Journal of Digital Intelligence and Economic Growth
Website: https://www.jdieg.com
Vol. 1 No. 1, June 2024, 14-30

ISSN (Print): 3058-3535
ISSN (Online): 3058-6518
DOI: https://doi.org/10.63768/jdieg.v1i1.002

The Effects of Green Digital Transformation Leadership and Normative Pressures on Sustainability Development: Mediating Role of Green innovation

Yang Du, Qiang Wang*, Qianli Wu

Ph.D. Student, Dept. of Global Business, Kyonggi University, Suwon, South Korea

Abstract: Environmental issues have become a key factor in the sustainable development. The main objective of this study is to explore the relationship between internal green digital transformation leadership and external normative pressures on the organization's sustainable innovation and development. Both transformational leadership theory and stakeholder theory are adopted in the theoretical framework, the direct and mediated effect have been explored. A total of 250 respondents were collected. The empirical results confirm the positive relationship between green digital transformation leadership, green innovation and sustainable development. This result highlights that green digital transformation leadership can enable an organization's employees to proactively engage in environmentally friendly and energy efficient behaviors. This enables organizations to achieve sustainable development and green innovation. Second, the positive link between normative pressure, green innovation and sustainable development was confirmed. This result suggests that normative pressure can be considered as an external driver of organizational sustainability goals. Continued social concern for corporate environmental protection will motivate organizations to pursue green innovation and sustainable development. Finally, linking internal and external factors to sustainable development through the mediating role of green innovation. The research findings provide recommendations for entrepreneurs to formulate organizations strategies and have practical significance for organizations to comply with the UN Sustainable Development Goals.

Keywords: Green Digital Transformation Leadership; Normative Pressures; Green innovation; Sustainable development

* Corresponding author: (First author) YangDu (379206959@qq.com), (Corresponding author) Qiang Wang (qiang621@126.com)
Received 30 April 2024, Revised 30 May 2024, Accepted 20 June 2024

1. Introduction

Nowadays, people concern about the environmental problems that has been caused by economic development (Ahmad and Wu, 2022). Therefore, according to a recent report by the UN Environment Programme, organizations ought to implement actions. If organizations do not operate in conformity with sustainable development practices, it will cause serious impact on climate. Consequently, it is imperative for organizations to adopt mutual strategies to harmonize their organizations with the Sustainable Development Goals (SDGs)(Zameer and Yasmeen, 2022).

However, Traditional business models have organizations maximizing profits by producing and selling products or services. Therefore, Traditional business models and technologies are inadequate for achieving the Sustainable Development Goals (SDGs). Organizations should choose sustainable initiatives and adopt green technologies to mitigate the negative impacts of their operations on the environment and improve their long-term viability (Xie et al., 2022).

Energy demand in developing countries is growing rapidly (Cui et al., 2023). Increased prosperity and improved living conditions have led to an increase in per capita energy use. Some countries began to publish policies to contribute to sustainability. For example, Chinese government's plan to be achieve carbon neutrality by 2060 and has led to higher demands from the government for manufacturing organizations of innovation and sustainable development (Hu et al., 2024).

Amid increasing environmental degradation, green innovation has become crucial for organizational growth (Song et al., 2022). As a result, organizations are proactively pursuing green innovation to lessen their environmental impact (Li et al., 2020). The external factors of green innovation mainly include the increasing environmental awareness of the consumers, as well as the attention and exposure of news media and non-governmental organizations (Li, 2014). Additionally, internal factors within the organization also influence its ability to innovate sustainably (Habib et al., 2019). Therefore, the competence of organizational leaders, along with particular internal resources, is crucial for developing innovative and eco-friendly strategic responses(Khan et al., 2021). Specific internal resources can encompass a variety of assets, both tangible and intangible, that leaders can leverage to drive environmental and innovative initiatives.

In reaction to the rise of environmental challenges, the concept of Green Digital Transformation Leadership (GDTL) has gained prominence. This concept underscores the necessity for leaders to not only prioritize eco-friendly projects but also to boost the technological preparedness of their teams, foster creativity, and facilitate collaboration. Such leadership is pivotal for orchestrating a sustained green digital transformation within organizations through effective coordination (Hanif et al., 2023). At the heart of the Green Digital Transformation Leadership (GDTL) approach is the goal to inspire employees to embrace eco-conscious behaviors and promote sustainability within their professional roles (Niazi et al., 2023). This approach to leadership is defined by its focus on sustainability, teamwork, innovation, and continuous improvement (Awan et al., 2023). In today's era, driven by both digital advancements and sustainability, the integration of leadership and sustainable practices has become a focal point in scholarly discussions.

For external factors, discussion centers on the concept of normative pressures (NP), which represent the societal expectations that businesses are expected to follow in terms of beliefs, values, and norms (Schaefer, 2007). Such pressures typically originate from influential non-governmental organizations, industry associations, academic entities, customers, and supply chain participants (Liu et al., 2010). It is crucial for organizations to acknowledge and comply with NP, as they align with the standards and norms set by their stakeholders, thereby influencing the legitimacy and reputation of the business (Eriksson and Svensson, 2016).

Pacheco et al. (2018) explored how both external and internal factors impact the financial performance of organizations. While Fan et al. (2023) considered sustainable development as a variable in their study, they did not explore the effects of green digital leadership on sustainable development. Nonetheless, there remains a scarcity of research concerning how external and internal factors affect an organization's sustainable development and its performance in green innovation. Drawing on Freeman (1984) stakeholder theory and Bass and Avolio (1993) transformational leadership theory, this study fills a significant gap in the current literature by examining the impact of both external and internal factors on an organization's sustainable development.

It also highlights how these factors contribute to promoting green innovation within the organization.

The conclusion drawn from these research inquiries contributes by bridging the transformational leadership theory and stakeholder theory. In the face of progressively serious environmental problems, organizations can improve their sustainable development and green innovation through green digital transformation leadership and the pressure of social supervision. Green innovation can play a pivotal role in enhancing sustainable development performance. It can provide theoretical support for organization managers to formulate organizations development strategies. Additionally, the case of China can provide a reference for other developing countries in Asia.

The remainder of this study is structured as follows: The second part, which reviews the existing literature, including conceptual models and research hypotheses, is presented. Methodology is discussed in section three, and the results are presented in the fourth section. A discussion stemming from these results is organized in section five, where the theoretical and practical contributions of this study are highlighted. The entire discussion is summarized in the final section, its limitations are appropriately highlighted, and some avenues for future research are suggested.

2. Theoretical and literature foundation

2.1 Stakeholders Theory and Transformational Leadership Theory

Freeman (1984) pioneered stakeholder theory in 1984, advocating that organizations should extend their focus beyond mere economic expansion to include their responsibilities towards stakeholders. Boulhaga et al. (2023) further articulate that stakeholders determine the degree to which their perspectives are integrated into organizational decision-making processes. Organizations interact with a variety of stakeholders, encompassing employees, customers, governmental bodies, and non-governmental organizations.

Transformational Leadership (TL) theory, as delineated by Bass and Avolio in 1993, characterizes transformational leadership as a managerial philosophy that inspires employees to innovate and thereby expand and enhance organizational success (Afsar and Umrani, 2020). Its primary aim is to develop a clear vision, effectively communicating it to followers and aligning their goals and values with this vision is essential (Odugbesan et al., 2023). Key components of this leadership style encompass intellectual stimulation, idealized influence, individualized consideration and inspirational motivation(Bass, 1985).Bass and Avolio (1993) emphasized transformational leaders drive cultural change by comprehending the existing organizational culture, guiding it toward a new vision, and reassessing shared norms, values and assumptions. In the context of Industry 4.0, digital leadership is indispensable for ensuring and facilitating transformation and change (Moeuf et al., 2018). Leadership significantly impacts the sustainability of innovation management, as evidenced by prior research (Schoemaker et al., 2018). Specifically, digital leadership plays a vital role in influencing innovation outcomes (Erhan et al., 2022). It represents a fusion of transformational leadership practices and the utilization of digital technology (Wang et al., 2022). Green Digital Transformation Leadership (GDTL) merges transformational leadership with green and digital strategies, focusing on motivating employees towards activities that support long-term environmental sustainability (Piwowar-Sulej and Iqbal, 2023).

Green Digital Transformation Leadership (GDTL) serves as a leadership paradigm focused on nurturing environmentally and sustainable aware organizational cultures (Susanto and Sawitri, 2022). This approach transcends traditional leadership models by prioritizing not only organizational objectives but also the crucial role of environmental stewardship (Majali et al., 2022). Moreover, it engages employees proactively in green initiatives and enables avenues for experimenting with green product innovation (Chen and Chang, 2013). This leadership approach is dedicated to conserving the natural environment by motivating team members to adjust their values, attitudes and actions in support of environmental sustainability, with the ultimate goal of fostering a greener and more sustainable organization.

2.2 Literature Review and Hypotheses Development

2.2.1 Green innovation

Green innovation is designed to minimize pollution by creating products that conserve resources. Employ clean energy

sources and minimize waste emissions. As well as by refining service processes and methods (Wu et al., 2020). As environmental considerations increasingly become critical for corporate sustainability, many organizations are actively pursuing green innovation to diminish their environmental impact and gain a competitive advantage (Takalo and Tooranloo, 2021). Yuan and Cao (2022) define green innovation as including green product innovation, green service innovation, and green process innovation. Specifically, Green product and service innovations focus on creating new offerings that consider environmental factors to reduce the effects of pollution and resource depletion. Green process innovation aims to decrease resource waste and enhance environmental efficiency by incorporating environmental concerns and green technologies into existing processes. Numerous researchers contend that adopting green innovation can alleviate the adverse environmental and resource impacts of organizational activities while promoting sustainability through the development and implementation of innovative products, services, and processes (Kong et al., 2020).

With the implementation of green innovation, organizations possess the capability to diminish or completely eradicate the harmful effects of their operations on the environment. Cai and Li (2018) emphasized the significance of an organization's technological prowess in crafting products that are energy-efficient and have minimal pollution emissions. According to Takalo and Tooranloo (2021), green innovation not only improves manufacturing processes but also reduces the utilization of natural resources and the generation of waste. Such enhancements not only curtail environmentally damaging practices but also yield economic benefits for the organization. Furthermore, Wu et al. (2022) found that organizations pioneering green innovation often gain competitive edges, such as bolstered customer loyalty, enhanced reputation, and augmented profitability. Consequently, organizations should invest in green manufacturing processes, sustainable procurement policies, eco-friendly information systems, and eco-design principles. These investments can reduce environmental impact, improve operational efficiency, and create new business opportunities.

2.2.2 Sustainable development

The concept of sustainable development performance encompasses the holistic progress across the three dimensions of sustainability—economic, social, and environmental—which are commonly known as the triple bottom line. Elkington (2018) advocates that a balanced performance across these three sustainability dimensions is essential for achieving sustainable development. Wang et al. (2021) advocates that given the pressing environmental issues, sustainable development is increasingly vital for the long-term viability and competitive edge of organizations. Parmentola et al. (2022) detail how green practices, including green manufacturing, green procurement, green information systems and eco-design, positively influence corporate sustainable development. Furthermore, Sharif et al. (2023) have noted that green innovation plays a vital role in mitigating the negative impacts of business activities on environmental sustainability.

Organizations should develop and implement an integrated sustainability strategy that addresses economic, social, and environmental dimensions. This strategy should be aligned with the company's overall vision and operational goals, ensuring that sustainability is embedded in the core business practices.

2.2.3 GDTL

Organizational strength is an internally generated activity that encompasses various internal factors including business resources, stakeholders, the environmental awareness of managers and employees, organizational culture, internal capabilities and business strategy (Pan et al., 2022). Digital leadership plays an indispensable role in facilitating green innovation within organizations (Ly, 2024). Contemporary studies, exemplified by the research of Aftab et al. (2023) and Odugbesan et al. (2023), underscore the favorable influence of green and digital leadership on organizational effectiveness in various contexts. (Wang et al., 2022) have pointed out that Green Digital Transformation Leadership (GDTL) is instrumental in propelling digital development, thereby enhancing overall organizational progress, boosting performance, and contributing to financial success. Furthermore, Yuan and Li (2023) contend that GDTL is among the most effective approaches for enhancing organizational performance. Encouraging a culture of innovation focused on sustainability can lead to the development of new products and services that meet the needs of a more environmentally conscious market. Organizations should support research and development in green technologies and create an environment that encourages creative solutions to sustainability challenges.

Moreover, Hojnik and Ruzzier (2016) suggest that the correlation between Green Digital Transformation Leadership (GDTL) and the trajectory of green innovation trends positively correlates with organizational management's ability to leverage employees' awareness and skills to promote the adoption and use of eco-friendly resources for innovation. Zhao and Huang (2022) effectively highlight the pivotal role of effective leadership in attaining digital and sustainability goals by fostering synergies between green and digital initiatives within organizations. Consequently, building on the discussions above, this study posits the following hypotheses. Andersén et al. (2020) have recognized green product innovation as a sustainable environmental practice for organizations.

As sustainability gains traction within the business landscape, a variety of green innovation activities have begun to proliferate in the market. The greater the level of uncertainty or disruption in the business environment, the more likely it is that organizations will mimic the practices of industry leaders to mitigate decision-making risks. Consequently, organizations might voluntarily adopt the strategies of pioneering organizations. Notably, green innovation uncertainty refers to the reluc tance of organizations to embrace green innovation, despite its potential benefits for competitive advantage (Zhu et al., 2016). As the adoption of green innovation practices becomes more widespread, it encourages the development of green innovation networks. These networks can reduce the risk associated and uncertainty with green innovation, whereas organizations that fail to ado pt green innovation may face increased entry barriers and diminished competitiveness (Zhang et al., 2022).

The existing body of literature widely recognizes the crucial significance of green innovation in improving corporate performance. This enhancement comes through satisfying stakeholders' environmental needs, boosting efficiency, and cutting costs (Wen et al., 2023). Green innovation aids organizations in refining their products and internal processes, enhancing efficiency, and reducing operational costs, which in turn improves economic outcomes (Zhang and Ma, 2021). Additionally, Grewatsch and Kleindienst (2017) found that corporate practices in environmental innovation have a beneficial effect on financial performance. Nonetheless, some research indicates that green innovation initiatives may lead to short-term cost increases that adversely impact a firm's economic results(Xie et al., 2022). Similarly, Aibar-Guzmán et al. (2023) suggest that although green innovations may yield competitive advantages in the long run, the initial investments and associated costs could impede short-term profitability.

Moreover, organizations increasingly acknowledge the importance of green innovations in processes and products as substantial contributors to sustainable development (Rehman et al., 2021). Zailani et al. (2014) organizations actively engage in green innovation, they not only enhance their social performance by meeting stakeholder expectations but also set benchmarks in environmental responsibility. This involvement promotes sustainable practices and enhances the organization's positive image in the public eye, offering a competitive edge in a demanding market. In doing so, organizations not only respond to market and societal calls but also contribute value to society through innovative solutions. Inigo et al. (2017) o bserve a changing landscape in consumer preferences, with a rising inclination to invest more in environmentally friendly products that improve environmental performance, as well as in process innovations that minimize energy consumption, waste generation, and pollution.

Furthermore, Green innovation compels organizations to develop eco-friendly products, boost environmental sustainability, and enhance their environmental performance by maximizing resource efficiency. This proactive approach to innovation allows companies to not only adhere to environmental regulations but also exceed them, resulting in significant benefits such as reduced waste, lower energy consumption, and minimized ecological footprint. By integrating these sustainable practices, organizations can achieve greater operational efficiencies and foster a stronger reputation for corporate responsibility. (Shahzad et al., 2020). Fernando et al. (2019) contend that green innovation drives the advancement of organizational processes and production technologies aimed at minimizing environmental impacts, mitigating pollution, and contributing to sustainable development. By prioritizing eco-friendly practices and technologies, organizations can overhaul traditional production methods to reduce waste, conserve natural resources, and decrease pollution levels. This commitment not only aligns with global sustainability goals but also enhances the long-term viability of the organization, setting a standard for industry practices and fostering a culture of environmental stewardship. Chen et al. (2006) research suggests that integrating green innovation

with corporate environmental management strategies can reduce production waste and improve environmental performance (Ahmed et al., 2023). Drawing from these insights, this study posits the following hypotheses.

H1. Green digital transformational leadership will have a positive (+) effect on sustainable development

H2. Green digital transformational leadership will have positive(+) effect on green innovation

H3: Green innovation will have a positive (+) effect on sustainable development.

2.2.4 Normative Pressures

Normative pressures are external factors stemming from the institutional environment, including the influences of both distant and immediate external stakeholders. Song et al. (2020) contend that stakeholder theory suggests that organizations incorporate stakeholder needs into their strategic decision-making processes. Adomako and Tran (2022) assert that corporate regulations often react positively to external pressures, leading businesses to adapt their models and practices to align with socially accepted standards. Furthermore, stringent environmental regulations can yield long-term benefits for corporate sustainable development, driving organizations toward sustainability (Li et al., 2020). Influenced by policies such as mandatory sustainability reporting and integrated reporting, organizations are compelled to annually document their operations, thereby promoting adherence to sustainable development practices (Hamad et al., 2020).

Normative pressures arise from the collective expectations, values, and standards prevalent within an organizational context (Kostova et al., 2008). These pressures, influenced by social norms and stakeholder expectations, compel organizations to adhere to environmental regulations and pursue green innovations to meet environmental mandates (Krell et al., 2016). Moreover, user behavior and the growing demand for ecological conservation necessitate organizations' adoption of green technologies and sustainable practices (Barth et al., 2021). Consequently, organizations not only enhance their environmental sustainability but also bolster their corporate reputation (Yadav et al., 2022). Market demand is often cited as a primary motivator for organizations to engage in green innovation (Huang and Chen, 2022). As public awareness of environmental protection intensifies, the market environment places increased responsibility on organizations regarding environmental stewardship (Wang et al., 2021). In light of technological advancements, it is crucial for organizations to formulate action plans for green innovation that respond to stakeholder and market pressures (Asadi et al., 2020). Multiple research findings suggest that alterations in external factors, including policies, competitive dynamics, and consumer preferences, exert a substantial impact on organizational strategies and operations (Hanim Mohamad Zailani et al., 2012; Zhang et al., 2022), as organizations strive to secure stakeholder support and enhance their effectiveness. These external factors within the institutional environment are pivotal in shaping the sustainable development trajectories of many businesses. Additionally, influenced by the external pressures of normative pressures, organizations are motivated to engage in green innovation (Adomako and Tran, 2022). Thus, drawing from the aforementioned discussion, this study posits the subsequent hypotheses.

H4: Normative pressures will have a positive (+) effect on sustainable development.

H5: Normative pressures will have a positive (+) effect on green innovation.

2.2.5 Mediation of Green innovation

Mughal et al. (2022) delved into the interplay among technological innovation, environmental pollution, and sustainable economic growth in South Asian nations, underlining how technological advancements and their commercialization markedly contribute to mitigating pollution and fostering environmentally sustainable economic expansion. Scrutinized green technology in China from the perspective of environmental performance, finding that the impacts of eco-friendly technology advancements on CO2 emissions vary across time periods and city classifications (Lin and Ma, 2022). They also observed that the integration of green technologies indirectly reduces CO2 emissions by enhancing industrial structure. Additionally, the decline in carbon emissions attributed to green innovation is most notable in regions with a high concentration of skilled labor. This study argues that both internal and external factors play pivotal roles in nurturing green innovation. Moreover, it stresses the necessity of investigating green innovation and its role in sustainable development, asserting that conventional practices and technologies alone cannot meet sustainable development objectives. Nonetheless, the adoption of green innovation by select organizations can substantially propel China's sustainable development agenda. Hence, based on the foregoing discussion, this study posits

the ensuing hypotheses. (Figure 1)

H6: Green innovation will positively mediate the relationship between green digital transformational leadership and sustainability development.

H7: Green innovation will positively mediate the association between normative pressures and sustainability development.

The conceptual model is presented in Figure 1.

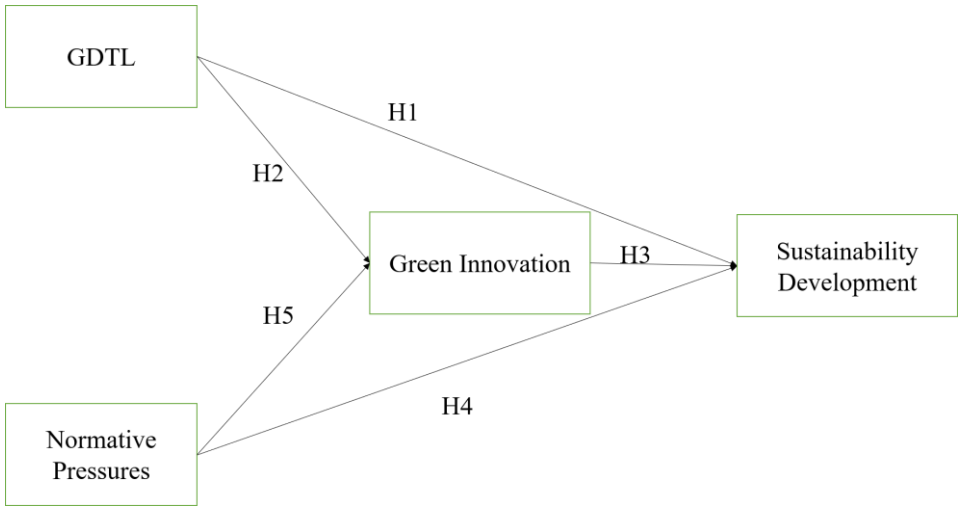

Figure 1. Conceptual model

3. Research method

3.1 Measures and validation

The questionnaire was made available for the respondents to self-administer by means of an online platform (Questionstar). Measurement items in the questionnaire in this paper were standardized on a Likert 7-point scale. Where "1=total disagreement /total non-compliance" and "7 =total agreement / full compliance.

The measurement consisted of two distinct sections. The first section included items related to Green Digital Transformation Leadership (GDTL) (Chen and Chang, 2013) and normative pressures(Christmann, 2004; Li, 2014; Massoud et al., 2010). The second section addressed items associated with green innovation(Engau and Hoffmann, 2009; Hartl and Kort, 1997; Phillips, 2017) and sustainable development (Bansal, 2005; Turker, 2009). After the collection process, questionnaires that were redundantly collected from the same company were discarded.

The questionnaires collected from the same company were removed after the questionnaires were collected. (Appendix 1)

3.2 Sample and procedure

The target population of the study is agricultural, electronic communication, pharmaceutical, automotive, textile and other manufacturing organizations in East China. The questionnaires were collected through the university alumni association method and 335 responses were collected, some of which were filled out for a short period of time and the options were exactly the same after deleting the questionnaires, the remaining valid questionnaires were 250, The respondents' demographic data is presented in Table 1. The sample size was determined following the guidelines provided by Barclay et al. (1995), suggesting that the sample size for PLS path model regression should be a minimum of ten times the number of variables.

The initial phase involves conducting descriptive statistics, followed by the computation of a measurement model to assess validity and reliability. Subsequently, the structural model is tested to ascertain its suitability for hypothesis testing. The subsequent section details the comprehensive range of analyses and novel discoveries unearthed in this study.

Table 1 Demographic information.

Particulars	Description	Values	%
Gender	Male	128	51.2
	Female	122	48.8
Job Experience	0-2 Years	40	16.0
	3-5 Years	118	47.2
	6-9 Years	76	30.4
	More than 10 Years	16	6.4
Job Title	Top Manager	19	7.6
	1st Line Manager	30	12.0
	2nd Line Manager	64	25.6
	3rd Line Manager	59	23.6
	Non-Managerial	78	31.2
Firm age	0-9 Years	72	28.8
	10-19 Years	124	49.6
	More than 20 Years	54	21.6
Firm sales (CNY)	0-5 million	40	16.0
	5 million-50 million	101	40.4
	50 million-400 million	67	26.8
	More than 400 million	42	16.8
Firm type	Agriculture	16	6.4
	Logistics	30	12.0
	Electrical	62	24.8
	Energy	33	13.2
	Semiconductor	45	18.0
	Biopharmaceutical	28	11.2
	Textile	27	10.8
	Miscellaneous Firms	9	3.6

4. Data analysis and results

Evaluate the reliability and validity of the measurement model to ensure that all structures are appropriately measured by the indicators. The results showed that the factor loading values were all 0.7 or higher in the sample. Assessing structural reliability using Cronbach's alpha and composite reliability tests. All calculations show good reliability as all values for each are above 0.7 (Alyoubi et al., 2018). The average variance extracted (AVE) was found to be 0.5 or higher, so it was judged that there was no problem with internal consistency. The results of the validity and reliability analyses are shown in Table 2.

Table 2 Results of reliability and validity

Construct	Item	Loadings	VIF	Cronbach's alpha	CA	CR	AVE
Green Digital Transformational Leadership(GDTL)				0.778	0.787	0.857	0.600
	GDTL1	0.771	1.565				
	GDTL2	0.727	1.531				
	GDTL3	0.828	2.130				
	GDTL4	0.769	1.973				
Normative Pressures(NP)				0.894	0.894	0.925	0.756
	NP1	0.871	2.392				
	NP2	0.854	2.250				
	NP3	0.868	2.588				
	NP4	0.884	2.706				
Green innovation(GI)				0.844	0.850	0.889	0.616
	GI1	0.744	1.608				
	GI2	0.779	1.790				
	GI3	0.757	1.698				
	GI4	0.798	1.956				
	GI5	0.843	2.148				
Sustainability Development (SD)				0.828	0.831	0.879	0.592
	SD1	0.807	1.837				
	SD2	0.739	1.555				
	SD3	0.710	1.472				
	SD4	0.792	2.044				
	SD5	0.796	2.044				

The discriminant validity was verified by whether the square root value of the AVE shown on the diagonal axis was greater than the value of the correlation coefficient between the other constituent concepts. This method of evaluating discriminant validity is also known as the Fornell and Larcker method (Fornell and Larcker, 1981). Discriminant validity is not a problem according to the Fornell and Larcker (1981) criterion because the minimum value in the sample (0.770) is higher than the maximum value of the correlation coefficient (0.740) (Zaiţ et al., 2011). The results of the Discriminant validity are shown in Table 3. Discriminant validity was also determined by heterotrait-monotrait ratio (HTMT) values. Sufficient discriminant

validity can be seen in Table 4, All HTMT values are less than 0.9 (Franke and Sarstedt, 2019 ; Rasoolimanesh 2022). A model fitness SRMR of less than 0.10 (Hu and Bentler, 1999) is considered a model is suitable for path analysis. Model Fit results are shown in Table 5.

Table 3 Discriminant validity (Fornell-Larcker criterion)

	GDTL	GI	NP	SD
GDTL	0.775			
GI	0.410	0.785		
NP	0.310	0.526	0.869	
SD	0.542	0.740	0.683	0.770

Table 4 Discriminant validity (HTMT)

	GDTL	GI	NP	SD
GDTL				
GI	0.495			
NP	0.366	0.601		
SD	0.672	0.862	0.795	

Table5 Model Fit

	Saturated model	Estimated model
SRMR	0.087	0.087
d_ULS	1.281	1.281
d_G	0.525	0.525
NFI	0.730	0.730

Structural models depict causal links between potential relationships, also known as internal models (Hult et al., 2018). The model was first analyzed using a coefficient of determination (R^2) representing the predictive accuracy of the model. The results show that the adjusted R2 values for green innovation and sustainable development are 0.339 and 0.712. As per the requirement, R^2 values of 0.75, 0.50 and 0.25 were obtained which can be considered as significant, moderate and weak respectively (Henseler et al., 2009). The model is then evaluated using a more conservative and robust technique (Stone-Geisser (Q^2). The Q^2 values for green innovation and sustainability development are 0.204 and 0.409, which are higher than 0 after performing the blindfolding procedures. Demonstrates that the predictive power of the model has been fully certified (Edeh et al., 2023）. Thus, the predicted relevance of the model for endogenous constructs is of high quality (Hult et al., 2018). The researchers then calculated the effect size of their findings(F^2). By using the F^2 statistic, it is possible to quantify how much influence potential constructs have on endogenous constructs. where the F^2 results all lie within the small, medium, and large threshold ranges of 0.02, 0.15, and 0.35 (Cohen，2013).

Table6 f-square

	f-square		f-square
GDTL→SD	0.172	NP→SD	0.350
GDTL→GI	0.103	NP→GI	0.268
GI→SD	0.454		

Structural relationships were tested at the 0.05 significance level by running a nonparametric bootstrap ping technique. This technique allows for the generation of 5000 subsamples from the original sample size by replacement, which also produces an approximate t-value structured path for testing significance. If the t-value exceeds 1.96, the pathway is considered significant at the significance level of 0.05. From the results of the structural equation modeling of the sample in Table 7, the relationships between green digital transformation leadership ($\beta = 0.273$, $p < 0.001$) and green innovation, green digital transformation leadership ($\beta = 0.244$, $p < 0.001$) and sustainability development, as well as normative pressure ($\beta = 0.373$, $p < 0.001$) and sustainability development, normative pressure ($\beta = 0.441$, $p < 0.001$) green innovation, and green innovation ($\beta = 0.443$, $p < 0.001$) sustainable development are all statistically significant. Therefore, hypotheses 1, 2, 3, 4, and 5 are supported.

Table7 Hypothesis testing

Hypothesis	Constructs	Coefficient	Sample Mean	Standard Deviation	t-value	p-value	Decision
H1	GDTL→SD	0.244	0.244	0.045	5.424	0.000***	Supported
H2	GDTL→GI	0.273	0.269	0.069	3.945	0.000***	Supported
H3	GI→SD	0.443	0.442	0.047	9.356	0.000***	Supported
H4	NP→SD	0.373	0.376	0.051	7.335	0.000***	Supported
H5	NP→GI	0.441	0.447	0.067	6.584	0.000***	Supported

Notes: ***p<0.001, **p<0.01, *p<0.05

Based on studies by Preacher and Hayes (2008) and Zhao et al. (2010) this paper analyzed the mediating effects through a nonparametric bootstrapping approach, testing the significance of the proposed indirect effects. The percentile bootstrap and deflection correction bootstrap were calculated using 5000 re-samples to test specific indirect effects. Results showed that the mediation was significant (p-value < 0.05).

According to the results in Table 8, the mediating outcome of green innovation ($\beta = 0.121$, $t = 3.444$, $p = 0.001$). Therefore, the results support the mediation hypothesis (H6), suggesting that green innovation partially mediates the positive effects o f green digital transformation leadership on sustainability development.

For normative pressures and sustainability development, intervened by green innovation ($\beta = 0.196$, $t = 5.531$, $p = 0.000$). The results similarly support the mediation hypothesis (H7), suggesting that green innovation partially mediates the positive effects of normative pressures on sustainability development.

Table8 Testing the mediation effects

Hypothesis	Constructs	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	t-Value	p-Value	Mediation
H6	GDTL→ GI →SD	0.121	0.119	0.035	3.477	0.001***	Partial mediation
H7	NP→ GI → SD	0.196	0.197	0.035	5.531	0.000***	Partial mediation

Notes: ***p<0.001, **p<0.01, *p<0.05

5. Conclusion

5.1 Discussion of Results

This study analyzes the impact of internal green digital transformation leadership, external normative pressure, and green innovation on sustainable development in enterprises located in Eastern China. By introducing green digital transformation leadership as a prerequisite for corporate sustainable development, this research contributes to the existing literature on corporate leadership. Additionally, the study explores the effects of normative pressure and green innovation on sustainable development. Green innovation serves as a mediating variable, partially influencing the impact of green digital transformation leadership and normative pressure on sustainable development. The results provide theoretical and empirical support for the association between green digital transformation leadership and sustainable development in manufacturing enterprises in Eastern China.

The study finds that GDTL has a positive impact on the SD of manufacturing enterprises in Eastern China. This implies that during business operations, leaders must prioritize integrating digital principles with environmentally conscious operational concepts, thereby disseminating the idea of green digital transformation within the organization (Yang et al., 2024). Effective propagation of this concept through operational practices can promote the integration of GDTL with GI and SD (Niu et al., 2022).

GDTL will consequently foster GI across various industries (Tian et al., 2023). Additionally, when senior leaders integrate green digital transformation into corporate culture, employees respond positively. Over time, this leads to the formation of corresponding values and concepts within the company, which are practiced in daily activities. This cultural atmosphere will have a long-term impact on corporate strategy formulation and employees' daily work. Companies will proactively explore green innovative products or services during this process, laying a solid foundation for SD (Sun et al., 2022).

GDTL through the integration of digital technology and green management, not only optimizes resource utilization efficiency but also reduces environmental pollution and energy consumption, thereby enhancing environmental performance and economic benefits. Leaders need to advocate for green digital thinking within the organization, promote cross-departmental collaboration, and enhance employees' environmental awareness and skills. Additionally, establishing a comprehensive green digital transformation management system and incentive mechanisms can stimulate employees' innovation drive and promote the research and application of green technologies. Regular training and awareness activities should strengthen employees' understanding and acceptance of green digital transformation, thereby achieving full participation and jointly advancing SD. Hence, GDTL is not only a key driver for achieving SD but also a crucial force for promoting industrial upgrading and socio-

economic green transformation. Through leadership demonstration and active participation of all employees, organizations can gain a competitive advantage in the market, achieve the goal of integrating green and digital development, and ultimately contribute to global SD.

Besides internal factors, customer demands and perceptions, as well as broader social and community expectations, significantly influence organizations' adoption of environmental innovation for sustainable development. Increased environmental awareness encourage organizations to adopt eco-friendly policies or implement sustainable development initiatives. The primary purpose of adjusting environmental strategies is to meet the demands of external stakeholders (Zhang and Zhu, 2019). These observations confirm the principles of stakeholder theory, which suggest that stakeholders not only are affected by organizational actions but also exert significant influence on organizational operations.

NP and GI can fundamentally promote SD when organizations engage in environmental innovation. This highlights that GI does not merely increase operational costs; on the contrary, it helps improve organizational sustainable performance. organizations' cautious approach towards the green market means that translating customer demands into green innovation practices takes time. However, the driving role of both formal and informal institutions in GI practices indicates that more Chinese organizations are realizing the importance of social reputation and green image and are willing to seek government and public recognition through environmental protection practices (Chen and Liang, 2023).

The study results suggest that NP drives companies to adopt GI and SD strategies. Enhanced environmental awareness and government regulations make eco-friendly policies a key factor in organizations operations. More organizations realize that GI not only enhances their social reputation and green image but also improves their sustainable performance and market competitiveness. During this process, organizations not only meet external stakeholders' demands but also lay a foundation for their long-term SD through GI.

GI is crucial for enhancing an organization's ability to achieve SD goals. GI significantly increases the potential for organizations to achieve SD goals (Abbas and Sağsan, 2019). Relying solely on traditional operational methods and technologies is insufficient to achieve these goals (SDGs). To align with the United Nations' climate change targets and ensure economic prosperity, organizations must incorporate green technologies into their strategic plans. Thus, GI is not only a key factor in enhancing organizations SD capacity but also a vital strategy for addressing global climate change challenges. Simultaneously, GI can boost organizations' market competitiveness, improve resource utilization efficiency, and reduce environmental impact. This transformation helps achieve the United Nations' climate change targets and promotes long-term economic prosperity and comprehensive social progress. By incorporating green technologies into strategic plans, organizations can better address environmental challenges, meet stakeholder expectations, and promote SD while achieving economic benefits.

In terms of mediating effects, GI demonstrates a positive partial mediating effect across all samples. This indicates that GDTL and NP can enhance organizational sustainable development capacity through GI. The findings align with (Iqbal, 2020), emphasizing that strengthening GI is crucial for achieving SD. Specifically, the research suggests that organizations can implement GI through GDTL, proactively responding to the evolving business environment to improve SD. The higher the level of GDTL, the stronger the organization's informed decision-making ability, enabling more effective development and implementation of green innovation strategies and products that contribute to SD. Additionally, organizations engaging in GI may increase R&D investment, enhance product delivery, and improve customer service innovation, ultimately creating significant value for customers. GI strengthens the impact of GDTL on organizational SD. It also plays a crucial mediating role in the process between NP and SD.

5.2 Research Significance

The findings of this study highlight the significant positive effects of both internal and external factors on sustainable development and green innovation. The conceptual framework aligns with the principles of stakeholder theory and transformational leadership theory.

The research reveals that external factors, such as consumer awareness and societal concerns, play a pivotal role in motivating organizations to embrace green innovation in their pursuit of sustainable development. Higher levels of awareness regarding green digital transformation among organizational leaders correlate with more effective sustainability strategy implementation, an increased propensity for adopting green innovation, and heightened organizational sustainable development. The critical role of both internal leadership and external stakeholder pressure in driving green innovation and sustainable development. By embracing digital transformation and integrating innovative management practices, organizations can not only improve their environmental performance but also achieve significant economic benefits. This dual focus on sustainability and innovation is essential for meeting the evolving demands of stakeholders and ensuring long-term organizational success.

The results of this study have practical implications. The imperative for managers to embrace the digital technologies emerging from Industry 4.0 and recognize their role in environmental stewardship. This entails integrating novel management approaches into the organizational leadership culture. Concurrently, businesses are urged to actively pursue green innovation, given its demonstrated positive impact on sustainable development, including the financial performance of organizations. Customers and society are acutely attuned to organizations' contributions to environmental conservation, exerting significant external pressure for increased investment in green innovation for sustainable development initiatives. This external pressure underscores the importance of aligning business strategies with environmental goals to meet stakeholder expectations and enhance overall sustainability performance.

5.3 Limitations of the Study

This study has pinpointed several limitations that necessitate consideration in future research endeavors. Firstly, the data for this investigation were obtained solely from one country. To enhance the applicability and generalizability of the findings, future studies could broaden their scope by integrating control groups from diverse regions. This should include developed nations such as Germany, Japan, and Korea, as well as developing countries like India and Vietnam. Expanding the geographical scope of the research will provide a more comprehensive understanding of the factors influencing green innovation and sustainable development across different economic contexts.

Secondly, the data collection process exclusively targeted manufacturing organizations. To achieve a more holistic analysis, subsequent research initiatives should strive to encompass a broader spectrum of sectors, including trading organizations, service providers, and other industries. This expansion will enrich the study's breadth and depth, offering insights into how different types of organizations approach green innovation and sustainability.

References

Abbas J, Sağsan M (2019). Impact of knowledge management practices on green innovation and corporate sustainable development: a structural analysis. J Clean Prod 229:611-620. https://doi.org/10.1016/j.jclepro.2019.05.024.

Adomako S, Tran MD (2022). Environmental collaboration, responsible innovation, and firm performance: the moderating role of stakeholder pressure. Bus Strategy Environ 31(4):1695-1704.

Afsar B, Umrani WA (2020). Transformational leadership and innovative work behavior: the role of motivation to learn, task complexity and innovation climate. Eur J Innov Manag 23(3):402-428.

Aftab J, Abid N, Cucari N, Savastano M (2023). Green human resource management and environmental performance: the role of green innovation and environmental strategy in a developing country. Bus Strategy Environ 32(4):1782-1798.

Ahmad M, Wu Y (2022). Combined role of green productivity growth, economic globalization, and eco-innovation in achieving ecological sustainability for OECD economies. J Environ Manage 302:113980. https://doi.org/10.1016/j.jenvman.2021.113980.

Ahmed RR, Akbar W, Aijaz M, Channar ZA, Ahmed F, Parmar V (2023). The role of green innovation on environmental and organizational performance: Moderation of human resource practices and management commitment. Heliyon 9(1):e12679. https://doi.org/10.1016/j.heliyon.2022.e12679.

Aibar-Guzmán B, Aibar-Guzmán C, Piñeiro-Chousa J, Hussain N, García-Sánchez I (2023). The benefits of climate tech: Do institutional investors affect these impacts? Technological forecasting & social change 192:122536. https://doi.org/10.1016/j.techfore.2023.122536.

Alyoubi B, Hoque MR, Alharbi I, Alyoubi A, Almazmomi N (2018). Impact of knowledge management on employee work performance: evidence from Saudi Arabia. The International Technology Management Review 7(1):13-24.

Andersén J, Jansson C, Ljungkvist T (2020). Can environmentally oriented CEOs and environmentally friendly suppliers boost the growth of small firms? Bus Strategy Environ 29(2):325-334.

Asadi S, Pourhashemi SO, Nilashi M, Abdullah R, Samad S, Yadegaridehkordi E, Aljojo N, Razali NS (2020) .Investigating influence of green innovation on sustainability performance: a case on Malaysian hotel industry. J Clean Prod 258:120860.

Awan FH, Dunnan L, Jamil K, Gul RF (2023). Stimulating environmental performance via green human resource management, green transformational leadership, and green innovation: a mediation-moderation model. Environ Sci Pollut Res Int 30(2):2958-2976.

Bansal P (2005). Evolving sustainably: a longitudinal study of corporate sustainable development. Strateg Manag J 26(3):197-218.

Barclay D, Higgins C, Thompson R (1995). The partial least squares (PLS) approach to casual modeling: personal computer adoption ans use as an Illustration.

Barth M, Masson T, Fritsche I, Fielding K, Smith JR (2021). Collective responses to global challenges: the social psychology of pro-environmental action. J Environ Psychol 74:101562.

Bass BM (1985). Leadership: Good, better, best. Organ Dyn 13(3):26-40.

Bass BM, Avolio BJ (1993). Transformational leadership and organizational culture. Public administration quarterly:112-121.

Boulhaga M, Bouri A, Elamer AA, Ibrahim BA (2023). Environmental, social and governance ratings and firm performance: the moderating role of internal control quality. Corp Soc Responsib Environ Manag 30(1):134-145.

Cai W, Li G (2018). The drivers of eco-innovation and its impact on performance: Evidence from China. J Clean Prod 176:110-118.

Chen Y, Chang C (2013). The determinants of green product development performance: Green dynamic capabilities, green transformational leadership, and green creativity. J Bus Ethics 116:107-119.

Chen Y, Lai S, Wen C (2006). The influence of green innovation performance on corporate advantage in Taiwan. J Bus Ethics 67:331-339.

Chen Z, Liang M (2023). How do external and internal factors drive green innovation practices under the influence of big data analytics capability: Evidence from China. J Clean Prod:136862.

Christmann P (2004). Multinational companies and the natural environment: Determinants of global environmental policy. Acad Manage J 47(5):747-760.

Cohen J (2013). Statistical power analysis for the behavioral sciences. Routledge.

Cui X, Umair M, Gayratovich GI, Dilanchiev A (2023). DO remittances mitigate poverty? An empirical evidence from 15 selected asian economies. The Singapore Economic Review (SER) 68(04):1447-1468.

Edeh E, Lo W, Khojasteh J (2023). Review of Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: a Workbook: by Joseph F. Hair Jr., G. Tomas M. Hult, Christian M. Ringle, Marko Sarstedt, Nicholas P. Danks, Soumya Ray. Cham, Switzerland: Springer,(2021). 197 pp. 0,OpenAccess; 59.99, Hardcover Book. In. Taylor & Francis.

Elkington J (2018). 25 years ago I coined the phrase "triple bottom line." Here's why it's time to rethink it. Harv Bus Rev 25(June):2-5.

Engau C, Hoffmann VH (2009). Effects of regulatory uncertainty on corporate strategy—an analysis of firms' responses to uncertainty about post-Kyoto policy. Environ Sci Policy 12(7):766-777.

Erhan T, Uzunbacak HH, Aydin E (2022) From conventional to digital leadership: exploring digitalization of leadership and innovative work behavior. Manag Res Rev 45(11):1524-1543

Eriksson D, Svensson G (2016) The Process of Responsibility, Decoupling Point, and Disengagement of Moral and Social Responsibility in Supply Chains: Empirical Findings and Prescriptive Thoughts. J Bus Ethics 134(2):281-298. https://doi.org/10.1007/s10551-014-2429-8

Fan Q, Abbas J, Zhong Y, Pawar PS, Adam NA, Alarif GB (2023) Role of organizational and environmental factors in firm green innovation and sustainable development: Moderating role of knowledge absorptive capacity. J Clean Prod 411:137262

Fernando Y, Jabbour CJC, Wah W (2019) Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: does service capability matter? Resources, conservation and recycling 141:8-20

Fornell C, Larcker DF (1981) Evaluating structural equation models with unobservable variables and measurement error. J Mark Res 18(1):39-50

Franke G, Sarstedt M (2019) Heuristics versus statistics in discriminant validity testing: a comparison of four procedures. Internet Res 29(3):430-447

Freeman RE (1984) Strategic management: a stakeholder theory. J Manage Stud 39(1):1-21

Grewatsch S, Kleindienst I (2017) When Does It Pay to be Good? Moderators and Mediators in the Corporate Sustainability–Corporate Financial Performance Relationship: a Critical Review. J Bus Ethics 145(2):383-416. https://doi.org/10.1007/s10551-015-2852-5

Habib M, Abbas J, Noman R (2019) Are human capital, intellectual property rights, and research and development expenditures really important for total factor productivity? An empirical analysis. Int J Soc Econ 46(6):756-774

Hamad S, Draz MU, Lai F (2020) The impact of corporate governance and sustainability reporting on integrated reporting: a conceptual framework. Sage Open 10(2):1479850951

Hanif S, Ahmed A, Younas N (2023) Examining the impact of Environmental Management Accounting practices and Green Transformational Leadership on Corporate Environmental Performance: the mediating role of Green Process Innovation. J Clean Prod 414:137584

Hanim Mohamad Zailani S, Eltayeb TK, Hsu C, Choon Tan K (2012) The impact of external institutional drivers and internal strategy on environmental performance. Int J Oper Prod Manage 32(6):721-745

Hartl RF, Kort PM (1997) Optimal input substitution of a firm facing an environmental constraint. Eur J Oper Res 99(2):336-352

Henseler J, Ringle CM, Sinkovics RR (2009) The use of partial least squares path modeling in international marketing. In: New challenges to international marketing, vol 20. Emerald Group Publishing Limited, 277-319

Hojnik J, Ruzzier M (2016) The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia. J Clean Prod 133:812-825

Hu LT, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural equation modeling: a multidisciplinary journal 6(1):1-55

Hu Z, Yu B, Liu L, Wei Y (2024) Evaluating rare-earth constraints on wind power development under China's carbon-neutral target. Sci Total Environ 912:168634

Huang Y, Chen CT (2022) Exploring institutional pressures, firm green slack, green product innovation and green new product success: Evidence from Taiwan's high-tech industries. Technol Forecast Soc Change 174:121196

Iqbal Q (2020) The era of environmental sustainability: Ensuring that sustainability stands on human resource management. Glob Bus Rev 21(2):377-391

Khan SJ, Kaur P, Jabeen F, Dhir A (2021) Green process innovation: Where we are and where we are going. Bus Strategy Environ 30(7):3273-3296

Kong T, Feng T, Huang Y, Cai J (2020) How to convert green supply chain integration efforts into green innovation: a perspective of knowledge-based view. Sustain Dev 28(5):1106-1121

Kostova T, Roth K, Dacin MT (2008) Institutional theory in the study of multinational corporations: a critique and new directions. Acad Manage Rev 33(4):994-1006

Krell K, Matook S, Rohde F (2016) The impact of legitimacy-based motives on is adoption success: an institutional theory perspective. Inf Manage 53(6):683-697

Li L, Msaad H, Sun H, Tan MX, Lu Y, Lau AK (2020) Green innovation and business sustainability: New evidence from energy intensive industry in China. International Journal of Environmental Research and Public Health 17(21):7826

Li Y (2014) Environmental innovation practices and performance: moderating effect of resource commitment. J Clean Prod 66:450-458

Lin B, Ma R (2022) Green technology innovations, urban innovation environment and CO2 emission reduction in China: Fresh evidence from a partially linear functional-coefficient panel model. Technol Forecast Soc Change 176:121434

Liu H, Ke W, Wei KK, Gu J, Chen H (2010) The role of institutional pressures and organizational culture in the firm's intention to adopt internet-enabled supply chain management systems. J Oper Manag 28(5):372-384

Ly B (2024) Inclusion leadership and employee work engagement: the role of organizational commitment in Cambodian public organization. Asia Pac Manag Rev 29(1):44-52

Majali TE, Alkaraki M, Asad M, Aladwan N, Aledeinat M (2022) Green Transformational Leadership, Green Entrepreneurial Orientation and Performance of SMEs: the Mediating Role of Green Product Innovation. Journal of Open Innovation: Technology, Market, and Complexity 8(4):191. https://doi.org/10.3390/joitmc8040191

Massoud MA, Fayad R, Kamleh R, El-Fadel M (2010) Environmental management system (ISO 14001) certification in developing countries: challenges and implementation strategies. In. ACS Publications,

Moeuf A, Pellerin R, Lamouri S, Tamayo-Giraldo S, Barbaray R (2018) The industrial management of SMEs in the era of Industry 4.0. Int J Prod Res 56(3):1118-1136

Mughal N, Arif A, Jain V, Chupradit S, Shabbir MS, Ramos-Meza CS, Zhanbayev R (2022) The role of technological innovation in environmental pollution, energy consumption and sustainable economic growth: Evidence from South Asian economies. Energy Strateg Rev 39:100745

Niazi UI, Nisar QA, Nasir N, Naz S, Haider S, Khan W (2023) Green HRM, green innovation and environmental performance: the role of green transformational leadership and green corporate social responsibility. Environ Sci Pollut Res Int 30(15):45353-45368

Niu S, Park BI, Jung JS (2022) The effects of digital leadership and ESG management on organizational innovation and sustainability. Sustainability 14(23):15639

Odugbesan JA, Aghazadeh S, Al Qaralleh RE, Sogeke OS (2023) Green talent management and employees' innovative work behavior: the roles of artificial intelligence and transformational leadership. J Knowl Manag 27(3):696-716. https://doi.org/10.1108/jkm-08-2021-0601

Pacheco LM, Alves MFR, Liboni LB (2018) Green absorptive capacity: a mediation-moderation model of knowledge for innovation. Bus Strategy Environ 27(8):1502-1513. https://doi.org/10.1002/bse.2208

Pan C, Abbas J, álvarez-Otero S, Khan H, Cai C (2022) Interplay between corporate social responsibility and organizational green culture and their role in employees' responsible behavior towards the environment and society. J Clean Prod 366:132878. https://doi.org/10.1016/j.jclepro.2022.132878

Parmentola A, Petrillo A, Tutore I, De Felice F (2022) Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). Bus Strategy Environ 31(1):194-217

Phillips LD (2017) What is strategy? J Oper Res Soc 62(5):926-929. https://doi.org/10.1057/jors.2010.127

Piwowar-Sulej K, Iqbal Q (2023) Leadership styles and sustainable performance: a systematic literature review. J Clean

Prod 382:134600

Preacher KJ, Hayes AF (2008) Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behav Res Methods 40(3):879-891

Rasoolimanesh SM (2022) Discriminant validity assessment in PLS-SEM: a comprehensive composite-based approach. Data Analysis Perspectives Journal 3(2):1-8

Schaefer A (2007) Contrasting institutional and performance accounts of environmental management systems: Three case studies in the UK water & sewerage industry. J Manage Stud 44(4):506-535

Schoemaker PJ, Heaton S, Teece D (2018) Innovation, dynamic capabilities, and leadership. Calif Manage Rev 61(1):15-42

Shahzad M, Qu Y, Javed SA, Zafar AU, Rehman SU (2020) Relation of environment sustainability to CSR and green innovation: a case of Pakistani manufacturing industry. J Clean Prod 253:119938

Sharif A, Kartal MT, Bekun FV, Pata UK, Foon CL, Depren SK (2023) Role of green technology, environmental taxes, and green energy towards sustainable environment: insights from sovereign Nordic countries by CS-ARDL approach. Gondwana Res 117:194-206

Song M, Peng L, Shang Y, Zhao X (2022) Green technology progress and total factor productivity of resource-based enterprises: a perspective of technical compensation of environmental regulation. Technol Forecast Soc Change 174:121276

Song M, Yang MX, Zeng KJ, Feng W (2020) Green knowledge sharing, stakeholder pressure, absorptive capacity, and green innovation: Evidence from Chinese manufacturing firms. Bus Strategy Environ 29(3):1517-1531

Sun X, El Askary A, Meo MS, Hussain B (2022) Green transformational leadership and environmental performance in small and medium enterprises. Economic Research-Ekonomska Istraživanja 35(1):5273-5291

Susanto PC, Sawitri NN (2022) Coaching, Mentoring, Leadership Transformation and Employee Engagement: a Review of the Literature. Dinasti International Journal Of Education Management And Social Science 4(2):297-308

Takalo SK, Tooranloo HS (2021) Green innovation: a systematic literature review. J Clean Prod 279:122474

Tian H, Han J, Sun M, Lv X (2023) Keeping pace with the times: research on the impact of digital leadership on radical green innovation of manufacturing enterprises. Eur J Innov Manag(ahead-of-print)

Turker D (2009) Measuring corporate social responsibility: a scale development study. J Bus Ethics 85:411-427

Wang M, Li Y, Li J, Wang Z (2021) Green process innovation, green product innovation and its economic performance improvement paths: a survey and structural model. J Environ Manage 297:113282

Wang Q, Wang H, Chang C (2022) Environmental performance, green finance and green innovation: what's the long-run relationships among variables? Energy Econ 110:106004

Wang T, Lin X, Sheng F (2022) Digital leadership and exploratory innovation: From the dual perspectives of strategic orientation and organizational culture. Front Psychol 13:902693

Wen X, Cheah J, Lim X, Ramachandran S (2023) Why does “green” matter in supply chain management? Exploring institutional pressures, green practices, green innovation, and economic performance in the Chinese chemical sector. J Clean Prod 427:139182. https://doi.org/10.1016/j.jclepro.2023.139182

Wu H, Hao Y, Ren S (2020) How do environmental regulation and environmental decentralization affect green total factor energy efficiency: Evidence from China. Energy Econ 91:104880

Wu J, Xia Q, Li Z (2022) Green innovation and enterprise green total factor productivity at a micro level: a perspective of technical distance. J Clean Prod 344:131070

Xie X, Hoang TT, Zhu Q (2022) Green process innovation and financial performance: the role of green social capital and customers’ tacit green needs. J Innov Knowl 7(1):100165. https://doi.org/10.1016/j.jik.2022.100165

Yadav VS, Singh AR, Gunasekaran A, Raut RD, Narkhede BE (2022) A systematic literature review of the agro-food supply chain: Challenges, network design, and performance measurement perspectives. Sustain Prod Consum 29:685-704

Yang Y, Din AU, Din QMU, Khan IU (2024) Green leadership in manufacturing industry: Unveiling the green

Revolution's impact on organizational performance. Heliyon 10(6)

Yuan B, Cao X (2022) Do corporate social responsibility practices contribute to green innovation? The mediating role of green dynamic capability. Technol Soc 68:101868

Yuan Y, Li D (2023) Urban economic efficiency, environmental factors, and digital finance: Impacts on sustainable development in Chinese cities. Sustainability 15(18):13319

Zaiţ A, Bertea P (2011) Methods for testing discriminant validity. Management & Marketing Journal 9(2):217-224

Zameer H, Yasmeen H (2022) Green innovation and environmental awareness driven green purchase intentions. Mark Intell Plan 40(5):624-638

Zhang F, Zhu L (2019) Enhancing corporate sustainable development: Stakeholder pressures, organizational learning, and green innovation. Bus Strategy Environ 28(6):1012-1026

Zhang J, Lyu Y, Li Y, Geng Y (2022) Digital economy: an innovation driving factor for low-carbon development. Environ Impact Assess Rev 96:106821

Zhang Q, Ma Y (2021) The impact of environmental management on firm economic performance: the mediating effect of green innovation and the moderating effect of environmental leadership. J Clean Prod 292:126057

Zhao W, Huang L (2022) The impact of green transformational leadership, green HRM, green innovation and organizational support on the sustainable business performance: Evidence from China. Economic Research-Ekonomska Istraživanja 35(1):6121-6141

Zhao X, Lynch Jr JG, Chen Q (2010) Reconsidering Baron and Kenny: Myths and truths about mediation analysis. J Consum Res 37(2):197-206

Zhu Q, Liu J, Lai K (2016) Corporate social responsibility practices and performance improvement among Chinese national state-owned enterprises. Int J Prod Econ 171:417-426

Appendix 1

	Questionnaire item	
	Green Digital Transformation Leadership	
GDTL1	Leaders encourage employees to utilize digital technology in order to protect the environment	Chen and Chang, 2013
GDTL2	Leaders engage employees to work together for green environment, digitalization and sustainability goals	
GDTL3	Leaders proactively engage in green behaviors and digital practices	
GDTL4	Leaders motivate their subordinates to think proactively about green digitization ideas and initiatives	
	Normative Pressure	
NP1	The public, communities and environmental organizations complain about corporate pollution practices	Christmann, 2004 Li, 2014
NP2	News media are highly motivated to report on corporate environmental behavior	Massoud et al., 2010
NP3	Consumers are concerned about the environmental reputation of corporations	Zhu and Sarkis, 2007
NP4	Consumers tend to buy green, environmentally friendly types of products	
	Green Innovation	
GI1	Actively developing a strategy for the future development of cleaner technologies	Christian and Volker, 2009
GI2	Actively investing in environmental projects	Hartl and Kort, 1997
GI3	Choose new energy-saving and low-carbon materials when purchasing raw materials	Phillips, 2011
GI4	Proactive compliance with ISO14001 environmental management system	Porter and Linde, 1995
GI5	Active technological innovation in the production process	Zhao et al., 2015
	Sustainable development	
SD1	Sustained increase in income	Bansal, 2005 Turker, 2009
SD2	Creation of new jobs	
SD3	High level of corporate satisfaction in the region where you are located	
SD4	Active use of renewable resources	
SD5	Production of environmentally friendly products continues to increase	