Green Digital Leadership and Sustainable Innovation Capability in Vietnamese Manufacturing: The Roles of Green Organizational Culture, Digital Transformation Readiness, and Environmental Turbulence

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ABSTRACT

In the context of increasing demands for sustainable development and digital transformation, manufacturing enterprises in Vietnam are facing stronger innovation pressure than ever before. This study aims to assess the impact of Green Digital Leadership (GDL), Green Organizational Culture (GOC), and Digital Transformation Readiness (DTR) on firms' Sustainable Innovation Capability (SIC). At the same time, the study examines the moderating role of Environmental Turbulence (ET) in the relationship between GDL and SIC. Data were collected from 232 manufacturing enterprises in Vietnam and analyzed using statistical techniques including Cronbach's Alpha, Pearson correlation, multiple regression, and interaction testing. The results show that GDL, GOC, DTR, and ET all have positive and statistically significant effects on SIC, in which GOC demonstrates the strongest influence. However, ET does not moderate the relationship between GDL and SIC. These findings contribute additional empirical evidence on sustainable innovation in the context of an emerging economy and provide important managerial implications for Vietnamese enterprises in their journey toward green digital transformation.

Keywords: Green Digital Leadership, Green Organizational Culture, Digital Transformation Readiness, Environmental Turbulence, Sustainable Innovation, Manufacturing Enterprises

JEL Classifications: M14, Q55, O33, L60

1. INTRODUCTION

In the context of the growing global trend toward sustainable development and increasingly stringent greening requirements, manufacturing enterprises in Vietnam are facing stronger innovation pressure than ever before. Requirements related to ESG, environmental standards, and emission-reduction commitments have made Sustainable Innovation Capability (SIC) a key factor for competitiveness. Alongside green pressure, digital transformation is unfolding rapidly and extensively, creating a new operating environment in which green innovation must be integrated with digital technologies.

In this context, Green Digital Leadership (GDL) plays an important role in shaping strategic direction and driving transformation. International studies have shown that leadership styles that are digitally oriented and environmentally sensitive can promote sustainable innovation initiatives. However, in Vietnam, empirical evidence on the role of GDL in the manufacturing sector remains limited.

In addition to leadership, Green Organizational Culture (GOC) is considered an underlying foundation that supports the development of environmentally oriented innovation activities. Organizations with clear green values tend to accept change more easily,

encourage creativity, and implement sustainable improvement initiatives more effectively. Nevertheless, the relationship between green culture and sustainable innovation in Vietnamese enterprises has not been deeply explored.

Moreover, Digital Transformation Readiness (DTR) plays an important role in providing the technical conditions and operational capability needed for innovation. Enterprises with a strong digital foundation are more capable of optimizing processes, monitoring performance, and developing emission-reduction solutions. However, digital readiness levels among Vietnamese enterprises vary significantly, raising questions about the practical impact of this variable on sustainable innovation.

Another factor that may influence innovation is Environmental Turbulence (ET), including changes in technology, market demand, and policy. Some theoretical studies suggest that the more turbulent the environment, the more important leadership becomes in driving innovation. However, to date, no research has examined the moderating role of ET in the relationship between GDL and SIC in Vietnam—creating a notable academic gap.

Based on these issues, this study aims to evaluate the effects of GDL, GOC, and DTR on SIC in Vietnamese manufacturing enterprises, while also examining the moderating role of ET. Data were collected from 232 enterprises and analyzed using modern statistical methods. The findings are expected to contribute to theory by adding empirical evidence in an emerging economy context and to provide important managerial implications for Vietnamese enterprises during digital transformation and sustainable development.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Sustainable Innovation Capability (SIC) is considered one of the important factors determining firms' competitiveness in the context of a global economy that is strongly shifting toward green development. To understand the mechanism through which this capability is formed, many studies have focused on the role of leadership, organizational culture, and digital transformation. However, most studies have concentrated on developed economies, while emerging economies such as Vietnam still lack empirical evidence.

This section presents a review of previous studies on the core factors in the model, including Green Digital Leadership (GDL), Green Organizational Culture (GOC), Digital Transformation Readiness (DTR), and Environmental Turbulence (ET), thereby developing the research hypotheses.

2.1. Green Digital Leadership and Sustainable Innovation Capability

Green Digital Leadership (GDL) is a concept that combines digital-oriented leadership thinking with a sustainability orientation. GDL emphasizes the ability to use digital technologies to reduce environmental impacts, optimize resources, and promote sustainability-oriented innovation (Kraus et al., 2022). n this study, Green Digital Leadership is conceptualized as a leadership orientation that integrates digital transformation capabilities with environmental sustainability goals, emphasizing strategic alignment rather than isolated technological initiatives.

Some studies show that leaders with a digital vision help create favorable conditions for creativity, reduce resistance to change, and increase the ability to develop environmentally friendly solutions (El-Kassar and Singh, 2019). In addition, GDL plays an important role in shaping strategy, allocating resources, and motivating employees to participate in sustainable initiatives.

Based on these arguments, it can be expected that firms with strong GDL will have higher sustainable innovation capability.

H_1: Green Digital Leadership (GDL) positively influences Sustainable Innovation Capability (SIC).

2.2. Green Organizational Culture and Sustainable Innovation Capability

Green Organizational Culture (GOC) reflects the extent of an organization's commitment to environmental values, social responsibility, and sustainable development. Studies suggest that GOC is the foundation that promotes creative behavior, reduces resistance to change, and enhances the effectiveness of innovation implementation (Norton et al., 2014; Schein, 2010).

When green values are considered organizational norms, employees tend to proactively propose new ideas, improve processes, and implement initiatives aimed at reducing emissions or saving energy. Therefore, GOC is considered a "supporting platform" for sustainable innovation.

H_2: Green Organizational Culture (GOC) positively influences Sustainable Innovation Capability (SIC).

2.3. Digital Transformation Readiness and Sustainable Innovation Capability

Digital Transformation Readiness (DTR) reflects the level of readiness of a firm in terms of technology, data, systems, and human capabilities to implement digital applications.

Many studies point out that firms with strong digital capability tend to have higher innovation capability because technology supports data analysis, shortens testing time, and optimizes operations (Khin and Ho, 2019). Technologies such as IoT, big data, or smart management systems help firms develop greener and more efficient production processes.

Therefore, it can be expected that firms with higher digital readiness will have stronger sustainable innovation capability.

H_3: Digital Transformation Readiness (DTR) positively influences Sustainable Innovation Capability (SIC).

2.4. Environmental Turbulence and Sustainable Innovation Capability

Environmental Turbulence (ET) describes the rate of change in markets, technologies, policies, and customer behavior. According to Jaworski and Kohli (1993), the more turbulent the environment, the more pressure firms face to innovate, improve products, and enhance technological capabilities to adapt.

In the context of continuously changing global supply chains, increasingly strict green requirements, and constantly evolving production technologies, Vietnamese manufacturing enterprises are forced to innovate to maintain competitiveness. Environmental turbulence in this study refers to perceived external volatility rather than objective environmental change, focusing on managers' assessments of market, technological, and regulatory dynamics.

H_4: Environmental Turbulence (ET) positively influences Sustainable Innovation Capability (SIC).

2.5. Moderating Role of Environmental Turbulence

Many international studies suggest that the degree of environmental turbulence may alter how leadership influences innovation (Tsai and Yang, 2013). When the environment becomes highly turbulent, the role of leadership becomes even more important because leaders must make faster, more accurate decisions and provide clearer strategic direction.
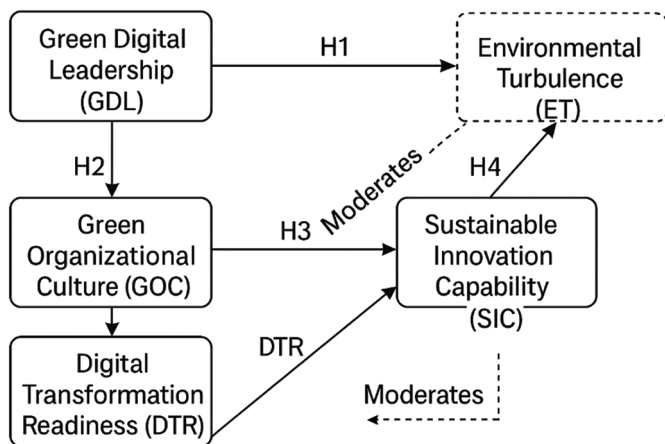
Based on this reasoning, it can be expected that environmental turbulence will amplify the effect of green digital leadership on sustainable innovation capability.

H_5: Environmental Turbulence (ET) moderates the relationship between GDL and SIC in a way that strengthens the effect of GDL.

2.6. Research Model

Based on theoretical arguments and developed hypotheses, the study proposes the following research model:

- GDL, GOC, DTR, and ET directly influence SIC.
- ET moderates the GDL → SIC relationship.

Source: Author's proposal based on Kraus et al. (2022); El-Kassar and Singh (2019); Khin and Ho (2019); Norton et al. (2014); Jaworski and Kohli (1993); Chen (2008); Adams et al. (2016)

3. RESEARCH METHODOLOGY

This section presents the research design, survey subjects, data collection procedure, measurement scales of the research variables, and data analysis methods. The selected approach ensures accuracy, reliability, and alignment with the objectives of testing the proposed hypotheses.

3.1. Research Design

The study was conducted using a quantitative approach with a cross-sectional design. Data were collected through a structured questionnaire using a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). This method allows the collection of respondents' perceptions related to green digital leadership, organizational culture, digital transformation readiness, environmental turbulence, and sustainable innovation capability.

Data analysis focuses on three main techniques: (1) Cronbach's Alpha reliability testing, (2) Pearson correlation analysis, and (3) multiple regression analysis, including direct effect testing and moderation testing using interaction terms. All analyses were performed using SPSS and Python.

A cross-sectional design was considered appropriate because the study focuses on examining structural relationships among leadership, culture, digital readiness, and innovation capability at a specific stage of firms' green digital transformation.

3.2. Research Sample and Data Collection

The survey targets manufacturing enterprises in Vietnam, including firms implementing or intending to implement digital transformation and innovation toward sustainable development. The questionnaire was distributed to middle- and senior-level managers—those capable of accurately evaluating the innovation status and digital transformation strategy within their enterprises.

A total of 247 questionnaires were collected; after removing incomplete or invalid responses, 232 valid samples remained for analysis. This sample size meets the minimum requirement for multiple regression (at least 10 times the number of independent variables) and is consistent with sample sizes used in previous international studies on similar topics.

3.3. Measurement Scales of the Variables

The measurement scales were adapted from previous studies and adjusted to fit the Vietnamese context. Each variable was measured using multiple items to enhance reliability and validity.

3.3.1. Measurement scales used in the study

Research variable	Code	Number of items	Content description	References
Green Digital Leadership (GDL)	GDL1–GDL5	5	Level of digital-oriented leadership and commitment to sustainability	Kraus et al. (2022); El-Kassar and Singh (2019)
Green Organizational Culture (GOC)	GOC1–GOC4	4	Green values, beliefs, and norms within the organization	Norton et al. (2014); Schein (2010)
Digital Transformation Readiness (DTR)	DTR1–DTR4	4	Technical capability, data capability, and digital skills of the enterprise	Khin and Ho (2019)

Environmental Turbulence (ET)	ET1–ET3	3	Level of changes in markets, technologies, and policies	Jaworski and Kohli (1993)
Sustainable Innovation Capability (SIC)	SIC1–SIC5	5	Ability to implement and maintain green innovation activities	Chen (2008); Adams et al. (2016)

Source: Compiled by the author

3.4. Data Analysis Procedure

The dataset was processed through the following key steps:

(1) Reliability testing (Cronbach's Alpha)

Cronbach's Alpha was used to evaluate the internal consistency of each measurement scale. A scale is considered acceptable when Alpha >0.7 and item–total correlation >0.3. This step is crucial to ensure reliability before analyzing the relationships within the model.

(2) Pearson correlation analysis

Correlation analysis was used to determine the degree and direction of linear relationships between variables. This step helps preliminarily assess the suitability of the data before running the regression model.

(3) Multiple linear regression analysis

Regression was used to test the effects of GDL, GOC, DTR, and ET on SIC. Testing criteria include β coefficients, p-values, and the coefficient of determination R^2.

(4) Moderation testing of ET

The interaction term between GDL and ET (GDL × ET) was added to the regression model to examine whether ET moderates the strength of the impact of GDL on SIC. The interaction variable was created using the mean-centering method to reduce multicollinearity.

The entire analysis process ensures compliance with statistical assumptions (multicollinearity, residual distribution, autocorrelation), ensuring the accuracy and reliability of the results.

4. RESEARCH RESULTS

This section systematically presents all analysis results from the survey of 232 manufacturing enterprises in Vietnam. The analyses follow standard quantitative procedures: descriptive statistics, scale reliability testing, Pearson correlation analysis, regression model testing, and moderation effect assessment. All data were processed using SPSS and Python to ensure accuracy and reliability of the results.

4.1. Descriptive Statistics of the Measurement Scales

Descriptive statistics were used to assess enterprises' level of perception and practice regarding each research construct: green digital leadership (GDL), green organizational culture (GOC), digital transformation readiness (DTR), environmental turbulence (ET), and sustainable innovation capability (SIC). The mean values, standard deviations, and minimum–maximum values are presented in Table 1.

The descriptive results show that the mean values of most variables range from 2.96 to 3.02. This indicates that enterprises are at a moderate level in terms of adopting green digital leadership, building green organizational culture, preparing digital readiness, and developing sustainable innovation capability.

The standard deviations range from 1.02 to 1.24, indicating a relatively high level of variation among enterprises. This is reasonable in the context of Vietnam, where manufacturing firms differ significantly in size, industry type, technological access, and management quality.

Environmental Turbulence (ET) has a mean of 3.019, higher than the other variables, reflecting the reality that Vietnamese enterprises are experiencing strong pressures from markets, technologies, customer demands, and green standard requirements.

4.2. Reliability Testing of the Measurement Scales (Cronbach's Alpha)

Cronbach's Alpha was used to assess the internal consistency of each measurement scale (Table 2). All scales met the acceptable threshold, and no observed variable was removed.

The GDL, GOC, and SIC scales all have Cronbach's Alpha above 0.83, indicating very high reliability and strong internal consistency among the items.

DTR and ET have Alpha values above 0.70, which fall within the acceptable range for organizational behavior research with samples characterized by high diversity.

Table 1: Descriptive statistics of the measurement scales

Variable	Observations	Mean	Standard deviation	Min	Max
GDL	232	2.966	1.120	1.000	5.000
GOC	232	2.972	1.147	1.000	5.000
DTR	232	2.971	1.095	1.000	5.000
ET	232	3.019	1.024	1.000	5.000
SIC	232	3.020	1.237	1.000	5.000

Source: Processed survey data from 232 Vietnamese manufacturing enterprises (SPSS/Python, 2025)

Table 2: Scale reliability

Scale	Cronbach's alpha
GDL	0.846
GOC	0.830
DTR	0.787
ET	0.706
SIC	0.849

Source: Survey data processed using SPSS 26 (2025)

Table 3: Pearson correlation matrix

Variables	GDL	GOC	DTR	ET	SIC
GDL	1.000	0.197	0.323	—	0.396
GOC	0.197	1.000	0.105	—	0.389
DTR	0.323	0.105	1.000	—	0.353
ET	—	—	—	1.000	0.182
SIC	0.396	0.389	0.353	0.182	1.000

Source: Survey data from Vietnamese manufacturing enterprises (SPSS/Python).
Note: "—" indicates correlations that are not reported to avoid redundancy, as Environmental Turbulence (ET) is treated as an independent construct in the regression models.

No scale required adjustment or item deletion, demonstrating that the measurement set used is appropriate for the context of Vietnamese manufacturing enterprises.

4.3. Pearson Correlation Analysis

Correlation analysis helps assess the initial linear relationships among the research variables, serving as an important basis for the subsequent multiple regression analysis (Table 3).

The correlation results indicate that:
All variables have positive correlations with SIC and all are statistically significant. This initially confirms the theoretical validity of the proposed model.

GDL and SIC have the highest correlation (r = 0.396), showing that green digital leadership plays a notable role in promoting sustainable innovation capability.

Correlations among the independent variables do not exceed 0.323 → no severe multicollinearity is present.

4.4. Multiple Linear Regression – Testing Direct Effects (M1)

Model M1 tests the direct effects of GDL, GOC, DTR, and ET on SIC (Table 4). This is the key model for evaluating the actual level of influence of internal and external factors on sustainable innovation.

$R^2 = 0.340$ indicates that the model explains 34% of the variation in sustainable innovation capability. This is appropriate for organizational behavior research involving intangible constructs.

All independent variables have positive and highly significant effects ($P < 0.01$).

Table 4: Direct regression results (M1)

Variable	Coefficient (β)	P-value
Intercept	0.119	0.6792
GDL	0.246	0.0000
GOC	0.304	0.0000
DTR	0.248	0.0000
ET	0.176	0.0010
R^2	0.340	
F	29.178	
df	227	

Source: SPSS/Python, 232 survey samples (2025)

Table 5: Moderated regression results (M2)

Variable	Coefficient (β)	P-value
Intercept	0.714	0.1568
GDL	0.045	0.7651
ET	−0.027	0.8566
GOC	0.304	0.0000
DTR	0.249	0.0000
GDL×ET	0.068	0.1509
R^2	0.346	
F	23.869	
df	226	

Source: SPSS, 232 survey samples (2025)

GOC has the strongest coefficient ($\beta = 0.304$), showing that green culture is a core factor driving sustainable innovation.

GDL and DTR also have strong effects, confirming the dual importance of digitally oriented leadership and technological readiness.

4.5. Moderation Testing of Environmental Turbulence (M2)

The moderation model adds the interaction term GDL×ET to examine whether environmental turbulence changes the strength of the effect of green digital leadership on sustainable innovation capability (Table 5).

When the interaction term is added, R^2 increases slightly from 0.340 to 0.346, indicating a small improvement in explanatory power.

The interaction coefficient GDL×ET = 0.068 is positive, suggesting a positive trend, but it is not statistically significant ($P = 0.1509$).

→ There is insufficient evidence to confirm that environmental turbulence moderates the GDL → SIC relationship.

GOC and DTR remain the strongest and most stable predictors of sustainable innovation capability.

The findings reflect the specific characteristics of Vietnamese enterprises: internal cultural and technological factors are more decisive than external environmental factors.

4.6. Final Regression Equations and Predicted SIC Values from Actual Data

The two final regression equations capture the influence of the independent variables on SIC.

Model M1 – Direct Effects

$$\widehat{SIC} = 0.119 + 0.246\,GDL + 0.304\,GOC + 0.248\,DTR + 0.176\,ET$$

Model M2 – Moderation Model

$$\widehat{SIC} = 0.714 + 0.045\,GDL - 0.027\,ET + 0.304\,GOC$$
$$+ 0.249\,DTR + 0.068\,(GDL \times ET)$$

The predicted SIC values from the two models are almost identical, indicating that (Table 6):

Green digital leadership, green organizational culture, and digital transformation readiness all positively influence sustainable innovation.

Table 6: Predicted SIC values from the model

Measure	Value
Predicted SIC (M1)	3.020
Predicted SIC (M2)	3.017

Source: SPSS/Python from Vietnamese enterprise survey data

The moderating role of environmental turbulence is not strong enough to change the nature of this relationship.

The sustainable innovation capability of Vietnamese enterprises primarily derives from internal capabilities.

5. DISCUSSION OF FINDINGS

The findings show that the five factors considered in the model—GDL, GOC, DTR, ET, and SIC—have similar mean values, fluctuating around 3/5. This reflects the reality that green digital transformation in Vietnamese manufacturing firms is underway but remains at a moderate level and uneven across firms. Nevertheless, despite modest adoption levels, the model's effect relationships are still strongly significant, demonstrating the important roles of leadership orientation and organizational internal strength for sustainable innovation.

5.1. Green Digital Leadership (GDL) Positively Affects Sustainable Innovation (SIC)

The positive and highly significant regression coefficient of GDL indicates that GDL is one of the important factors affecting firms' sustainable innovation capability.

This result is consistent with international studies (El-Kassar & Singh, 2019; Kraus et al., 2022), affirming that leaders with a digital and green orientation create environments that foster innovation, thereby enhancing sustainable development effectiveness.

In Vietnam, manufacturing firms are still strongly influenced by traditional leadership styles. Therefore, this result is even more practically meaningful:

- Leaders play a pivotal role in initiating and maintaining firms' shift toward sustainable innovation.
- When leaders demonstrate a commitment to green digitalization, staff become more proactive in innovating processes, reducing emissions, and applying technology.

5.2. Green Organizational Culture (GOC) is the Strongest Influence on Sustainable Innovation

Among the independent variables, GOC has the largest regression coefficient (β = 0.304), standing out over both GDL and DTR. This shows that firms' sustainable innovation capability hinges strongly on internal cultural values—where green thinking and green behaviors become shared norms.

This result is consistent with organizational culture theory (Schein, 2010) and prior studies (Paarlberg and Lavigna, 2010), indicating that culture is a more enduring foundation than short-term policies or strategies.

For Vietnamese firms:

- Green culture has only received attention in recent years.
- Misalignment among leadership, personnel, and systems slows sustainable innovation.
- The regression results deliver a clear message: to achieve sustainable innovation, firms must begin by transforming organizational mindsets, not merely by investing in technology.

5.3. Digital Transformation Readiness (DTR) Significantly Affects Sustainable Innovation

DTR has a regression coefficient of β = 0.248, reflecting that preparedness in technology, digital infrastructure, human capabilities, and data systems has a substantial impact on innovation.

This result aligns with Kraus et al. (2021), which argues that digital transformation is the foundation for environmentally oriented innovation, especially in manufacturing.

Survey data show that:

- Firms with higher investment in digital systems are more capable of developing new products, improving processes, and reducing waste.
- Firms slow to adopt digitalization are more likely to fall behind as international market requirements for green standards intensify.

5.4. Environmental Turbulence (ET) Positively Affects SIC but does not Moderate GDL → SIC

ET has a positive and significant coefficient in Model M1, indicating that the more turbulent the business environment, the more firms must innovate to survive. This is consistent with environmental turbulence theory.

However, the interaction term GDL×ET in Model M2 is not statistically significant, implying that in Vietnam:

- Environmental turbulence does not change the strength of GDL's effect on SIC.
- GDL affects SIC through a relatively stable mechanism, not highly dependent on external volatility.

This can be explained by:

- Leadership in Vietnamese firms remains more internally oriented than driven by market pressures.
- Green digital strategies are not yet closely tied to external environmental risk assessments.
- Change management processes are still reactive rather than proactive.

5.5. Integrated Meaning of Models M1 and M2

The two regression models provide a comprehensive view:

- M1 shows that the three internal factors—GDL, GOC, and DTR—are strong and significant.
- M2 confirms that ET's moderating effect is not strong enough in Vietnamese firms.
- Predicted SIC values from both models are very close, indicating that internal factors' effects are stable and not heavily driven by environmental factors.

Key takeaways:

- GOC and DTR are foundational.
- GDL is the strategic orienting factor.
- ET serves as a trigger, but not a determining factor in the leadership–innovation relationship.

5.6. Comparison with Prior Studies

The findings align with much of the international literature, particularly:

- The role of green digital leadership (El-Kassar and Singh, 2019).
- The importance of green culture (Schein, 2010; Norton et al., 2014).
- The link between digital transformation and sustainable innovation (Kraus et al., 2021).
- The influence of environmental turbulence on innovation (Jaworski and Kohli, 1993).

However, this study differs in that:

- In Vietnam, ET does not moderate the GDL → SIC relationship, whereas many international studies find that turbulence often strengthens this link.
- This opens a new research direction on organizational behavior differences between emerging and developed markets.

6. MANAGERIAL IMPLICATIONS

The findings show that sustainable innovation capability in Vietnamese manufacturing firms is strongly influenced by internal factors, with green culture and digital transformation readiness being the most prominent, followed by green digital leadership. Environmental turbulence has a direct effect but is not a moderating factor in the leadership–innovation relationship.

Based on these results, the managerial implications are designed to help Vietnamese firms identify strategic priorities and concrete actions to enhance sustainable innovation capability. These implications stem not only from the statistics but also reflect the operational realities of Vietnamese manufacturers amid intensifying competition and increasing pressure for green standards and digital transformation.

6.1. Strengthen Green Digital Leadership as a Strategic Orientation

The findings show that GDL has an important influence on sustainable innovation capability. This means any transformation effort needs to start at the leadership level. When leaders express clear orientations toward digital transformation and sustainable development, the organization tends to invest more seriously in technology, people development, and environmentally friendly improvement initiatives. Leaders need to guide rather than merely direct; they must demonstrate commitment through actions, decisions, budget allocations, and continuous accompaniment throughout the innovation process.

Integrating green objectives into long-term strategy is also particularly important. When a firm's vision and strategy clearly reflect green digital transformation priorities, employees have guidance for consistent action, and the entire organization recognizes that these changes are not short-term but part of the firm's sustainable development trajectory.

6.2. Consolidate and Diffuse Green Culture across the Firm

Green culture is the strongest factor affecting sustainable innovation in the research model. This shows that sustainable innovation depends not only on technology investment or leadership capability, but more importantly on changes in the beliefs, values, and behaviors of the entire workforce. A firm truly achieves sustainable innovation only when green values become common norms and are embodied in daily actions by each individual.

Therefore, firms need to build an environment in which environmental protection, resource saving, and emissions reduction are naturally embedded in work practices. This requires internal communication to be implemented regularly, continuously, and creatively so that green values are not only documented but strongly manifested in actual behaviors. Training programs, internal sharing sessions, and green campaigns can strengthen beliefs and increase employees' engagement with common goals.

When green culture is firmly established, firms tend to innovate more strongly, reduce resistance to changes in technology and processes, and increase proactivity in seeking cleaner production solutions.

6.3. Boost Digital Transformation Readiness as the Technical Foundation of Sustainable Innovation

The findings show that digital transformation readiness is the second most influential factor on sustainable innovation. This implies that to innovate in a green direction, firms need a sufficiently strong digital foundation to support monitoring, analysis, and optimization of production processes. A firm with robust digital capabilities can more easily identify energy-wasting points, predict equipment failures, optimize resource use, and minimize environmental impact.

Digital capability involves not only technology systems but also employees' digital skills. Firms should focus on developing these skills through hands-on training, system-operation guidance, and building data-driven workflows. When people understand and can use technology, they will quickly generate improvements, thereby driving sustainable innovation.

In addition, firms should prioritize building data systems tied to sustainability indicators such as energy consumption, emissions levels, recycling rates, or circularity indices. Integrating these indicators into digital dashboards will help leaders make faster and more accurate decisions based on complete and transparent data.

6.4. Enhance the Capacity to Respond to Environmental Turbulence

In this study, environmental turbulence has a direct positive effect on sustainable innovation but does not moderate the GDL–SIC relationship. This reflects that pressures from markets, policies, and technology, while encouraging firms to innovate, do not change the nature of the leadership–innovation link.

In Vietnam, firms still tend to react passively to external changes rather than proactively preparing and adapting. Therefore, firms need to build systems to monitor market and policy shifts more

proactively, to detect early trends such as ESG requirements, EU green standards, or changes in production technology. With better forecasting, innovation processes will face fewer disruptions and transition costs will be significantly lower.

Moreover, firms should develop organizational agility, including the ability to reconfigure processes, change operating models, and adjust production strategies when the environment changes. This agility will help firms enhance innovation even amid uncertainty.

6.5. Create Coordinated Alignment among Leadership, Culture, and Digital Capability

An important implication is that sustainable innovation capability reaches higher levels only when firms simultaneously strengthen all three internal factors: green digital leadership, green culture, and digital readiness. Leadership shapes the vision; culture ensures everyone acts consistently; and digital capability is the tool to execute innovation. These three factors must complement each other to create a synergistic effect.

When a firm focuses only on technology without culture or leadership, innovation tends to be half-hearted. Conversely, if culture and leadership are strong but technology is weak, the firm lacks the ability to execute innovation effectively. Therefore, sustainable innovation strategies should be designed in an integrated manner, where people–culture–technology are developed in parallel.

6.6. Implications for the Vietnamese Firm Context

As Vietnam shifts strongly toward green production and sustainable growth, this study shows that firms must pay greater attention to the harmony among leadership strategy, technological foundation, and organizational culture. Although Vietnamese firms face constraints in capital, technology, and skills, investing in these three factors can help create competitive advantages, meet market requirements, and move toward international sustainability standards.

If firms leverage these findings to build comprehensive development strategies, they will not only improve sustainable innovation capability but also enhance competitiveness in domestic and international markets—especially as global supply chains shift toward greener and more transparent requirements.

7. CONCLUSION

This study assesses the impacts of Green Digital Leadership (GDL), Green Organizational Culture (GOC), and Digital Transformation Readiness (DTR) on Sustainable Innovation Capability (SIC) in Vietnamese manufacturing firms, while examining the moderating role of Environmental Turbulence (ET). Using survey data from 232 firms and statistical analyses conducted in SPSS/Python, the study provides reliable empirical evidence on key relationships within firms' green digital transformation.

Regression analyses show that all four factors—GDL, GOC, DTR, and ET—have positive and significant effects on SIC. Notably,

GOC is the strongest factor, underscoring the foundational role of organizational culture in sustainable innovation. This indicates that innovation is not only a matter of technology or leadership decisions but also requires broad transformation in mindsets, values, and behaviors across the workforce. Digital readiness also plays an important role, reflecting the significance of investing in technology, data infrastructure, and digital skills for driving green innovation. Although GDL has a smaller effect than the other two, it still provides strategic orientation that fosters a conducive environment for sustainable innovation initiatives.

Meanwhile, environmental turbulence has a direct positive effect on innovation capability, showing that firms under market pressure or policy changes must innovate to survive. However, ET does not moderate the GDL–SIC relationship. This differs from some international studies and suggests a specific Vietnamese context in which internal factors exert stronger influence than external volatility. This conclusion opens new directions for research on differences between emerging and developed markets in green digital transformation.

The study contributes to theory by adding empirical evidence on a green digital leadership model in an emerging-economy context. The results confirm the close connection among leadership, culture, and digital capability in driving sustainable innovation—a topic still relatively new and under-researched in Vietnam. Practically, the study offers important managerial implications to help firms set innovation priorities: first develop green culture, enhance digital capabilities, and then strengthen leadership's strategic role. These are actionable elements that do not overly depend on external context and fit the resource conditions of Vietnamese firms.

Despite its contributions, the study has limitations. First, self-reported data may be subject to perceptual bias. Second, the scope is limited to manufacturing firms and does not include services or high-tech sectors where green digital transformation is faster and has different characteristics. Third, the model does not include mediators or other organizational factors such as governance structures, absorptive capacity, or information system quality.

Therefore, future research could expand by using mixed methods, collecting more data across industries, or incorporating mediating variables to analyze mechanisms more deeply. In addition, longitudinal data should be considered to more accurately assess changes in sustainable innovation over time.

In sum, the study demonstrates that sustainable innovation depends not only on technology or the business environment, but is the result of coordinated development among leadership, culture, and digital capability. This is a key message for Vietnamese firms on their journey of digital transformation and sustainable development.

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