free from multicollinearity issues, ensuring the robustness and reliability of the empirical analysis.

Baseline Results

Table 3 presents the baseline regression results for the impact of DT on FEP. In column (1), the key independent variable DT demonstrates a positive and highly significant relationship with FEP, indicating that digital transformation plays a crucial role in enhancing firms' environmental performance. This positive relationship remains robust, though with a slight reduction in magnitude, even after the inclusion of additional control variables in column (2).

The control variables included in column (2) provide further insights into the determinants of firm environmental performance. Firm characteristics, such as listing age, indicate that older firms, benefiting from accumulated experience and resources, tend to achieve better environmental outcomes. In contrast, firms with higher leverage may face financial constraints that limit their capacity to invest in sustainability initiatives. Profitability, reflected in return on equity, positively influences FEP, as financially sound firms are more capable of implementing environmental strategies. Corporate governance variables, such as board size, proportion of independent directors, ownership concentration, and managerial ownership, all exhibit positive associations with environmental performance, underscoring the importance of governance structures and aligned interests in supporting firms' environmental efforts. Collectively, these findings highlight that financial strength, experience, and governance quality play pivotal roles in driving firms' environmental outcomes alongside digital transformation.

Overall, the results strongly support Hypothesis 1 (H1), which posits that digital transformation positively influences firm environmental performance. These findings are consistent with RBV, which emphasizes that firms' valuable, rare, inimitable, and non-substitutable resources – such as digital technologies – can generate competitive advantages [30; 35]. By integrating advanced technologies like artificial intelligence, big data, and cloud computing, firms can enhance operational efficiency, reduce emissions, and achieve environmental sustainability [31]. The results align with prior studies that link digital transformation to improved environmental practices through innovation, resource optimization, and supply chain transparency [23; 28; 29]. Furthermore, the findings suggest that firms with stronger governance mechanisms are better positioned to exploit digital technologies, reinforcing the RBV argument that organizational resources and capabilities underpin environmental performance [39].

Robustness Check

To ensure the reliability and consistency of the baseline results, we conduct several robustness checks (Table 4). Specifically, three approaches are employed: adding year-industry interaction fixed effects, replacing the independent variable with an alternative measure, and incorporating additional control variables.

First, column (1) incorporates year-industry interaction fixed effects to account for unobserved heterogeneity that may vary simultaneously across time and industry. This approach is particularly useful for controlling for time-vary-

Table 3. Baseline Regression Results

	(1) FEP	(2) FEP
DT	0.387***	0.351***
	(0.129)	(0.128)
LA		3.116***
		(0.541)
LEV		-1.762*
		(0.917)
ROE		4.577***
		(0.708)
CH		0.447
		(1.380)
BS		2.939***
		(0.887)
ID		0.114***
		(0.027)
OC		0.040***
		(0.015)
MO		0.043***
		(0.016)
_cons	8.286***	-11.439***
	(0.192)	(3.019)
Year FE	yes	yes
Firm FE	yes	yes
N	10531	10531
Adj. R^2	0.646	0.650

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are given in parentheses.

Table 4. Robustness Check

	(1) FEP	(2) FEP	(3) FEP	(4) FEP	(5) FEP
DT	0.342***		0.349***	0.344***	0.275**
	(0.130)		(0.128)	(0.128)	(0.126)
DT-dummy		0.411*			
		(0.235)			
LA	3.212***	3.181***	3.118***	3.056***	3.702***
	(0.548)	(0.540)	(0.541)	(0.542)	(0.524)
LEV	-1.857**	-1.692*	-1.707*	-1.930**	-3.393***
	(0.916)	(0.916)	(0.919)	(0.920)	(0.890)
ROE	4.501***	4.617***	4.128***	4.244***	4.237***
	(0.716)	(0.707)	(0.903)	(0.722)	(0.689)
CH	0.338	0.367	0.483	0.232	0.028
	(1.381)	(1.381)	(1.379)	(1.384)	(1.358)
BS	2.900***	3.011***	2.945***	2.867***	2.142**
	(0.892)	(0.887)	(0.887)	(0.889)	(0.866)
ID	0.107***	0.112***	0.114***	0.114***	0.100***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)
OC	0.041***	0.039***	0.040***	0.040***	0.047***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
MO	0.053***	0.043***	0.043***	0.044***	0.034**
	(0.016)	(0.016)	(0.016)	(0.016)	(0.015)
LOSS			-0.290		
			(0.351)		
MFEE				-4.437**	
				(1.824)	
SA					24.432***
					(1.974)
_cons	-11.378***	-11.469***	-11.411***	-10.666***	83.154***
	(3.057)	(3.026)	(3.020)	(3.051)	(7.867)
Year FE	yes	yes	yes	Yes	yes
Firm FE	yes	yes	yes	Yes	yes
Year * Industry	yes	no	no	No	no
N	10531	10531	10531	10531	10531
Adj. R^2	0.653	0.650	0.650	0.650	0.662

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are given in parentheses.

ing industry-specific shocks, as it captures any systematic variation in FEP attributable to interactions between industry-level factors and temporal trends. The coefficient of DT remains positive and significant, further confirming the robustness of the baseline results.

Second, column (2) replaces the continuous measure of digital transformation (DT) with a dummy variable (DT-dummy), which equals 1 if a firm's digital transformation index is above the sample median and 0 otherwise. This test checks whether the relationship between digital transformation and FEP holds when one uses a simplified binary measure of digitalization. The results indicate that DT-dummy maintains a positive and significant effect on FEP, reinforcing the robustness of the baseline findings to alternative variable specifications.

Third, columns (3) to (5) introduce additional control variables to address concerns about omitted variable bias. Specifically, firm losses (LOSS), management expense ratio (MFEE), and financing constraints (SA index) are included. Firm losses, measured as a dummy variable equal to 1 for firms reporting negative net profits, are controlled because financial distress can limit investments in sustainability initiatives, thereby influencing environmental performance [40]. The management expense ratio (MFEE), calculated as the ratio of management expenses to revenue, serves as a proxy for agency costs, which may affect managerial efficiency in implementing digital transformation strategies [41]. Finally, the SA index, a widely used measure of financing constraints, is included to control for firms' financial flexibility, as constrained firms may struggle to adopt costly digital technologies for environmental improvements [42].

The results in columns (3)–(5) demonstrate that the positive effect of DT on FEP remains significant even after including these additional controls. While firm losses (LOSS) are not statistically significant, both management expense ratio (MFEE) and SA index show significant effects, suggesting that agency costs and financial constraints play critical roles in shaping firms' environmental performance. Significantly, the coefficient for DT remains robust across all specifications, further supporting the validity of the main findings.

In conclusion, these robustness checks – using year-industry interaction fixed effects, alternative measures of digital transformation, and additional controls – confirm that the positive relationship between digital transformation and firm environmental performance is both consistent and reliable. The findings underscore the critical role of digital technologies in driving environmental outcomes, even under varying model assumptions.

Moderating Role of Managerial Overseas Experience

As shown in Table 5, the interaction term c.DT#c.MOE is significantly positive (α_2 = 0.454, $p < 0.05$ in model (1); α_2 = 0.434, $p < 0.05$ in model (2)), indicating that MOE strengthens the positive relationship between DT and FEP. This suggests that firms with internationally experienced managers are better positioned to leverage digital technologies for environmental outcomes, as their global perspectives enable more effective integration of advanced digital strategies into sustainability initiatives.

These findings support Hypothesis 2 (H2) and align with the predictions of the Upper Echelons Theory [17], which

Table 5. Moderating Effect

	(1)	(2)
	FEP	FEP
DT	0.372**	0.337*
	(0.185)	(0.185)
MOE	-0.578	-0.559
	(0.366)	(0.364)
c.DT#c.MOE	0.454**	0.434**
	(0.220)	(0.219)
LA		3.043***
		(0.888)
LEV		-1.784
		(1.416)
ROE		4.525***
		(0.920)
CH		0.452
		(1.610)
BS		3.071**
		(1.336)
ID		0.116***
		(0.039)
OC		0.039*
		(0.023)
MO		0.045*
		(0.025)
_cons	8.633***	-11.252**
	(0.332)	(4.628)
Year FE	yes	yes
Firm FE	yes	yes
N	10531	10531
Adj. R^2	0.647	0.651

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are given in parentheses.

emphasizes that executives' experience shapes their strategic decisions and ability to leverage organizational resources. Managers with overseas backgrounds bring a global mindset and exposure to advanced sustainability practices, allowing them to better recognize and implement digital technologies such as AI and big data to improve environmental performance [34; 42]. These results are consistent with prior studies which show that international experience enhances firms' innovation and sustainability efforts [5; 20]. While the direct negative effect of MOE may reflect challenges in aligning global strategies with local contexts, its significant interaction with digital transformation underscores its critical enabling role in amplifying environmental benefits.

Heterogeneity Analysis

The heterogeneity analysis in Table 6 examines the differential impact of DT on FEP across high-pollution firms (High Pollution = 1) and non-high-pollution firms (High Pollution = 0).

In column (1), which represents high-pollution firms, the coefficient for DT is negative but not statistically significant. This result suggests that digital transformation does not significantly enhance environmental performance for firms in highly polluting industries. One possible explanation is that high-pollution firms often face rigid regulatory pressures, legacy systems, and higher transition costs, which may limit their ability to leverage digital technologies effectively for environmental improvements.

In contrast, column (2) shows a significantly positive coefficient for DT in non-high-pollution firms ($\beta = 0.713$, $p < 0.01$), indicating that digital transformation significantly improves environmental performance in these firms. Non-high-pollution firms, which generally face fewer regulatory constraints and operate in less resource-intensive environments, are better positioned to adopt and integrate advanced digital technologies such as big data, AI, and cloud computing to optimize operations and achieve environmental efficiency.

These findings support Hypothesis 3 (H3), which predicts that the positive impact of digital transformation on firm environmental performance is stronger in non-high-pollution firms compared to high-pollution firms. The results align with RBV, which posits that firms must strategically deploy valuable resources, such as digital technologies, to enhance performance [32; 43]. Non-high-pollution firms are better able to capitalize on digital transformation due to lower technological adaptation costs and fewer structural barriers. Consistent with prior studies, Zhang et al. (2023) [44] argue that firms in less resource-intensive industries can implement digital solutions more efficiently to achieve sustainability outcomes, while Firoozi et al. (2024) [45] highlight that digital transformation is more effective in environments with fewer compliance burdens, enabling innovation and resource optimization. In contrast, high-pollution firms face substantial financial and operational hurdles during their transition to digital processes [46], which limits the environmental benefits of digitalization. The insignificant result for high-pollution firms also reflects the challenges of path dependence in environmentally intensive industries, where reliance on outdated technologies and strict regulatory pressures reduce flexibility for adopting innovative, digital-driven solutions. In comparison, non-high-pollution firms are better positioned to integrate digital technologies into their operations, achieving measurable improvements in environmental performance.

Table 6. Heterogeneity Analysis

	High Pollution =1	High Pollution=0
	(1)	(2)
	FEP	FEP
DT	-0.089	0.713***
	(0.229)	(0.157)
LA	1.960*	3.651***
	(1.071)	(0.629)
LEV	-0.321	-1.964*
	(1.697)	(1.098)
ROE	2.577*	4.349***
	(1.399)	(0.800)
CH	-1.029	1.249
	(2.750)	(1.540)
BS	2.358	3.459***
	(1.667)	(1.021)
ID	0.107**	0.115***
	(0.050)	(0.031)
OC	-0.005	0.057***
	(0.025)	(0.019)
MO	0.011	0.038**
	(0.031)	(0.019)
_cons	-3.318	-15.934***
	(5.863)	(3.421)
Year FE	yes	yes
Firm FE	yes	yes
N	3584	6916
Adj. R^2	0.669	0.641

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are given in parentheses.

Conclusion

This study investigates the impact of digital transformation on firm environmental performance while examining the moderating roles of managerial overseas experience and industry heterogeneity. The results confirm that digital transformation significantly enhances firm environmental performance, as advanced technologies like artificial intelligence, big data, and cloud computing enable firms to optimize resource usage and reduce environmental footprints. Further, the moderating effect analysis reveals that managerial overseas experience amplifies this positive relationship, as internationally experienced managers bring a global perspective and familiarity with advanced sustainability practices, enhancing the effectiveness of digital transformation. Heterogeneity tests show that the positive effect of digital transformation on environmental performance is more pronounced in non-high-pollution firms, which face fewer regulatory and structural barriers, while the effect is insignificant in high-pollution firms due to path dependence and the costs of transitioning to cleaner processes. These findings collectively highlight the significant role of digital transformation in improving environmental performance and emphasize the importance of managerial expertise and industry context in shaping its effectiveness.

This study makes several important theoretical contributions. First, it extends the Resource-Based View by demonstrating that digital transformation serves as a valuable strategic resource for firms to achieve environmental sustainability, particularly under favourable organizational and contextual conditions. Second, by integrating the Upper Echelons Theory, we highlight the critical enabling role of managerial overseas experience in enhancing firms' capabilities to utilize digital technologies for environmental improvements. Third, this study contributes to the literature on industry heterogeneity by illustrating how firms operating in different environmental contexts (e.g., high-pollution vs. non-high-pollution industries) show varying degrees of effectiveness in their digital transformation efforts.

The findings offer several practical insights for corporate leaders, policymakers, and stakeholders. For firms, the results emphasize the importance of strategically investing in digital transformation technologies to improve environmental performance. Managers with overseas experience should be actively leveraged to drive these initiatives, as their global perspectives can enhance the effective implementation of sustainability-oriented digital strategies. Firms in high-pollution industries, however, may need additional support, such as targeted policy incentives or financial assistance, to overcome barriers to adopting digital solutions for environmental improvements.

For policymakers, our findings highlight the need to create favourable conditions for firms to invest in digital transformation and leverage managerial expertise. Policies that support technological upgrading and provide regulatory flexibility for high-pollution firms could help them better harness digital technologies for sustainability. Additionally, fostering leadership development programmes that encourage international exposure among corporate managers could amplify the environmental benefits of digital transformation.

Despite its contributions, this study has several limitations. First, the analysis focuses on Chinese publicly listed firms, which may limit the generalizability of the findings to other institutional contexts. Future research could explore cross-country or cross-regional comparisons to provide broader evidence on the relationship between digital transformation and environmental performance. Second, while this study identifies managerial overseas experience as a key moderating factor, other leadership characteristics – such as managerial risk appetite or innovation mindset – could also play a role. Third, further investigation into the mechanisms through which digital transformation impacts environmental performance, such as green innovation or supply chain optimization, could deepen our understanding of these dynamics.

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