

Green Supply Chain Management, Digital Transformation, and Environmental Performance: A Natural Resource-Based View Perspective

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ABSTRACT

Digital transformation can improve operational efficiency, but its environmental benefits remain uncertain. Drawing on the Natural Resource-Based View (NRBV), this study examines the relationships between green supply chain management (GSCM), digital transformation (DT), and environmental performance in Indonesian manufacturing firms. Data were collected from the 2023 sustainability reports of 49 firms listed on the Indonesia Stock Exchange. Corporate disclosures were coded using a three-point ordinal scale and analyzed using partial least squares structural equation modeling (PLS-SEM). The results show that GSCM is positively associated with environmental performance ($\beta = 0.573$, $p < 0.001$), whereas DT has a negative association ($\beta = -0.239$, $p = 0.027$). The model explains 71.6% of the variance in environmental performance. These findings indicate that green supply chain practices and digital transformation have different environmental implications. Practices that incorporate environmental objectives into supply chain activities are associated with better environmental performance, while digital transformation alone does not show the same benefit. This study contributes to the NRBV literature by distinguishing environmentally oriented capabilities from digital capabilities serving broader operational purposes. For managers, the findings emphasize the importance of strengthening green supply chain practices and evaluating digital investments against environmental targets. The cross-sectional design and reliance on corporate disclosures limit causal interpretation. Further research should investigate the mechanisms underlying the negative relationship between DT and environmental performance.

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1. Introduction

Manufacturing firms face increasing pressure to improve environmental performance because their operations require substantial energy, water, and material resources and generate waste and emissions. Climate change, resource constraints, and environmental regulations have intensified

this pressure. Firms therefore need organizational capabilities that can reduce resource consumption and environmental impacts while maintaining operational efficiency. Green Supply Chain Management (GSCM) provides one response by integrating environmental considerations into supply chain activities. Digital Transformation (DT) provides another response by improving information processing, resource monitoring, and operational efficiency. These developments have increased academic and managerial interest in how GSCM and DT shape firms' environmental performance (Ba Awain et al., 2023; Lerman et al., 2022; Raman et al., 2023).

Firms can respond to environmental pressures through green and digital capabilities. GSCM directly embeds environmental objectives into supply chain activities. It promotes responsible sourcing, supplier collaboration, environmentally friendly materials, and environmental cost management. These practices can reduce resource consumption, waste, and emissions across the supply chain. DT follows a different pathway. Digital technologies improve information processing, resource monitoring, and operational efficiency. However, digital capabilities do not inherently pursue environmental objectives. Their environmental benefits may depend on how firms align digital technologies with sustainability practices. GSCM and DT may therefore produce different environmental outcomes despite their potential contribution to environmental performance (Cardinali & De Giovanni, 2022).

Empirical evidence shows different environmental outcomes for GSCM and DT. Previous studies consistently associate GSCM with better environmental performance through resource efficiency, waste reduction, and environmental coordination (Al-Sheyadi et al., 2019; Martínez-Falcó, Sánchez-García, Marco-Lajara, & Andreu, 2024). In contrast, studies report mixed environmental outcomes from digital transformation. Digital technologies can improve resource efficiency, green innovation, and environmental monitoring (Xu et al., 2022; Peng et al., 2023). However, digitalization can also increase energy demand and resource consumption through rebound effects (Thanh et al., 2023). Other evidence suggests that the relationship can be nonlinear and context-dependent (Ahmadova et al., 2022). These conflicting findings challenge the assumption that digital transformation inherently improves environmental performance. They also raise an important question about whether green and digital capabilities generate comparable environmental outcomes.

The NRBV provides a useful framework for addressing this question. The theory explains how environmentally oriented capabilities can improve environmental outcomes through efficient resource use and pollution prevention. GSCM closely reflects this logic because it embeds environmental objectives into supply chain activities. Digital transformation differs because digital capabilities primarily support information processing, monitoring, and operational efficiency. These capabilities may not improve environmental performance unless firms align them with environmental objectives. This distinction remains insufficiently understood, particularly in emerging-market manufacturing firms. These firms may face resource constraints and uneven capabilities in implementing digital and environmental initiatives. Therefore, examining GSCM and DT within the same model can clarify whether green and digital capabilities generate similar environmental outcomes.

This study examines the relationships between GSCM, DT, and Environmental Performance in manufacturing firms. The study contributes to the NRBV by distinguishing environmentally oriented capabilities from general digital capabilities. This distinction clarifies whether organizational capabilities with different strategic orientations generate comparable environmental outcomes. By examining GSCM and DT within the same empirical model, the study provides a more differentiated understanding of how organizational capabilities relate to Environmental Performance.

Literature Review and Hypothesis Development

Green Supply Chain Management and Environmental Performance

Green Supply Chain Management (GSCM) refers to the integration of environmental considerations into supply chain activities. In this study, it is operationalized through environmentally responsible sourcing (Berlian et al., 2023; Yildiz Çankaya & Sezen, 2019), supplier collaboration (Tarigan et al., 2021; Wamalwa & Nang'ole Meyer, 2024), environmentally friendly materials, employee environmental training (Khan et al., 2020), and environmental cost management (García Alcaraz et al., 2022; Uemura Reche et al., 2022). Rather than focusing solely on internal environmental practices, GSCM extends environmental responsibility across the entire supply chain to minimize

resource consumption, waste generation, and environmental pollution throughout production and distribution processes.

The relationship between GSCM and Environmental Performance can be explained through the Natural Resource-Based View (NRBV), which argues that environmentally oriented organizational capabilities enable firms to achieve sustainable competitive advantage while improving environmental outcomes (Hart, 1995). From this perspective, GSCM represents a strategic environmental capability because it integrates environmental objectives into procurement, production, logistics, and supplier relationships. Such integration allows firms to improve resource efficiency, reduce emissions and waste, and enhance compliance with environmental regulations.

Previous empirical studies consistently support this theoretical argument. Appiah and Odartey (2021) show that GSCM improves environmental performance by reducing waste and emissions and by extending environmental responsibility across supply chain activities. Odamtten et al. (2025) further confirm that environmentally oriented internal capabilities embedded in GSCM contribute to better environmental performance in manufacturing firms. Martínez-Falcó et al. (2024) highlight the role of green ambidexterity innovation in translating GSCM into sustainable outcomes, while Naz et al. (2024) demonstrate that practices such as green purchasing, eco-design, green manufacturing, and investment recovery support carbon-neutral supply chain performance. These studies indicate that GSCM enhances environmental outcomes through coordinated, resource-efficient, and environmentally responsible practices across the supply chain. Based on the NRBV and the previous empirical evidence, firms that more extensively implement green supply chain practices are expected to achieve higher environmental performance by embedding environmental considerations throughout their supply chain activities.

H1: Green Supply Chain Management has a positive effect on Environmental Performance.

Digital Transformation and Environmental Performance

Digital Transformation refers to the integration of digital technologies into organizational processes to improve information processing, operational efficiency, resource utilization, and decision-making (Sun & Guo, 2022). From the Natural Resource-Based View (NRBV), digital resources can contribute to environmental performance when they strengthen organizational capabilities for managing natural resources, reducing environmental impacts, and supporting environmentally oriented innovation (Dai & Zhu, 2024; Peng et al., 2023). Digital technologies such as big data analytics, digital monitoring systems, and information-sharing platforms can improve firms' ability to monitor energy and resource consumption, optimize production processes, and identify opportunities for pollution and waste reduction.

Previous studies provide empirical support for a positive relationship between Digital Transformation and Environmental Performance. Xu et al. (2022) show that digital transformation can enhance environmental performance through improved information sharing, resource acquisition capabilities, green technology innovation, and corporate governance. Peng et al. (2023) similarly demonstrate that digital technologies can improve environmental outcomes by stimulating green innovation and pollution-abatement activities. Sun and Guo (2022) further suggest that digitalization can support resource-efficient manufacturing, recycling, predictive maintenance, and energy efficiency. Collectively, these findings indicate that digital transformation can strengthen firms' environmental capabilities by improving resource allocation, environmental monitoring, and green innovation. Therefore, firms with higher levels of digital transformation are expected to achieve better environmental performance. Accordingly, the following hypothesis is proposed:

H2: Digital Transformation has a positive effect on Environmental Performance.

2. Methods

2.1 Research Design and Data Source

This study employed a quantitative research design to examine the effects of digital transformation and green supply chain management on the environmental performance of manufacturing firms listed on the Indonesia Stock Exchange (IDX). The analysis relied on secondary data obtained from corporate sustainability reports for the 2023 reporting period. The reports were retrieved from the official websites of the respective companies and served as the primary documentary source for identifying and measuring the study variables. The empirical hypothesis testing is based on

quantitative content analysis data derived from corporate disclosures and subsequently analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Therefore, for the purpose of reporting the study in an international journal article, the research design is more appropriately characterized according to the actual empirical procedure employed.

2.2 Population and Sample

The population comprised manufacturing firms listed on the Indonesia Stock Exchange. The sample was selected based on predetermined eligibility criteria, particularly the availability of the corporate information required to measure digital transformation, green supply chain management, and environmental performance. Following the sample-selection procedure, 49 manufacturing firms met the criteria and were included in the final analysis. Because the study covered a single reporting period, 2023, the final dataset consisted of 49 firm observations. The use of sustainability reports was particularly relevant because these reports provide firm-level information concerning digital initiatives, environmental practices, resource utilization, and other sustainability-related activities that are not necessarily available in conventional financial statements.

2.3 Variable Measurement and Content Analysis

The study examined three latent constructs: digital transformation, green supply chain management, and environmental performance. Digital transformation was operationalized using indicators related to employee digital training, digital resources, investment in digital technology, and operational efficiency derived from digital technology. Green supply chain management was represented by indicators related to environmental expenditure, the use of environmentally friendly materials, employee development expenditure, and suppliers. Environmental performance was assessed through indicators capturing water-use efficiency, waste-management efficiency, greenhouse gas emissions, and energy consumption. These indicators were identified from information disclosed in the firms' sustainability reports.

The documentary information was transformed into quantitative measures using an ordinal scoring scheme ranging from 1 to 3. The scoring procedure was designed to classify the information reported by firms according to the observed level of change in the relevant sustainability indicators. This process enabled qualitative information contained in corporate sustainability reports to be converted into structured numerical data suitable for subsequent statistical analysis.

2.4 Data Analysis

The empirical model was estimated using Partial Least Squares Structural Equation Modeling (PLS-SEM). The model consisted of two exogenous constructs—digital transformation and green supply chain management—and one endogenous construct, environmental performance. All three constructs were specified as reflective measurement models. The PLS-SEM analysis was conducted in two stages. First, the measurement model was evaluated to assess the adequacy of the constructs and their indicators. The assessment included convergent validity, internal consistency reliability, and discriminant validity. Convergent validity was evaluated using indicator loadings and average variance extracted (AVE), while internal consistency was examined using the reliability measures reported in the model. Discriminant validity was assessed using the heterotrait–monotrait ratio (HTMT). These procedures were used to establish the adequacy of the measurement model before evaluating the hypothesized structural relationships. Second, the structural model was assessed to examine the explanatory power and hypothesized relationships among the constructs. The evaluation included the coefficient of determination (R^2), effect size (f^2), inner variance inflation factor (VIF), and standardized path coefficients (β). The VIF values were considered to assess potential collinearity among the predictor constructs, whereas R^2 was used to evaluate the model's explanatory power for environmental performance.

2.5 Hypothesis Testing

The statistical significance of the hypothesized relationships was evaluated using a bootstrapping procedure in PLS-SEM. Bootstrapping was employed to generate the standard errors and inferential statistics associated with the estimated structural paths. Hypothesis decisions were based on the

standardized path coefficients (β), t-values, and p-values. A two-tailed test at the 5% significance level was applied. Accordingly, a structural relationship was considered statistically significant when its t-value exceeded the critical value of 1.960 and its p-value was below 0.05. The sign of the standardized path coefficient was subsequently used to determine the direction of each statistically significant relationship.

3. Results

3.1 Descriptive Statistics of Bankruptcy Prediction Models

Descriptive statistics show the characteristics of the data across the observed indicators of Digital Transformation, Green Supply Chain Management, and Environmental Performance.

Table 1. Descriptive Statistics and Normality Assessment

Construct	Item	Min	Max	Mean	Std.Dev	Excess Kurtosis	Skewness
Digital Transformation	Employee Digital Training	1.000	3.000	2.449	0.608	-0.484	-0.641
	Digital Resource Availability	1.000	3.000	2.245	0.624	-0.557	-0.236
Green Supply Chain	Environmental Costs	1.000	3.000	2.388	0.633	-0.577	-0.556
	Environmentally Friendly Materials	1.000	3.000	2.041	0.880	-1.757	-0.082
	Employee Training Costs	1.000	3.000	2.347	0.822	-1.140	-0.740
	Suppliers	1.000	3.000	2.306	0.645	-0.664	-0.403
Environmental Performance	Water Consumption	1.000	3.000	2.102	0.763	-1.270	-0.179
	Energy Consumption	1.000	3.000	2.388	0.778	-0.869	-0.821
	Waste Generated	1.000	3.000	2.245	0.743	-1.079	-0.441

Table 1 presents the descriptive statistics of data items. It shows that all indicators range from 1.000 to 3.000, consistent with the three-point measurement scale. Mean values range from 2.041 to 2.449, indicating generally moderate-to-high levels across the observed indicators. Standard deviations range from 0.608 to 0.880, suggesting reasonable variation among observations. Employee Digital Training records the highest mean (2.449), while Environmentally Friendly Materials has the lowest (2.041). Skewness values range from -0.821 to -0.082 , whereas excess kurtosis ranges from -1.757 to -0.484 . Overall, no indicators exhibit extreme skewness or kurtosis.

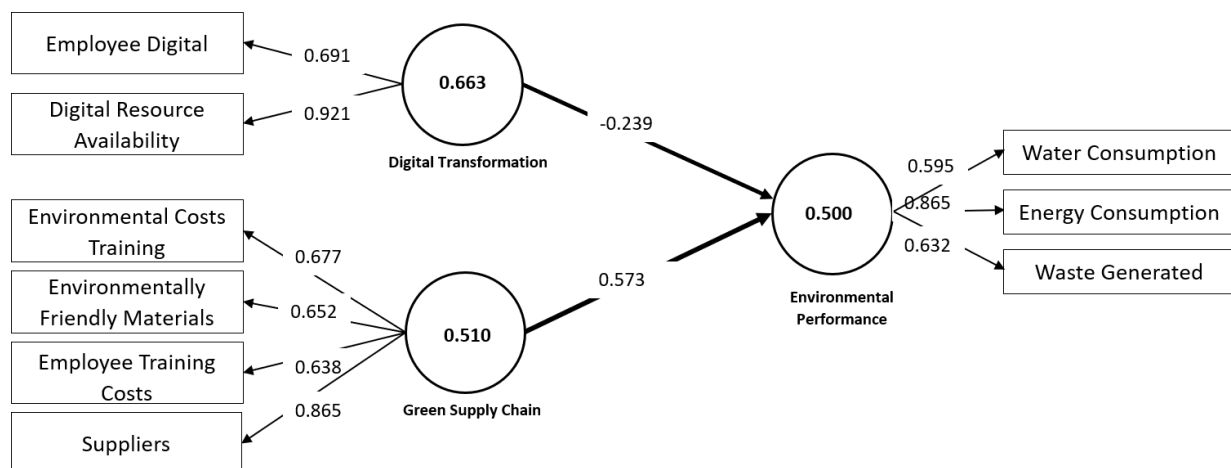


Figure 1. Convergent Validity

The measurement model was assessed by examining outer loadings to evaluate the extent to which each indicator reliably represents its respective latent construct. Figure 1 presents the PLS-SEM results for the relationships among Digital Transformation, Green Supply Chain Management, and Environmental Performance. The measurement model shows indicator loadings ranging from 0.595 to 0.921, while the AVE values are 0.663, 0.510, and 0.500 for Digital Transformation, Green

Supply Chain Management, and Environmental Performance, respectively, indicating acceptable convergent validity. Regarding the structural model, Green Supply Chain Management has a positive effect on Environmental Performance ($\beta = 0.573$), whereas Digital Transformation exhibits a negative effect ($\beta = -0.239$). These results indicate that stronger green supply chain practices are associated with improved environmental performance, while greater digital transformation is associated with lower environmental performance in the observed sample.

Table 2. Convergent validity and internal consistency reliability for reflective constructs

Construct	Item	Outer Loading	Cronbach's alpha	Rho_A	Rho_C	AVE
Digital Transformation	Employee Digital Training	0.691	0.525	0.657	0.794	0.663
	Digital Resource Availability	0.921				
Green Supply Chain	Environmental Costs	0.652	0.780	1.078	0.803	0.510
	Environmentally Friendly Materials	0.638				
	Employee Training Costs	0.677				
	Suppliers	0.865				
Environmental Performance	Water Consumption	0.595	0.526	0.584	0.745	0.500
	Energy Consumption	0.865				
	Waste Generated	0.632				

The measurement model in table 2 generally demonstrates acceptable convergent validity and internal consistency. Outer loadings range from 0.595 to 0.921, with several indicators below the preferred 0.70 threshold. Nevertheless, the AVE values for Digital Transformation (0.663), Green Supply Chain (0.510), and Environmental Performance (0.500) meet the minimum threshold of 0.50. Composite reliability (rho_C) values range from 0.745 to 0.803, indicating acceptable internal consistency. However, the relatively low Cronbach's alpha values for Digital Transformation (0.525) and Environmental Performance (0.526), as well as the rho_A value of 1.078 for Green Supply Chain, warrant cautious interpretation.

Table 3. Discriminant Validity: Heterotrait-Monotrait Ratio (HTMT)

	Environmental Performance	Green Supply Chain	Digital Transformation
Environmental Performance			
Green Supply Chain	0.580		
Digital Transformation	0.586	0.284	

The HTMT results in Table 3 confirm adequate discriminant validity among all constructs. The HTMT values range from 0.284 to 0.586, with Environmental Performance–Green Supply Chain at 0.580, Environmental Performance–Digital Transformation at 0.586, and Green Supply Chain–Digital Transformation at 0.284. All values are below the commonly applied threshold of 0.85, indicating that the three constructs are empirically distinct from one another. Therefore, the measurement model demonstrates satisfactory discriminant validity, supporting the use of these constructs in the subsequent structural model analysis.

These assessments are part of the measurement model (outer model) evaluation in PLS-SEM. Internal consistency reliability examines whether indicators consistently measure the same construct, while convergent validity assesses whether the indicators share sufficient variance in representing their underlying construct. Together, these tests establish the reliability and validity of the measurement model before proceeding to the structural model and hypothesis testing.

Table 4. Hypothesis Testing

Hypotheses	Std.Beta (β)	Std. Error	t-value	p-value	R ²	F ²	VIF	Decision
H1 Green Supply Chain → Environmental Performance	0.573	0.118	4.878	0	0.716	0.414	1.038	Supported

H2	Digital Transformation → Environmental Performance	-0.239	0.108	2.207	0.027	–	0.098	1.038	Not Supported
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Table 4 presents the results of the hypothesis testing examining the effects of green supply chain management and digital transformation on environmental performance. The results indicate that both hypothesized relationships are statistically significant at the 5% level. H1 is supported, as Green Supply Chain Management has a positive and significant effect on Environmental Performance ($\beta = 0.573$, $t = 4.878$, $p < 0.001$). The relatively large effect size ($f^2 = 0.414$) further indicates a substantial contribution of Green Supply Chain Management to Environmental Performance. In contrast, H2 is also supported but shows a negative relationship. Digital Transformation has a negative and significant effect on Environmental Performance ($\beta = -0.239$, $t = 2.207$, $p = 0.027$), with a relatively small effect size ($f^2 = 0.098$). The model explains 71.6% of the variance in Environmental Performance ($R^2 = 0.716$). Furthermore, VIF values of 1.038 for both predictors indicate no critical collinearity issues in the structural model.

4. Discussion

Green Supply Chain Management and Environmental Performance.

The findings demonstrate that Green Supply Chain Management (GSCM) has a positive and significant effect on Environmental Performance, supporting H1 ($\beta = 0.573$, $t = 4.878$, $p < 0.001$). This finding is consistent with the Natural Resource-Based View (NRBV), which suggests that firms can improve environmental outcomes by developing organizational capabilities that integrate environmental considerations into resource utilization and operational processes (Hart, 1995). In a supply chain context, such capabilities extend beyond internal environmental management to the coordination of suppliers, environmentally friendly materials, resource efficiency, and environmentally responsible operational practices. Previous evidence similarly indicates that GSCM practices can improve environmental performance by reducing waste, emissions, and resource use and by strengthening environmental coordination across supply chain partners (Al-Ghwayeen & Abdallah, 2018; Al-Sheyadi et al., 2019; Appiah & Odartey, 2021). More recent studies further support this relationship in manufacturing and emerging-market contexts, showing that environmentally oriented supply chain practices contribute to improved environmental outcomes (Mustafi et al., 2026; Odamtten et al., 2025). Therefore, the present finding reinforces the view that environmental performance is shaped not only by internal environmental initiatives but also by the extent to which environmental considerations are embedded throughout the supply chain.

Digital Transformation and Environmental Performance.

The findings reveal that Digital Transformation has a negative and significant effect on Environmental Performance ($\beta = -0.239$, $t = 2.207$, $p = 0.027$). This result indicates that greater digitalization does not automatically translate into improved environmental outcomes. From a Natural Resource-Based View perspective, digital resources generate environmental value only when they are effectively combined with environmentally oriented organizational capabilities, such as green innovation, pollution prevention, resource efficiency, and environmental management. Previous studies similarly suggest that the environmental benefits of digital transformation are often mediated by green technology innovation, organizational governance, and firms' ability to integrate digital technologies with sustainability objectives (Cardinali & De Giovanni, 2022; Xu et al., 2022). The negative relationship identified in this study may also be explained by the rebound effect, whereby efficiency gains from digital technologies are offset by increased energy demand, expanded production, greater use of digital infrastructure, and additional resource consumption. Thanh et al. (2023) show that increasing digitalization may generate higher energy consumption and environmental deterioration through such rebound mechanisms, while Cardinali and De Giovanni (2022) note that robotics, big data, and other capital-intensive digital technologies can increase overall energy demand. Moreover, prior studies indicate that the relationship between digitalization and environmental performance can be nonlinear and context-dependent rather than uniformly positive (Ahmadova et al., 2022). Accordingly, the present finding suggests a possible digital adoption–environmental integration disconnect, in which firms adopt digital technologies primarily

for productivity and operational objectives without sufficiently embedding environmental considerations into their digital transformation strategies.

This study extends the Natural Resource-Based View by showing that environmental capabilities can be embedded across supply chain activities rather than developed solely within firms. While GSCM strengthens environmental performance, digital transformation does not inherently generate environmental benefits. Its environmental value depends on the integration of digital resources with sustainability-oriented capabilities. The negative effect of digital transformation further highlights a potential digital adoption–environmental integration disconnects, suggesting that digitalization focused primarily on efficiency and competitiveness may produce limited or adverse environmental outcomes when environmental objectives are not sufficiently integrated into digital strategies.

The findings suggest that manufacturing firms should strengthen Green Supply Chain Management by integrating environmental considerations into supplier selection, material sourcing, environmental cost management, employee development, and supply chain collaboration. At the same time, digital transformation should not be treated as inherently sustainable. Digital investments should be aligned with environmental objectives, including energy efficiency, resource optimization, waste reduction, and environmental monitoring. Therefore, managers should integrate digital transformation and environmental management within a unified sustainability strategy, ensuring that digital technologies support both operational performance and environmental improvement.

5. Conclusion

This study examined the relationships between Green Supply Chain Management, Digital Transformation, and Environmental Performance among 49 manufacturing firms listed on the Indonesia Stock Exchange. The findings reveal different environmental outcomes for green and digital capabilities. GSCM is positively associated with Environmental Performance, indicating that capabilities that explicitly embed environmental objectives into supply chain activities can support better environmental outcomes. In contrast, DT is negatively associated with Environmental Performance. This finding suggests that digitalization does not inherently translate into environmental improvement. Digital initiatives may generate limited environmental value when firms prioritize operational efficiency and technological advancement without sufficiently integrating environmental objectives.

The study contributes to the NRBV by distinguishing environmentally oriented capabilities from general digital capabilities. The findings suggest that the environmental value of an organizational capability depends not only on the resources and technologies that firms possess but also on their strategic orientation toward environmental objectives. For managers, this distinction emphasizes the need to integrate digital investments with environmental monitoring, resource efficiency, waste reduction, and other sustainability priorities. Future research could employ longitudinal data to examine how green and digital capabilities evolve over time. Researchers could also investigate mechanisms such as green innovation, environmental management systems, or digital–environmental integration to explain when digital transformation generates positive environmental outcomes.

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