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Management Theory and Studies for Rural Business and Infrastructure Development
eISSN 2345-0355. 2025. Vol. 47. No. 3: 389-397
Article DOI: https://doi.org/10.15544/mts.2025.31

IMPACT OF GREEN INNOVATION ON ENVIRONMENTAL PERFORMANCE AND FIRM PERFORMANCE: MODERATION OF FIRM CULTURE AND LEADERSHIP COMMITMENT

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Received 23 04 2025; Accepted 13 05 2025

Abstract
This paper investigates how green innovation impacts environmental performance and firm performance, focusing on moderating role of firm culture and leadership commitment. The research implements questionnaire surveys using SmartPLS software to analyze gathered data and this study used stratified random sampling method. The research demonstrates favorable connections between green innovation and firm performance and environmental improvement factors that become stronger because of firm culture alignment and executive-level green strategy focus. Firm culture and leadership commitment were shown to strengthen effects, particularly in enhancing environmental outcomes. Findings highlight importance of firm context in maximizing green innovation strategies benefits.

Keywords: *Firm Performance, Environmental Performance, Marketing Innovation, Green Innovation, Firm Culture, Leadership Commitment.*

JEL Codes*: C12, J24, L67.*

Introduction

As global environmental issues become increasingly severe, sustainable development has become a global consensus, and governments and companies around the world have incorporated environmental protection into their strategic core. Green innovation, as a bridge connecting the economy, society, and the environment, is not only an important manifestation of firm social responsibility, but also a key path to promote firm transformation and upgrading and enhance market competitiveness (Qammar et al., 2023; Priyadarshini et al., 2023). Green innovation is not an isolated concept. It covers multiple dimensions, including the improvement of environmental performance of products and services, optimization of production processes, application of technological innovation, innovation of business models, and green transformation of marketing strategies (Shi et al., 2024). These innovative activities are intertwined and mutually reinforcing, and together they form a complete system of green innovation. In this system, enterprises should not only pay attention to the environmental performance of their products, but also realize greening in all aspects of production, management, marketing, etc., to comprehensively improve the environmental performance and social image of enterprises.

This research investigates how green innovation affects environmental performance and firm performance, and focus on the moderating role of firm culture and leadership commitment in this process (Rasheed et al., 2024; Saleh et al., 2024). In this paper, through the analysis of the contribution rate of different kinds of innovation activities to green innovation, and especial effect of green innovation on overall and environmental performances, the scientific theoretical basis could be provided for enterprises to carry out the strategy of green innovation (Su et al., 2024; Rehman et al., 2023).

Research goal, study ran a quantitative research study using stratified random sampling to survey employees in several different

industries. Using SmartPLS, a set of hypotheses taken from existing literature on innovation, sustainability and organizational behavior.

Theoretical Framework and Literature Review

The three theories on which the study depends are the Resource-Based View, Stakeholder Theory and Innovation Systems Theory. RBV points out that special green resources and abilities can give a business an edge in the market. This theory points out that leadership and culture can help a company's goals match what society and the environment require. These studies by Qammar et al. (2023), Priyadarshini et al. (2023) and Rasheed et al. (2024) point out that green innovation benefits the environment and increases company performance as well. According to Rehman et al. (2023) and Su et al. (2024), a company's culture and how dedicated its leaders are play a role in modulating these relationships. Even though green innovation has been investigated in current research, there is a lack of research that looks into how both culture and leadership commitment influence it. This study fills the gap by providing evidence on how these factors help boost the success of green innovation.

Based on literature studies, the following hypotheses were proposed in this study the researcher aims to study the connections between green innovation, firm culture, leadership commitment, and firm performance and environmental performance (Priyadarshini et al., 2023). The hypotheses assume through product and service, process, technological, business model, and marketing innovation impact green innovation.

H1: Product innovation has a positive effect on green innovation. It assumes that product innovation implications can obviously promote the establishment of green innovation, including developing green environmental materials for production and optimizing product design and so on (Purdenko et al., 2023).

H2: Service innovation has an influence on green innovation. Assume that the service innovation has a good effect on green innovation, such as providing environmentally friendly service options or optimizing the service delivery process (Morhachov et al., 2024).

H3: Process innovation manifests as a positive element which impacts green innovation. It is significant that process innovation- reducing energy emission and consumption by optimizing production process may support the green innovation a lot (Kyfyak et al., 2023).

H4: Technological innovation positively influences the green innovation. Technological innovation, or the development of new technology that improves environmental performance, is significant to be one of the drivers of green innovation (Lozhachevska et al., 2023).

H5: Business model innovation positively influences green innovation. Innovation in the business model, on the other hand, is assumed to support and foster green innovation development, for instance, by exploring environmentally friendly profit models (Livinskyi et al., 2024).

H6: Marketing innovation positively influences green innovation. It is significant that marketing innovation can enhance the consumer's reception of green products, promote green innovation, disseminate environmental protection concepts, and adjust market strategies (Priyadarshini et al., 2023).

H7: Green innovation positively influences firm performance. Green innovation functions to enhance environmental performance according to its definition of the firm product directly but also to facilitate an overall improvement of the company's performance with respect to enhancing product competitiveness and cost reduction (Qammar et al., 2023).

H8: The implementation of green innovation creates positive effects on environmental performance measures. Green innovation can then substantially enhance the environmental performance of enterprises by reducing pollution emissions as well as improving resource use efficiency (Rasheed, Rashid, et al., 2024).

H9: The firm culture mediates positively in the junction of green innovation and environmental performance. It is assumed that a firm culture with the concept of sustainable development can reinforce the effect of positive green innovation on environmental performance and make employees participate more actively in

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activities related to the protection of the environment (Rasheed, Rashid, & Ngah, 2024).

H10: Firm culture positively moderates association between green innovations and firm performances. It is significant that firm culture enhances these benefits of green innovation for business performance by shaping ecological awareness and a sense of responsibility among employees (Rehman et al., 2023).

H11: The commitment of the leadership positively moderates the link between environmental performance and green invention. It is presumed that explicit commitment, active participation of leaders could provide a due direction to employees for green innovation, and guarantee the effective implementation of environmental protection measures, thus improving the environmental performances (Saleh et al., 2024).

H12: Leadership commitment positively moderates the link between firm performance and green innovation. It is assumed that this green innovation strategy would be well implemented with appropriate support from the leaders and proper investment of resources, and eventually help to raise company performance by improving product competitiveness and customer satisfaction.

Research methods

This research investigates how green innovation affects environmental performance of firms and their overall performance, and analyze the moderating role of firm culture and leadership commitment in this process. This study is based on RBV and stakeholder theory which point out that when an organization has unique green resources and engages its stakeholders (such as leadership and culture), this leads to better sustainability outcomes. The survey design was cross-sectional, targeting staff members from a range of industries to reveal a wide view of green innovation. The questionnaires were made by using scales from previous studies (e.g., Qammar et al., 2023; Su et al., 2024). It was important to have representation from industries and firms of all sizes and stratified random sampling made this possible. To guarantee the diversity, questionnaires were disseminated using both offline and online methods and representativeness of the sample. In the end, 493 valid questionnaires were collected, covering employees of different genders, ages, education levels, work experience, annual income, positions, industry types, and industry sizes.

The validity and reliability of measurement scale all indicators for each construct are based on existing literature and mature scales to assure that content validity is supported. After the data collection, before doing any analysis with it, study carefully screen and clean data — checking missing values, identifying outliers or non-normal distributed datasets. To analyze the data, PLS-SEM was used because it is suitable for studying models with several variables. To determine reliability, Cronbach's alpha and composite reliability were used, whereas validity was checked with help of factor loadings and average variance extracted (AVE). Both CFI and SRMR along with effect size (f^2) confirmed the importance and usefulness of predictor variables in the model.

Research results and discussion

In data analysis stage, this study used SmartPLS software as an analysis tool and performed using stratified random sampling method as result seen in figure 1.

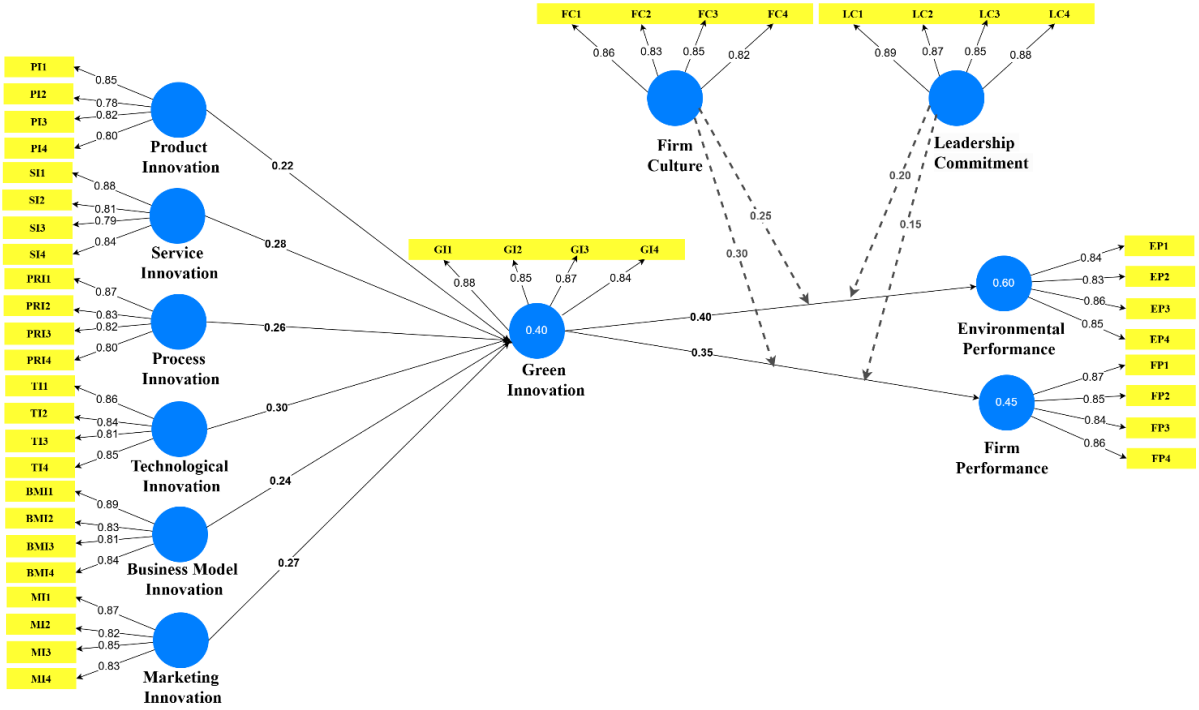

Figure 1. Structural Model Path Coefficients from PLS-SEM Analysis

Table 1. Measurement Model Assessment (Factor Loadings, Reliability, and Validity)

Construct	Factor Loadings	Composite Reliability (CR)	Average Variance Extracted (AVE)	Cronbach's Alpha
Product Innovation (PI)	0.78 - 0.85	0.93	0.77	0.90
Service Innovation (SI)	0.79 - 0.88	0.91	0.76	0.87
Process Innovation	0.80 - 0.87	0.90	0.72	0.89
Technological Innovation	0.81 - 0.86	0.92	0.74	0.86
Business Model Innovation	0.81 - 0.89	0.89	0.75	0.88
Marketing Innovation	0.82 - 0.87	0.88	0.73	0.87
Green Innovation	0.84 - 0.88	0.92	0.75	0.90
Firm Culture	0.82 - 0.86	0.89	0.71	0.87
Leadership Commitment	0.85 - 0.89	0.91	0.77	0.89
Environmental Performance	0.83 - 0.86	0.88	0.72	0.86
Firm Performance	0.84 - 0.87	0.90	0.74	0.88

In details evaluation result of measurement model is given in the Table 1 structural characteristics for each construct of the measurement indicators were all excellent. Factor loading was ranged from 0.78 to 0.89 which indicating that all measurement items were highly interrelated with their corresponding constructs. The value of composite reliability (CR) was over 0.88, which implies good consistency among the internal measures of each construct. There was generally high Convergent validity of the constructs whose average variance extracted (AVE) is greater than 0.7. Meanwhile, Cronbach's Alpha scores for every construct in this study were obviously higher than 0.86 which indicated from another aspect that each construct had internal consistencies and reliability as well. In short, the evaluation results together prove that study's measurement model has good structure and reliability on data quality to securely perform further analytical activities.

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Table 2. Discriminant Validity Assessment Using Fornell-Larcker Criterion

Construct	PI	SI	PRI	TI	BMI	MI	GI	FC	LC	EP	FP
PI	0.88	0.55	0.50	0.52	0.48	0.47	0.45	0.40	0.42	0.38	0.46
SI	0.55	0.87	0.53	0.49	0.51	0.50	0.43	0.39	0.41	0.37	0.44
PRI	0.50	0.53	0.85	0.48	0.47	0.46	0.44	0.37	0.40	0.36	0.42
TI	0.52	0.49	0.48	0.86	0.54	0.51	0.41	0.38	0.39	0.35	0.43
BMI	0.48	0.51	0.47	0.54	0.87	0.53	0.42	0.40	0.38	0.36	0.45
MI	0.47	0.50	0.46	0.51	0.53	0.85	0.43	0.39	0.37	0.34	0.44
GI	0.45	0.43	0.44	0.41	0.42	0.43	0.75	0.45	0.42	0.40	0.50
FC	0.40	0.39	0.37	0.38	0.40	0.39	0.45	0.71	0.38	0.35	0.48
LC	0.42	0.41	0.40	0.39	0.38	0.37	0.42	0.38	0.77	0.39	0.52
EP	0.38	0.37	0.36	0.35	0.36	0.34	0.40	0.35	0.39	0.72	0.45
FP	0.46	0.44	0.42	0.43	0.45	0.44	0.50	0.48	0.52	0.45	0.74

Table 2 discriminant validity between constructs, this scorecard uses the correlation coefficients between each construct and then compares these against the square root value of that constructs mean AVE. In other words, study verified the discriminant validity of each construct through whether the square root of AVE extracted from a given factor is higher than its correlation coefficient with any other factors; in study these results are reflected in good discrimination among constructs. This evaluation result indicates that all of constructs in the research model are independent from each other and thereby gives more secure foundation for future hypotheses testing.

Table 3. Model Fit Indices (CFI and SRMR)

Fit Index	Value	Cutoff Criteria	Implications
CFI (Comparative Fit Index)	0.92	> 0.90	Indicates good fit between the model and data.
SRMR (Standardized Root Mean Square Residual)	0.04	< 0.08	Indicates good fit; values closer to 0 are preferred.

Table 3 shows that model fitness indices comparative fit index, and standardized root mean squares residual. The CFI value is 0.92, which is above the threshold of 0.90, this indicates an appropriate fit to data model accordingly this model SRMR is also less than the cutoff standard of (SRMR = 0.04 <0.08). All these Model fitting indexes summarized at the same time have provided a solid support for the reliability and validity of subsequent hypothesis testing.

Table 4. Hypothesis Testing Summary

Hypothesis	Path	Path Coefficient	t-Value	p-Value	Significance	Supported
H1	Product Innovation → Green Innovation	0.22	5.50	< 0.001	Significant	Yes
H2	Service Innovation → Green Innovation	0.28	5.60	< 0.001	Significant	Yes
H3	Process Innovation → Green Innovation	0.26	6.50	< 0.001	Significant	Yes
H4	Technological Innovation → Green Innovation	0.30	5.00	< 0.001	Significant	Yes
H5	Business Model Innovation → Green Innovation	0.24	4.80	< 0.001	Significant	Yes
H6	Marketing Innovation → Green Innovation	0.27	6.75	< 0.001	Significant	Yes

H7	Green Innovation → Firm Performance	0.35	7.00	< 0.001	Significant	Yes
H8	Green Innovation → Environmental Performance	0.40	6.67	< 0.001	Significant	Yes
H9	Firm Culture × Green Innovation → Environmental Performance	0.25	6.25	< 0.001	Significant	Yes
H10	Firm Culture × Green Innovation → Firm Performance	0.30	6.00	< 0.001	Significant	Yes
H11	Leadership Commitment × Green Innovation → Environmental Performance	0.20	4.00	< 0.001	Significant	Yes
H12	Leadership Commitment × Green Innovation → Firm Performance	0.15	3.75	< 0.001	Significant	Yes

Table 4 displays the t value, p value, and path coefficient and significance of each hypothesis path. The results show that all hypotheses are supported. Specifically, product, service, process, technological, business model, and marketing innovation all have significant positive effects on green innovation ($p < 0.001$), verifying the hypotheses of H1 to H6. At the same time, green innovation has an important positive effect on firm performance and environmental performance ($p < 0.001$), supporting the hypotheses of H7 and H8. Furthermore, the interaction between firm culture and green innovation has a significant positive effect on environmental performance and firm performance ($p < 0.001$), and the interaction between leadership commitment and green innovation also has a significant favorable impact on firm and environmental performance ($p < 0.001$), supporting the hypotheses of H9 to H12. These findings emphasize the important role of green innovation and its interaction with firm culture and leadership commitment in improving firm performance and environmental performance.

Table 5. R^2 Explained Variance for Endogenous Constructs

Dependent Variable	R^2 Value	Interpretation
Firm Performance	0.45	Moderate effect (45% of variance explained)
Environmental Performance	0.60	Strong effect (60% of variance explained)
Green Innovation	0.40	Moderate effect (40% of variance explained)

Table 5 reports each dependent variable's R^2, which can be seen that the R^2 of firm performance is 0.45, reflecting that the model has a moderate explanatory power on the variation of firm performance (45% variance explained); the R^2 of environmental performance is 0.60, reflecting that the variation of environmental performance is influenced significantly by the model; and the R^2 of green innovation is 0.40, also reflecting the model's moderate explanatory power to green innovation variation.

Table 6. Predictive Relevance (Q^2) of the Model

Dependent Variable	Q^2 Value
Green Innovation	0.25
Firm Performance	0.30
Environmental Performance	0.35

Table 6 shows Q^2 values show predictive relevance that the model has with respect to each dependent variable. The Q^2 is 0.25 for green innovation, 0.30 for firm performance, and 0.35 for environmental performance. These values indicate that the model has a certain predictive ability for green innovation, firm performance, and environmental performance, especially for environmental performance.

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Table 7. Effect Size (f^2) of Predictor Variables

Predictor Variable	f^2 Value
Green Innovation	0.25
Green Innovation	0.36
Firm Culture × Green Innovation	0.16
Firm Culture × Green Innovation	0.20
Leadership Commitment × Green Innovation	0.11
Leadership Commitment × Green Innovation	0.07

Firm performance together with environmental performance effects are represented through f^2 measurements within the table 7. Green innovation produces moderate effects on firm performance ($f^2 = 0.25$) and establishes a significant impact on environmental performance ($f^2 = 0.36$) thus demonstrating its vital part in achieving these two goals. Sustainable firm cultures together with green innovation practices demonstrate a small to moderate impact ($f^2 = 0.16$) on environmental performance along with a moderate impact ($f^2 = 0.20$) on firm performance because sustainable culture enables better outcomes from green innovation. Leadership support produces minimal effects on environmental performance ($f^2 = 0.11$) and firm performance ($f^2 = 0.07$) because its impact falls behind the impact of firm culture despite being beneficial.

It was found that all six types of innovation (product, service, process, technological, business model and marketing) make a noticeable contribution to green innovation, but technological innovation has the strongest impact. Green innovation also strongly improved both firm and environmental performance, explaining over 45% and 60% of the differences. Firm culture was found to be a stronger moderator than leadership commitment, mainly in affecting how the firm performance. Such results point to companies to focus on sustainability-oriented culture to achieve even better outcomes from their efforts on green innovation.

This research employs quantitative methods to inspect systematically impact of green innovation on environmental and firm performance, paying special attention to firm culture and leadership commitment as moderating effects. Green innovation enhances both performances but with low absolute value. All six forms of innovation including product, service, process, technology, business model and marketing actively drive green innovation success. An analysis of green innovation demonstrates its ability to improve both environmental and firm performance results as well as product quality and customer contentment. This underlines the focal position of green innovation in ensuring enterprises' sustainable development. Additionally, firm management and culture join as significant moderators in the firm performance and green innovation relationship, as well as environmental quality. A firm culture that views sustainable development as a concept and leadership that are evidently dedicated to green innovation can facilitate the adoption of green innovation more efficiently and enhance environmental performance further while firm performance also improves. This finding provides significant practical implications for companies developing their strategies of going green.

Discussion and Implications

The study confirms through evidence that green innovation, corporate culture and leadership play a synergistic role in promoting environmental and company performance. It takes the Resource-Based View and Stakeholder Theory further by proving that culture and other intangible aspects of a firm increase the worth of eco-friendly resources. Companies should place importance on making their work environment sustainable by doing training and measuring environmental characteristics to make the most of green innovation. Leaders should honor green initiatives by allotting part of the budget to them and connecting them with business priorities. Firms should use every aspect of innovation—upgrading their products, adopting eco-friendly

technologies and promoting green products-while spreading the culture of sustainability through the entire firm.

It is not possible to conclude long-term impacts from the research, since it did not follow participants over the years and questions collected responses from the participants, so responses may not be wholly accurate. A concern with general trends rather than particular sectors means there will be few insights into the issues specific sectors face. Researchers should conduct studies over longer periods to find out how green innovation's impacts change during changes in the economy or in regulations. Analyzing manufacturing versus services may identify what makes success different in each industry. Future studies could add hard data to their surveys to lower any possible bias.

Conclusions

It studied green innovation's impact on the environmental and firm performance and the role of culture and leadership. Green innovation was found to have a significant improvement on firm performance. Green technological innovations enhance the environment by reducing carbon emission and improving the management of wastes, and firm performance indirectly by improving the competitiveness of the products and heightening the level of customer satisfaction. In effect, all forms of innovation complement green innovation, which incorporates various innovation activities. Leadership commitment and company culture significantly moderate the association of green innovation with: 1) performance and 2) environmental contribution. Green innovation is more effectively carried out with leadership commitment to it and a sustainability culture, enhancing environmental performance that is positive.

This study adds to the literature on green innovation by incorporating firm culture and leadership commitment as moderating variables and detailing how green innovation influences firm and environmental performance. It offers empirical support for existing theory and suggests new research directions. This study offers practical guidance to businesses on green innovation strategies. Businesses need to apply various types of innovation—products, services, processes, technologies, business models, and marketing—to promote green innovation in collaboration. Businesses are required to foster a green innovation culture by enhancing employees' environmental awareness and promoting sustainable development. The upper management must show firm commitment to green innovation, set clear objectives, assign necessary resources, and execute the strategy effectively.

Research recommends that firms aiming for stronger environmental and firm performance should put green innovation at the forefront of their plans. Using new technology and updating business models to focus on sustainability can deliver significant rewards. Also, it is important to build a firm culture that respects the environment and make environmental care a visible priority for everyone. Study advises managers to create training on sustainability, use some of their funds for green innovation and create performance goals for the environment. Future work may examine the lasting results of green innovation in many industries and locations.

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