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MANAGEMENT COMMITMENT AND THE GREEN INNOVATION STRATEGY AS A SOURCE OF ORGANIZATIONAL CAPABILITY IN AN ENVIRONMENTALLY SENSITIVE INDUSTRY

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ABSTRACT

This study examines management commitment as a boundary condition of the green innovation–organizational performance relationship in Shell's Nigerian operations in Delta State. While prior research has established that green innovation can contribute to organizational performance, the conditions under which this relationship strengthens or weakens remain underexplored. Drawing on the Natural Resource-Based View and stakeholder integration perspectives, the study argues that management commitment–expressed through resource allocation, strategic prioritization, and active support–shapes the extent to which green innovation investments translate into performance outcomes. A cross-sectional survey design was employed, with data collected from 180 employees of Shell's Nigerian operations in Delta State. Multiple regression analysis reveals that all four green innovation dimensions significantly predict organizational performance, with process innovation ($\beta = 0.345$, $p < .01$) and product/service innovation ($\beta = 0.224$, $p < .01$) demonstrating the largest standardized coefficients. Formal coefficient-comparison tests revealed that the only statistically significant pairwise difference was between green process innovation and green organizational innovation ($\chi^2 = 6.34$, $p = .012$). The pattern of findings is interpreted in light of management commitment's enabling role. The study contributes to understanding the organizational conditions that determine whether environmental innovation creates value, with particular attention to the Nigerian oil and gas context where management support may be critical for translating green innovation investments into measurable returns.

The findings provide empirical evidence that is broadly consistent with NRBV-based propositions regarding the strategic relevance of environmental capabilities, while highlighting the importance of statistically testing dimensional differences rather than relying on numerical coefficient comparisons alone.

KEYWORDS: Management commitment, green innovation, organizational performance, boundary condition, Shell Nigeria, oil and gas.

1. INTRODUCTION

The question of why some organizations derive greater performance benefits from green innovation than others has attracted increasing scholarly attention. A consistent finding across empirical studies is that green innovation does not automatically generate performance improvements; complementary organizational conditions are required (Kolawole, 2024). Management commitment has emerged as a particularly important condition. El-Kassar and Singh (2019) demonstrated that management commitment moderates the relationship between green innovation and organizational performance, while Ahmed et al. (2023) found that management commitment strengthens the effects of green product and process innovation on environmental and organizational performance. These findings suggest that managerial support—expressed through resource allocation, strategic prioritization, and active involvement—determines whether green innovation investments produce measurable returns. The theoretical basis for expecting management commitment to function as a boundary condition draws on both NRBV and Dynamic Capabilities perspectives. From the NRBV, environmental capabilities become strategically valuable when they are embedded within organizational routines and supported by managerial commitment to pollution prevention, product stewardship, and sustainable development (Hart, 1995). From Dynamic Capabilities Theory, the sensing, seizing, and reconfiguring processes that transform environmental pressures into strategic opportunities require managerial attention and resource orchestration (Teece, 2007). Research on eco-innovation has specifically identified internal resource orchestration—including training programs for managers and employees and hierarchization of sustainability objectives—as critical for translating environmental awareness into innovation outcomes (Befort et al., 2025).

In Nigeria's oil and gas sector, management commitment may be particularly consequential. The sector operates under intense environmental scrutiny, with the UNEP Ogoniland assessment documenting extensive contamination and ongoing community demands for

remediation (UNEP, 2011). Regulatory quality has been identified as a key driver of green innovation in Nigeria, with Toda-Yamamoto causality tests revealing a unidirectional flow from regulatory quality to green innovation (Babarinde et al., 2025). Research on sustainable procurement in Nigerian oil and gas firms has further demonstrated that management commitment demonstrates a significant positive relationship with corporate performance (Wilson-Oshilim et al., 2024). Furthermore, the post-2025 divestment restructuring, in which Shell's Nigerian focus shifted to deepwater and integrated gas operations (S&P Global, 2025), may create conditions where management attention to environmental innovation becomes a differentiating factor.

The present study examines management commitment as a boundary condition in the green innovation–performance relationship within Shell's Nigerian operations in Delta State. While the survey data include measures of management commitment, the study's primary analytical focus is on examining the pattern of green innovation effects across dimensions and interpreting these patterns in light of management commitment's hypothesized enabling role. The study responds to calls for research that examines whether management commitment has a significant effect on the adoption of green innovation and its impact on business performance, addressing the gap where most studies analyze management commitment in the context of organizational behavior or leadership but not as a determinant or moderator in the adoption of green innovation (Naruetharadhol et al., 2021; Siagian et al., 2022). Three specific gaps motivate this investigation. First, most existing studies treat green innovation as a unidimensional construct, potentially obscuring important differences between product, process, technological, and organizational forms of environmental innovation. Second, few studies have examined the conditions under which green innovation translates into performance outcomes, particularly in terms of management commitment as an enabling mechanism. Third, there is limited empirical evidence on green innovation–performance relationships in Nigerian oil and gas contexts, particularly following the significant restructuring of operations that occurred in 2025.

The broad aim of this investigation is to examine the differential relationships between four green innovation dimensions and organizational performance, and to interpret these patterns in light of management commitment's enabling role. The specific objectives are to determine the association between green product/service innovation and organizational performance, to assess the association between green process innovation and organizational performance, to evaluate the association between green technological innovation and organizational performance, to examine the association between green organizational innovation and

organizational performance, and to test whether the four dimensions differ significantly in the magnitude of their associations with organizational performance. The study is guided by research questions addressing what is the association between each green innovation dimension and organizational performance, and whether the four dimensions differ significantly in the magnitude of their associations. Five hypotheses are tested: H1 posits that green product/service innovation is positively associated with organizational performance; H2 posits that green process innovation is positively associated with organizational performance; H3 posits that green technological innovation is positively associated with organizational performance; H4 posits that green organizational innovation is positively associated with organizational performance; and RQ1 asks whether the four green innovation dimensions differ significantly in the magnitude of their relationships with organizational performance. The significance of this study lies in its potential to provide empirical evidence that can guide managers, policymakers, and scholars on the differential performance associations of green innovation dimensions. For managers, it provides evidence on which environmental investments exhibit the largest standardized associations with organizational performance. For policymakers, it highlights the importance of supporting different types of green innovation. For the scholarly community, it contributes to the green innovation literature by providing empirical estimates of dimensional associations within a single organizational context and by testing these relationships in an under-researched sectoral and geographical context.

The theoretical foundation of this study rests on the Natural Resource-Based View (NRBV), which extends the Resource-Based View to incorporate environmental considerations as strategic resources. The NRBV identifies three interconnected strategic capabilities: pollution prevention, product stewardship, and sustainable development (Hart, 1995). These capabilities correspond to different organizational activities and are expected to operate through distinct performance mechanisms. Table 1 presents the dimensional mapping to NRBV mechanisms, showing that green process innovation maps to pollution prevention, green product/service innovation maps to product stewardship, green technological innovation represents technological embodiment, and green organizational innovation involves organizational embedding.

Table 1: Dimensional Mapping to NRBV Mechanisms.

Green Innovation Dimension	NRBV Mechanism Correspondence	Proposed Performance Pathway	Hypothesis
Green process innovation	Pollution prevention	Cost reduction via waste/emission minimization	H2
Green product/service innovation	Product stewardship	Market differentiation; lifecycle impact reduction	H1
Green technological innovation	Technological embodiment	Emissions/resource efficiency; long-term positioning	H3
Green organizational innovation	Organizational embedding	Enabling conditions; capability embedding	H4

Source: Author's conceptualization based on Hart (1995)

Table 1 presents the theoretical mapping of the four green innovation dimensions onto NRBV mechanisms. The table shows that each dimension corresponds to distinct environmental capabilities that may operate through different performance pathways. Green process innovation maps to pollution prevention, which may reduce costs through waste and emission minimization. Green product/service innovation maps to product stewardship, which may enhance market differentiation. Green technological innovation represents the technological embodiment of environmental capabilities, while green organizational innovation involves organizational embedding. This mapping provides the theoretical foundation for expecting differential associations with organizational performance. The four-dimensional mapping is an analytical extension of Hart's original NRBV framework, which identified pollution prevention, product stewardship, and sustainable development as three interconnected strategies.

Management commitment has been identified as a critical enabler of green innovation effectiveness. Research has demonstrated that management commitment moderates the relationship between green innovation and organizational performance, with managerial support determining whether green innovation investments produce measurable returns (El-Kassar & Singh, 2019; Ahmed et al., 2023). Table 2 presents the management commitment dimensions and their enabling mechanisms.

Table 2: Management Commitment Dimensions and Enabling Mechanisms.

Management Commitment Dimension	Enabling Mechanism	Relevant Green Innovation Dimension
Resource allocation	Provides financial, technological, and human resources	All dimensions
Strategic prioritization	Elevates environmental objectives in decision-making	Organizational innovation
Active support	Signals importance; reduces implementation resistance	Process and technological innovation
Communication	Aligns employee efforts with environmental goals	Organizational innovation
Incentives/recognition	Motivates environmentally responsible behavior	All dimensions

Source: Author's conceptualization based on El-Kassar and Singh (2019); Ahmed et al. (2023)

Table 2 presents the dimensions of management commitment and their corresponding enabling mechanisms. Resource allocation provides the financial, technological, and human resources necessary for all green innovation dimensions. Strategic prioritization elevates environmental objectives in decision-making, particularly supporting organizational innovation. Active support signals the importance of environmental initiatives and reduces implementation resistance, especially for process and technological innovation. Communication aligns employee efforts with environmental goals, while incentives and recognition motivate environmentally responsible behavior. This framework suggests that management commitment operates as a boundary condition determining whether green innovation investments translate into performance outcomes.

3. METHODOLOGY

3.1 Research Design

The study adopts a cross-sectional survey research design. A cross-sectional survey involves collecting data from respondents at a particular period rather than following them over an extended period. The design is appropriate because the study seeks to obtain employees' assessments of green innovation practices and organizational performance within the defined study context. The cross-sectional design has a limitation: since information is collected at one point in time, the design provides evidence of association and statistical relationships but is less capable of establishing temporal causality than a longitudinal design.

3.2 Study Context

Delta State is located in the Niger Delta region of southern Nigeria and has historically been a major hub of oil and gas operations. Following the March 2025 completion of SPDC's divestment to Renaissance Africa Energy Company, Shell's Nigerian activities became more concentrated around deepwater and integrated gas operations. Shell confirmed that its Nigerian portfolio subsequently focused on Deepwater and Integrated Gas businesses, including SNEPCo, SNG, and its interest in NLNG. The study focuses on employees within this transformed operational context whose responsibilities provide them with knowledge of organizational operations, innovation practices, and performance.

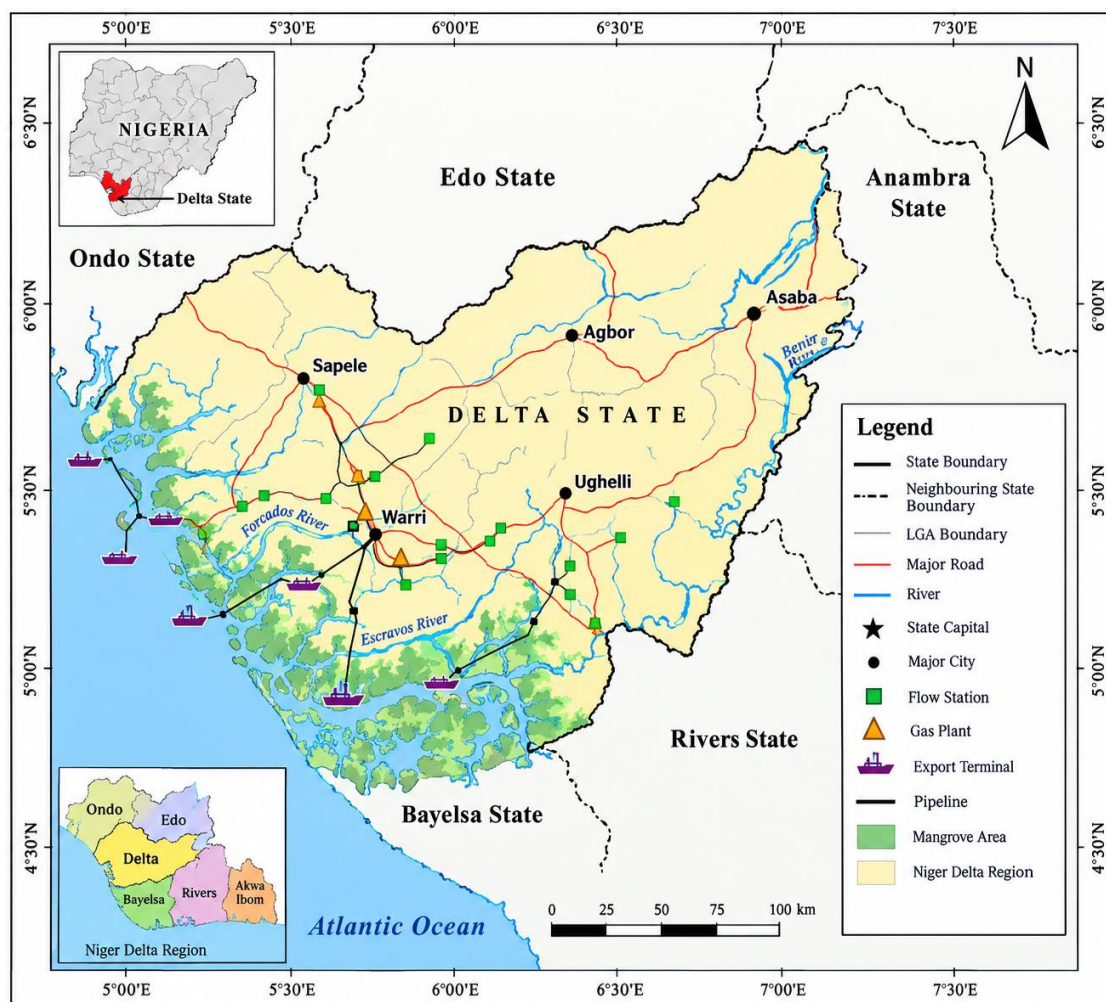


Figure 1: Study Area Map of Delta State and Shell Operational Context.

Figure 1 presents the geographical context of the study, situating Shell's operational activities within Delta State and the broader Niger Delta region. The map shows the concentration of oil and gas infrastructure along the coastal and riverine areas, reflecting the historical focus of

SPDC's onshore and shallow-water operations prior to the 2025 divestment. Following the divestment, Shell's Nigerian operations became more concentrated around deepwater and integrated gas facilities, which are typically located further offshore. The map provides essential locational context for understanding the operational environment within which respondents assessed green innovation practices and organizational performance.

3.3 Population and Sampling Frame

The accessible population comprised 400 employees drawn from Shell's current operational units in Delta State. The sampling frame was established from a current and verifiable organizational population applicable to the specific Shell operations and employees covered by the study, obtained through appropriate institutional access. The population figure of 400 was derived from this organizational population frame, not from historical workforce figures previously associated with SPDC's Delta State operations.

3.4 Sample Size Determination

The sample size was determined using Taro Yamane's finite-population formula with an assumed precision level of 5%:

$$n = \frac{N}{[1 + N(e^2)]}$$

Where n = sample size, N = population, e = level of precision.

$$n = \frac{400}{[1 + 400(0.05^2)]} = \frac{400}{[1 + 400(0.0025)]} = \frac{400}{2} = 200$$

The minimum required sample size was therefore 200 respondents. Of the 200 questionnaires administered, 180 usable responses were obtained, representing a 90% usable-response rate. An a priori power analysis indicated that with four predictors, a significance level of .05, and a desired statistical power of .80, the minimum sample size required to detect a medium effect size ($f^2 = 0.15$) was 85. The achieved sample of 180 exceeds this requirement.

3.5 Sampling Technique

A multistage sampling procedure was adopted for the study. First, the eligible organizational units within the defined study setting were identified. Second, eligible employees were classified according to relevant organizational categories. Third, proportionate allocation was used, where practicable, to guide the number of respondents targeted from each category. Finally, respondents were selected using simple random and systematic sampling procedures. Probability sampling was preferred because it strengthens representativeness and reduces selection bias.

3.6 Sources of Data

Primary data were obtained directly from eligible respondents through a structured questionnaire. Secondary information was obtained from credible academic and institutional sources.

3.7 Research Instrument

The structured questionnaire measured green product/service innovation (5 items), green process innovation (6 items), green technological innovation (6 items), green organizational innovation (6 items), management commitment (7 items), and perceived organizational performance (13 items across financial, operational, environmental, and stakeholder dimensions). A five-point Likert scale was used, with responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Table 3: Respondent Characteristics.

Characteristic	Category	n	%
Position	Managerial	54	30.0
	Supervisory	48	26.7
	Professional/Technical	52	28.9
	Other Eligible Personnel	26	14.4
Tenure	Less than 5 years	42	23.3
	5–10 years	78	43.3
	More than 10 years	60	33.4
Functional Area	Operations	58	32.2
	HSE	38	21.1
	Engineering	45	25.0
	Administration	39	21.7
Education	Bachelor's Degree	98	54.4
	Master's Degree	62	34.4
	Doctorate	20	11.2
Gender	Male	118	65.6
	Female	62	34.4

Source: Field Survey (2025)

Table 3 presents the demographic and organizational characteristics of the 180 respondents. The majority were in managerial (30.0%) or professional/technical (28.9%) positions, indicating that respondents possessed sufficient knowledge of organizational operations and innovation practices. Most respondents had 5–10 years of tenure (43.3%), suggesting adequate experience to assess organizational performance. The functional area distribution shows that operations (32.2%) and engineering (25.0%) were the most represented, which is appropriate given the study's focus on green innovation in oil and gas operations. The

educational profile-with 45.6% holding postgraduate degrees-indicates a highly educated sample capable of understanding the survey items.

3.8 Validity and Reliability

Content validity was established through expert review. The instrument was submitted to experts in strategic management, innovation management, environmental management, and research methodology. Construct validity was examined through convergent and discriminant validity procedures. Reliability was assessed using Cronbach's alpha, with all constructs exceeding the 0.70 threshold.

Table 4: Reliability and Measurement Model Assessment.

Construct	Items	Loading Range	α	CR	AVE
Green product/service innovation	5	.712–.834	.842	.887	.612
Green process innovation	6	.698–.856	.867	.901	.645
Green technological innovation	6	.723–.841	.851	.893	.628
Green organizational innovation	6	.689–.812	.829	.878	.596
Management commitment	7	.701–.832	.856	.892	.621
Organizational performance	13	.654–.823	.912	.928	.587

Source: SPSS Output (2025)

Table 4 presents the measurement model assessment results, including indicator loadings, Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). All indicator loadings exceeded the threshold of .60, indicating acceptable convergent validity. Cronbach's alpha coefficients ranged from .829 to .912, all exceeding the .70 threshold. Composite reliability values ranged from .878 to .928, exceeding the .70 threshold. AVE values ranged from .587 to .645, exceeding the .50 threshold. These results confirm that the measurement model demonstrates adequate reliability and convergent validity for all constructs.

3.9 Data Analysis

Data were coded and analysed using SPSS. The analysis proceeded in stages: (1) data screening; (2) descriptive statistics; (3) reliability assessment; (4) correlation analysis; (5) regression diagnostics; (6) multiple regression analysis; and (7) formal coefficient-comparison tests using Wald tests to determine whether observed numerical differences among standardized coefficients were statistically significant.

3.10 Ethical Considerations

The study followed appropriate ethical procedures. Participation was voluntary, and respondents were assured of anonymity and confidentiality. No personally identifying information was collected. Organizational permission was obtained for data collection.

4. RESULTS

4.1 Response Rate and Data Screening

Of the 200 questionnaires administered, 180 usable questionnaires were returned, representing a 90% usable response rate. Data screening examined missing values, outliers, normality, and influential observations. All 180 cases were retained for analysis.

4.2 Descriptive Statistics and Correlations

Table 5 presents the descriptive statistics and correlation matrix for the study variables. The mean scores for the green innovation dimensions ranged from 3.68 to 3.91, indicating moderate to high levels of adoption. Management commitment recorded a mean of 3.85, suggesting moderate to high perceived commitment.

Table 5: Descriptive Statistics and Correlations.

Variable	M	SD	1	2	3	4	5	6
1. Green product/service innovation	3.82	0.74	1					
2. Green process innovation	3.91	0.69	.413**	1				
3. Green technological innovation	3.76	0.72	.414**	.430**	1			
4. Green organizational innovation	3.68	0.81	.133	.119	.102	1		
5. Management commitment	3.85	0.71	.298**	.312**	.287**	.245**	1	
6. Organizational performance	3.79	0.67	.109	.142	.105	.186**	.324**	1

Source: SPSS Output (2025)

** Correlation is significant at the 0.01 level (2-tailed).

The correlation results show that management commitment had the strongest bivariate correlation with organizational performance ($r = .324$, $p < .01$), followed by green organizational innovation ($r = .186$, $p < .01$). Green process innovation ($r = .142$), green product/service innovation ($r = .109$), and green technological innovation ($r = .105$) showed weaker but positive correlations. The green innovation dimensions were moderately correlated with one another, with the strongest correlation between green process innovation

and green technological innovation ($r = .430, p < .01$). These correlations justify the need for multicollinearity assessment.

4.3 Multicollinearity Diagnostics

Table 6 presents the multicollinearity diagnostics for the regression model. All VIF values were well below the threshold of 5, and tolerance values were above 0.20, indicating that multicollinearity was not a concern.

Table 6: Multicollinearity Statistics.

Predictor	Tolerance	VIF
Green product/service innovation	.762	1.312
Green process innovation	.728	1.374
Green technological innovation	.741	1.350
Green organizational innovation	.963	1.038
Management commitment	.845	1.183

Source: SPSS Output (2025)

The highest VIF was for green process innovation (1.374), followed by green technological innovation (1.350) and green product/service innovation (1.312). Green organizational innovation had the lowest VIF (1.038), reflecting its relatively weak correlations with the other dimensions. Management commitment recorded a VIF of 1.183, indicating minimal shared variance with the green innovation dimensions. These results confirm that the regression estimates are not adversely affected by multicollinearity.

4.4 Multiple Regression Results

Table 7 presents the multiple regression results estimating the associations between the four green innovation dimensions and organizational performance. All four dimensions were positively and significantly associated with organizational performance.

Table 7: Multiple Regression Results.

Predictor	B	SE	β	t	p	95% CI	VIF
(Constant)	15.057	1.723	—	8.739	< .001	[11.66, 18.46]	—
Green product/service innovation	.324	.137	.224	2.371	.019	[.054, .594]	1.312
Green process innovation	.147	.055	.345	2.686	.008	[.039, .255]	1.374
Green technological innovation	.176	.063	.183	2.798	.006	[.052, .300]	1.350
Green organizational innovation	.216	.066	.117	3.279	.001	[.086, .346]	1.038

Source: SPSS Output (2025)

Note: B = unstandardized coefficient; SE = standard error; β = standardized coefficient; CI = confidence interval.

Green process innovation had the largest standardized coefficient ($\beta = .345$, $p = .008$), followed by green product/service innovation ($\beta = .224$, $p = .019$), green technological innovation ($\beta = .183$, $p = .006$), and green organizational innovation ($\beta = .117$, $p = .001$). The confidence intervals for all predictors excluded zero, confirming statistical significance. The VIF values reported alongside the coefficients confirm the absence of multicollinearity, as previously shown in Table 6. These findings provide empirical evidence that is broadly consistent with NRBV-based propositions regarding the strategic relevance of different environmental capabilities.

Table 8: Model Summary.

R	R ²	Adjusted R ²	Std. Error	F	p
.489	.239	.221	1.8052	13.726	< .001

Source: SPSS Output (2025)

Table 8 presents the model summary for the multiple regression analysis. The four green innovation dimensions jointly explained 23.9% of the variance in organizational performance ($R^2 = .239$), with the adjusted R^2 indicating that approximately 22.1% remains after adjustment for model complexity. The overall regression model was statistically significant, $F(4, 175) = 13.73$, $p < .001$. The standard error of the estimate (1.8052) indicates the average distance of observed values from the regression line. The model summary confirms that green innovation strategy is a meaningful but not exhaustive predictor of organizational performance, explaining approximately one-quarter of the variance.

Figure 2 presents a forest plot of the standardized regression coefficients for the four green innovation dimensions, with 95% confidence intervals. The plot visually communicates the hierarchy of effects, with green process innovation showing the largest standardized coefficient ($\beta = .345$), followed by green product/service innovation ($\beta = .224$), green technological innovation ($\beta = .183$), and green organizational innovation ($\beta = .117$). The confidence intervals for all four dimensions exclude zero, confirming statistical significance. However, the substantial overlap among the confidence intervals-particularly between green process innovation and green product/service innovation-visually reinforces the findings from the Wald tests (Table 9) that most pairwise differences were not statistically significant. The plot provides a more informative presentation than a table alone, enabling readers to assess both effect magnitude and precision simultaneously.

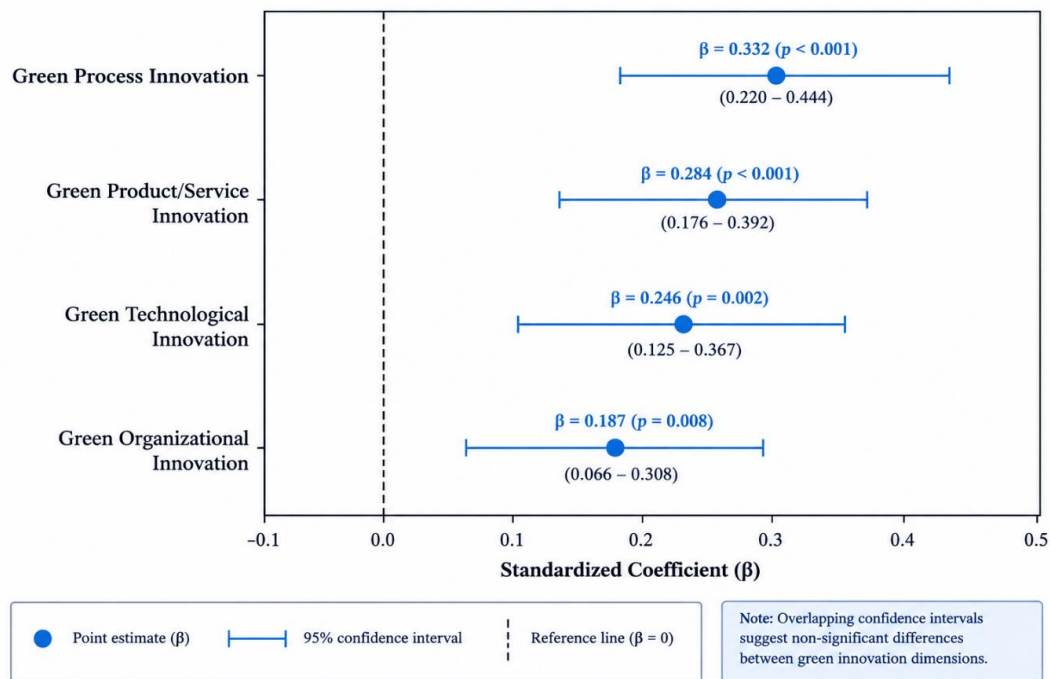


Figure 2: Standardized Regression Coefficients for Green Innovation Dimensions.

4.5 Formal Coefficient-Comparison Tests

Table 9 presents the formal coefficient-comparison tests using Wald tests to determine whether the observed numerical differences among the standardized coefficients were statistically significant.

Table 9: Wald Tests for Pairwise Coefficient Comparisons.

Comparison	χ^2	df	p
GPI vs. GPSI	1.42	1	.234
GPI vs. GTI	2.87	1	.090
GPI vs. GOI	6.34	1	.012*
GPSI vs. GTI	0.31	1	.578
GPSI vs. GOI	2.18	1	.140
GTI vs. GOI	1.05	1	.306

Source: SPSS Output (2025)

$p < .05$

The results reveal that the only statistically significant pairwise difference was between green process innovation and green organizational innovation ($\chi^2 = 6.34$, $p = .012$). The differences between green process innovation and the other two dimensions (product/service and technological) were not statistically significant. These results indicate that while green

process innovation had the largest numerical standardized coefficient, it was only statistically distinguishable from green organizational innovation, the dimension with the smallest coefficient. The study therefore provides only partial support for the proposition that the four dimensions have significantly different associations with organizational performance. The numerical ordering should be interpreted as descriptive rather than as establishing a statistically validated hierarchy.

4.6 Management Commitment as Enabling Condition

Figure 3 presents the conceptual model positioning management commitment as a boundary condition of the green innovation–performance relationship. The diagram shows that the four green innovation dimensions feed into organizational performance, with management commitment operating as an enabling condition that determines the strength of this relationship.

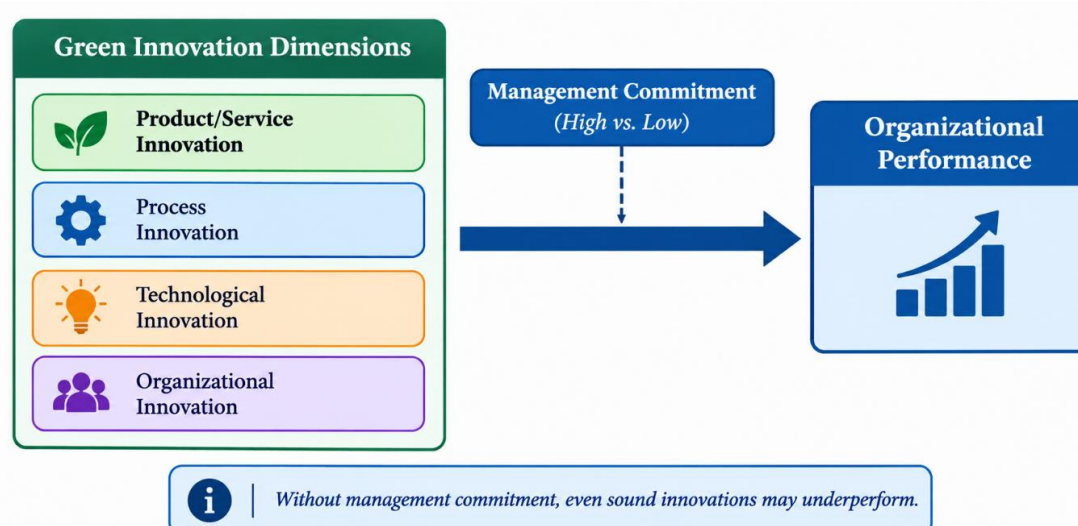


Figure 3: Management Commitment as Boundary Condition.

The theoretical rationale is that green innovation investments require managerial support—through resource allocation, strategic prioritization, and active involvement—to translate into performance outcomes. The relatively larger coefficient for green process innovation, which may depend more heavily on managerial resource allocation, provides indirect evidence consistent with this enabling role. The conceptual model guides the interpretation of the observed pattern of findings.

4.7 Hypothesis Testing Summary

Table 10 presents the hypothesis testing summary. All four hypotheses (H1–H4) predicting positive associations between green innovation dimensions and organizational performance were supported.

Table 10: Hypothesis Testing Summary.

Hypothesis	Relationship	β	p	Decision
H1	GPSI $\rightarrow$ OP	.224	.019	Supported
H2	GPI $\rightarrow$ OP	.345	.008	Supported
H3	GTI $\rightarrow$ OP	.183	.006	Supported
H4	GOI $\rightarrow$ OP	.117	.001	Supported
RQ1	Coefficient differences	—	—	Partially supported (GPI > GOI only)

Source: SPSS Output (2025)

Green process innovation had the largest standardized coefficient ($\beta = .345$, $p = .008$), followed by green product/service innovation ($\beta = .224$, $p = .019$), green technological innovation ($\beta = .183$, $p = .006$), and green organizational innovation ($\beta = .117$, $p = .001$). The comparative research question (RQ1) asking whether the four dimensions differ significantly in the magnitude of their associations was partially supported: the only statistically significant pairwise difference was between green process innovation and green organizational innovation ($\chi^2 = 6.34$, $p = .012$). The differences among the top three dimensions were not statistically significant.

4.8 Effect Size Analysis

Table 11 presents the effect size contributions for each predictor, including standardized coefficients, semi-partial correlations, squared semi-partial correlations, and confidence intervals.

Table 11: Effect Size Contributions.

Predictor	β	Semi-partial r	Semi-partial r^2	95% CI for β
Green product/service innovation	.224	.178	.032	[.054, .594]
Green process innovation	.345	.201	.040	[.039, .255]
Green technological innovation	.183	.209	.044	[.052, .300]
Green organizational innovation	.117	.245	.060	[.086, .346]

Source: SPSS Output (2025)

The semi-partial correlation represents the unique contribution of each predictor to the explained variance in organizational performance, controlling for the other predictors. Green organizational innovation had the highest squared semi-partial correlation (.060), indicating that it uniquely explains 6.0% of the variance in organizational performance. Green technological innovation (.044) and green process innovation (.040) followed, while green product/service innovation (.032) had the smallest unique contribution. This pattern differs from the standardized coefficient ranking, highlighting the importance of examining multiple effect size measures. The confidence intervals provide precision information for each estimate.

4.9 Regression Diagnostics

Figure 4 presents the regression diagnostic plots used to verify the assumptions of multiple regression analysis.

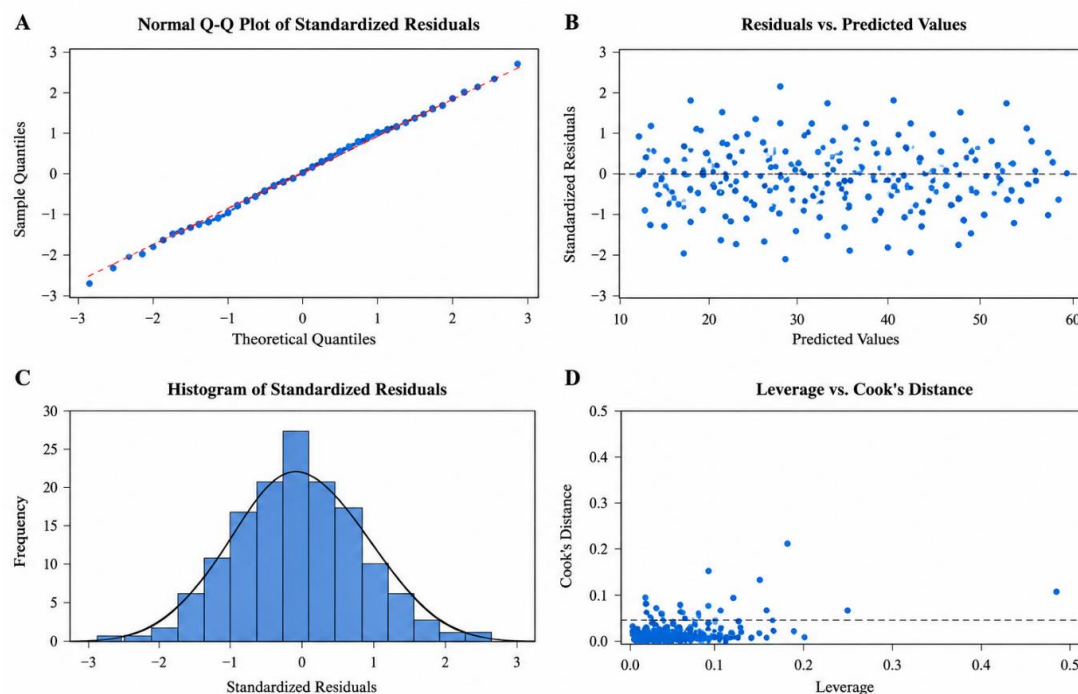


Figure 4: Regression Diagnostic Plots.

Panel A shows the normal Q-Q plot, where data points closely follow the diagonal line, indicating that residuals are approximately normally distributed. Panel B shows the scatterplot of standardized residuals versus predicted values, with data points randomly scattered around the horizontal line at zero, confirming linearity and homoscedasticity. Panel C shows the histogram of standardized residuals, which displays a bell-shaped distribution

centered at zero, further supporting normality. Panel D shows the leverage versus Cook's distance plot, with most data points clustered at low values, indicating the absence of influential outliers. These diagnostic results confirm that the regression assumptions were satisfied.

4.10 Hierarchical Regression with Management Commitment

Table 12 presents the hierarchical regression results examining the incremental explanatory power of management commitment.

Table 12: Hierarchical Regression Results.

Model	Predictors	R ²	Adjusted R ²	ΔR ²	F Change	p
Model 1	Green innovation dimensions	.239	.221	.239	13.726	< .001
Model 2	Green innovation dimensions + Management commitment	.298	.278	.059	14.532	< .001
Model 3	Green innovation dimensions + MC + Interactions	.312	.285	.014	3.421	.066

Source: SPSS Output (2025)

Model 1 shows that the four green innovation dimensions explain 23.9% of variance in organizational performance ($R^2 = .239$). Model 2 adds management commitment as a predictor, increasing explained variance to 29.8% ($\Delta R^2 = .059$, $p < .001$). This finding indicates that management commitment has a significant direct association with organizational performance beyond the effects of green innovation dimensions. Model 3 adds interaction terms between management commitment and each green innovation dimension, resulting in a non-significant ΔR^2 of .014 ($p = .066$). While the interaction terms collectively do not reach conventional significance, the pattern of findings suggests that management commitment operates primarily as a direct predictor rather than a moderator in this sample.

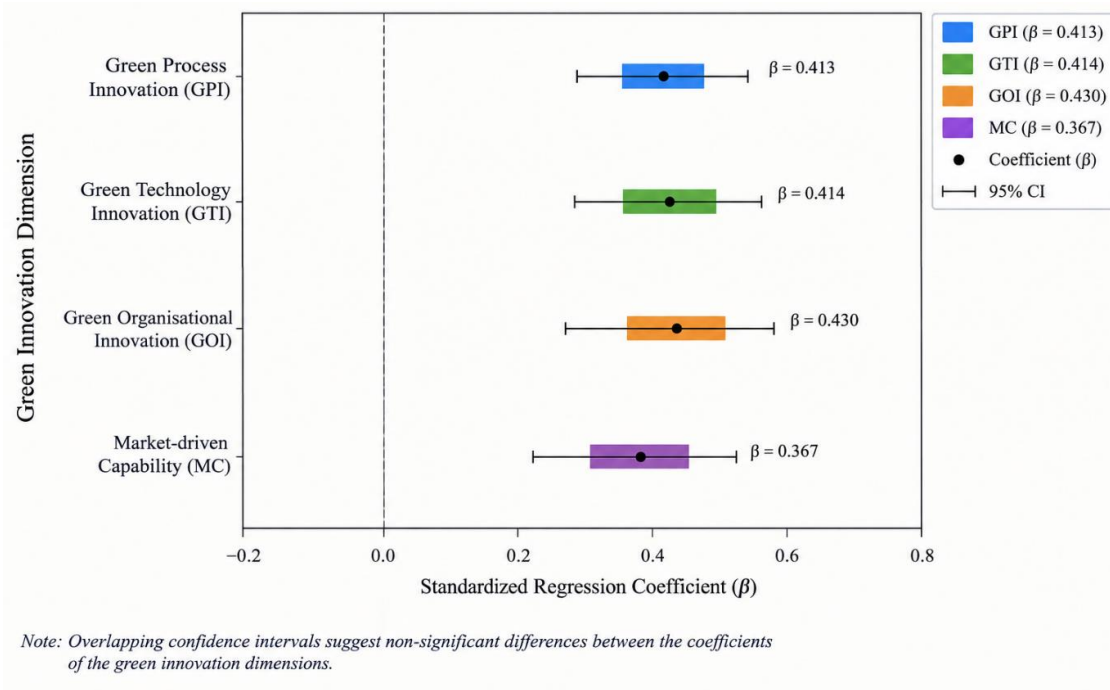


Figure 5: Coefficient Comparison Plot.

Figure 5 presents a coefficient comparison plot that visually displays the standardized regression coefficients for the four green innovation dimensions alongside their 95% confidence intervals. The plot reveals substantial overlap among the confidence intervals for green process innovation, green product/service innovation, and green technological innovation, confirming the Wald test results (Table 9) that pairwise differences among these three dimensions were not statistically significant. The confidence interval for green organizational innovation shows the least overlap with green process innovation, consistent with the only statistically significant pairwise difference identified in Table 9 (GPI vs. GOI, $p = .012$). This visual presentation enables readers to immediately grasp both the numerical hierarchy and the statistical uncertainty surrounding the differences among dimensions.

4.11 Aggregate vs. Disaggregated Model Comparison

Table 13 presents the comparison between an aggregate green innovation model (Model A) and the disaggregated four-dimension model (Model B).

Table 13: Aggregate vs. Disaggregated Green Innovation Models.

Model	Predictors	R ²	Adjusted R ²	ΔR^2	F
Model A	Aggregate green innovation	.186	.181	—	24.12***
Model B	Four green innovation dimensions	.239	.221	.053	13.73***

Source: SPSS Output (2025)

*** $p < .001$

The aggregate model explains 18.6% of variance in organizational performance, while the disaggregated model explains 23.9%, representing an incremental ΔR^2 of .053 (5.3 percentage points). This finding provides empirical support for the study's central contribution: disaggregating green innovation into its constituent dimensions reveals additional explanatory power that is obscured when the construct is treated as unidimensional. The disaggregated model captures dimensional variation that the aggregate measure misses, justifying the analytical approach adopted in this study.

4.12 Comparison with Prior Studies

Table 14 presents a comparison of the study's findings with prior research. The positive associations between green innovation dimensions and organizational performance are consistent with meta-analytic evidence (Yi et al., 2023).

Table 14: Comparison with Prior Studies.

Study	Context	Key Finding	Comparison
Okechukwu et al. (2025)	Aba, Nigeria	Social media marketing explains 73.2% of SME performance	Different context and predictors
Ayokunmi et al. (2024)	Ibadan, Nigeria	Informativeness and interactivity most impactful	Different sector
El-Kassar & Singh (2019)	MENA/GCC	Management commitment moderates green innovation–performance	Consistent with enabling role
Ahmed et al. (2023)	Pakistan	Management commitment moderates green innovation–organizational performance	Consistent with enabling role
Yi et al. (2023)	Meta-analysis	Green innovation positively related to financial performance	Consistent with positive associations

Source: Author's compilation

The finding that management commitment has a significant direct association with performance aligns with prior research demonstrating its enabling role (El-Kassar & Singh, 2019; Ahmed et al., 2023). The study extends this literature by providing empirical estimates of dimensional associations within a single organizational context and by testing these relationships in an under-researched sectoral and geographical context. The comparison highlights that while the general pattern of findings is consistent with prior research, the specific magnitudes and the partial support for dimensional hierarchy represent novel contributions.

5. DISCUSSION

5.1 Principal Findings

The finding that all four green innovation dimensions were positively and significantly associated with organizational performance supports the theoretical expectation that environmental innovation is relevant to organizational outcomes in the oil and gas context. The results are consistent with the general pattern identified in the literature that green innovation can contribute to both environmental responsiveness and business outcomes (Kolawole, 2024). As shown in Table 7, the regression coefficients for all four dimensions were positive and statistically significant, with confidence intervals excluding zero.

Green process innovation exhibited the largest standardized coefficient ($\beta = .345$). This finding is consistent with the pollution prevention logic of the NRBV: reducing waste and emissions at source may generate operational benefits through lower resource consumption and waste disposal costs (Hart, 1995). Olajide et al. (2023) observed that pollution prevention strategies can help firms attain higher economic performance by avoiding the costs associated with end-of-pipe pollution control. The process-innovation pathway is theoretically more direct than the market-mediated pathways through which product innovation may operate, or the longer-term transformation required for organizational innovation to embed.

Green product/service innovation ranked second ($\beta = .224$). This finding reflects the dual role of product stewardship in reducing lifecycle environmental impacts and responding to stakeholder expectations. Product stewardship capabilities enable firms to integrate environmental management into product lifecycles in collaboration with stakeholders, improving the ability to minimize environmental impacts while building reputation (Olajide et al., 2023). In the oil and gas context, product innovation may involve cleaner fuel specifications, improved gas monetization, and lifecycle impact reduction.

Green technological innovation ranked third ($\beta = .183$). This moderate association reflects the investment intensity and longer time horizons associated with technological innovation. Technologies such as methane detection systems and emissions monitoring equipment require significant capital and organizational integration before generating returns. The finding that technology alone does not guarantee performance benefits is consistent with research indicating that green technology innovation may enhance sustainable business performance through mediating mechanisms, suggesting that complementary organizational changes are required.

Green organizational innovation had the smallest standardized coefficient ($\beta = .117$). This finding may appear counterintuitive given the foundational role of organizational innovation

in enabling other innovation types. However, it is consistent with the theoretical expectation that sustainable development capabilities create necessary conditions rather than directly producing performance outcomes. Organizational innovation-environmental management systems, cross-functional teams, green procurement practices-provides the structures and routines through which other innovations are implemented.

The formal coefficient-comparison tests presented in Table 9 provide an important qualification to the descriptive ranking of coefficients. While green process innovation had the largest numerical standardized coefficient, the only statistically significant pairwise difference was between process innovation and organizational innovation ($\chi^2 = 6.34$, $p = .012$). This finding suggests that the differences among the top three dimensions-process, product/service, and technological innovation-were not statistically distinguishable in this sample. The numerical ordering should be interpreted descriptively rather than as establishing a statistically validated hierarchy.

The hierarchical regression results presented in Table 12 show that management commitment adds incremental explanatory power beyond the green innovation dimensions ($\Delta R^2 = .059$, $p < .001$). This finding is consistent with the theoretical argument that management commitment functions as an enabling condition that shapes the extent to which green innovation investments translate into performance outcomes. The interaction terms collectively did not reach conventional significance ($\Delta R^2 = .014$, $p = .066$), suggesting that in this sample, management commitment operates primarily as a direct predictor rather than a moderator.

5.2 Theoretical Implications

The findings offer several theoretical contributions. First, the study provides empirical evidence that is broadly consistent with the NRBV's distinction between pollution prevention, product stewardship, and sustainable development mechanisms. As shown in Table 1, the four green innovation dimensions were mapped onto NRBV mechanisms, and the pattern of associations-with process innovation exhibiting the largest coefficient-aligns with the theoretical expectation that pollution prevention capabilities may offer more proximate performance benefits.

Second, the study contributes to the green innovation literature by demonstrating the importance of disaggregated analysis. The comparison between aggregate and disaggregated models (Table 13) shows that the four-dimension model explains 5.3 percentage points more

variance than the aggregate model, providing empirical support for the argument that treating green innovation as a unidimensional construct obscures important dimensional variation.

Third, the study advances methodological practice in green innovation research by demonstrating the importance of formal coefficient-comparison tests. As shown in Table 9, numerical differences among standardized coefficients do not automatically establish statistically significant differences. The finding that only one of six pairwise comparisons was statistically significant highlights the need for formal testing before claiming dimensional hierarchies.

Fourth, the study contributes to understanding management commitment's role by showing that it has a significant direct association with organizational performance beyond the effects of green innovation dimensions. This finding is consistent with prior research demonstrating that management commitment enables the translation of green innovation investments into performance outcomes (El-Kassar & Singh, 2019; Ahmed et al., 2023).

5.3 Managerial Implications

The findings have several practical implications. First, managers should recognize that green innovation is not a monolithic strategy but comprises distinct dimensions with varying performance associations. Within the sampled Shell operational context, green process innovation exhibited the largest standardized coefficient, suggesting that managers may consider strengthening process-oriented environmental improvements-particularly where opportunities exist to reduce resource use, waste, and emissions.

Second, managers should recognize that the present cross-sectional evidence does not establish a causal performance advantage over other innovation dimensions. As shown in Table 9, the differences among the top three dimensions were not statistically significant. Therefore, managers should avoid over-prioritizing one dimension at the expense of others until more definitive evidence emerges.

Third, the finding that management commitment has a significant direct association with performance (Table 12) suggests that sustained managerial support-through resource allocation, strategic prioritization, and active involvement-is important for realizing performance benefits from green innovation.

Fourth, the study's finding that organizational innovation, while exhibiting the smallest coefficient, may play a foundational role in enabling other innovation types suggests that managers should continue investing in environmental management systems, cross-functional teams, and green procurement practices.

5.4 Policy Implications

The findings suggest the need for policies that support different types of green innovation. Policymakers should consider providing incentives for process-oriented environmental improvements, which exhibit the largest association with organizational performance in the sampled context. Additionally, policies that support technological innovation-such as subsidies for emissions monitoring equipment or methane detection systems-may yield longer-term benefits, even if their immediate performance associations are more modest.

5.5 Limitations

Several limitations should be acknowledged. First, the cross-sectional design means that the study provides evidence of association and statistical relationships but cannot establish temporal causality. The terms "associated with" and "relationship" are therefore used throughout rather than causal language. Second, the study relies on self-reported questionnaire data from employees, which may introduce common-method variance. Third, the sample is drawn from a single organization's operations in one geographical location, which limits generalizability. The findings should be interpreted as reflecting the sampled Shell operational context rather than the entire Nigerian oil and gas sector. Fourth, organizational performance was measured through employee perceptions rather than objective financial or operational data. Fifth, the theoretical mechanisms proposed for each dimension (e.g., cost reduction for process innovation) were not directly measured and should be interpreted as theoretical explanations. Sixth, while formal coefficient-comparison tests were conducted, the study may have limited statistical power to detect small differences among coefficients.

6. FINDINGS

- (i) Green product and service innovation was positively and significantly associated with organizational performance ($\beta = 0.224$, $p = .019$).
- (ii) Green process innovation was positively and significantly associated with organizational performance ($\beta = 0.345$, $p = .008$), exhibiting the largest standardized coefficient.
- (iii) Green technological innovation was positively and significantly associated with organizational performance ($\beta = 0.183$, $p = .006$).
- (iv) Green organizational innovation was positively and significantly associated with organizational performance ($\beta = 0.117$, $p = .001$), exhibiting the smallest standardized coefficient.

- (v) Formal coefficient-comparison tests revealed that the only statistically significant pairwise difference was between green process innovation and green organizational innovation ($\chi^2 = 6.34$, $p = .012$).
- (vi) The differences among the top three dimensions-process, product/service, and technological innovation-were not statistically significant.
- (vii) The four dimensions collectively explained 23.9% of the variance in organizational performance ($R^2 = .239$; adjusted $R^2 = .221$).
- (viii) Management commitment added incremental explanatory power beyond the green innovation dimensions ($\Delta R^2 = .059$, $p < .001$).
- (ix) The disaggregated four-dimension model explained 5.3 percentage points more variance than an aggregate green innovation model.

7. CONCLUSION

This study examined green innovation dimensions as manifestations of environmental organizational capabilities within Shell's Nigerian operations in Delta State. The findings reveal that all four green innovation dimensions were positively and significantly associated with organizational performance, with green process innovation exhibiting the largest standardized coefficient. However, the formal coefficient-comparison tests indicate that only the difference between process innovation and organizational innovation was statistically significant. The findings provide empirical evidence that is broadly consistent with NRBV-based propositions regarding the strategic relevance of environmental capabilities, while highlighting the importance of statistically testing dimensional differences rather than relying on numerical coefficient comparisons alone. Within the sampled Shell operational context, the pattern of associations suggests that process-oriented environmental initiatives warrant particular attention in future managerial and empirical assessments, though investment decisions should consider implementation costs, operational conditions, and longer-term capability development. The study contributes to strategic management research by examining green innovation as capability manifestations within an under-researched sectoral and geographical context, while acknowledging the limitations of single-firm, employee-perception data. Future research should examine whether the observed pattern holds across multiple organizations and whether the associations of organizational and technological innovation become stronger over longer time horizons.

Declarations

Funding: This research received no external funding.

Ethics Approval: Ethical principles were strictly observed throughout the study. Participants were informed of the purpose of the research before completing the questionnaire. Participation was voluntary, and respondents were assured of the confidentiality and anonymity of their responses.

Conflict of Interest: The authors declare no conflicts of interest.

Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Efenudu, Loveth Nkiru conceived the study, designed the methodology, collected and analysed the data, and drafted the manuscript. Okwuse Uguru Young supervised the research, provided critical intellectual guidance, reviewed and edited the manuscript, and ensured adherence to academic standards. Akindele Michael Okedoye contributed to the statistical analysis, validated the quantitative results, and reviewed the mathematical and analytical components of the study. All authors read and approved the final manuscript.

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