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Greening Sustainable Supply Chain Performance: The Moderating and Mediating Influence of Green Value Co-Creation and Green Innovation

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Abstract: This paper aimed to analyze the effect of green supply chain integration (GSCI) on sustainable supply chain performance (SSCP), as well as consider the mediating and moderating effects of green innovation (GInv) and green value co-creation (GVCc). This empirical study is based on a survey of 317 senior managers from agro-based companies involved in manufacturing and extractive industries in Nigeria. The empirical research model is examined utilizing partial least squares structural equation modeling (PLS-SEM). The discovery entails that GSCI positively and substantially impacted SSCP and GInv. The research suggests that green innovation serves as a mediator in the relationship between GSCI and SSCP. Moreover, green value co-creation exerts a detrimental moderating influence on the GSCI-SSCP paradigm. Meanwhile, the originality of this study emanated from being the first to objectively explore the simultaneous moderating and mediating effects of GInv and GVCc on the relationship between GSCI and SSCP.

Keywords: green value co-creation; green supply chain integration; green innovation; partial least squares structural equation modeling; sustainable supply chain performance

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1. Introduction

To maintain success, the societal, economic, and environmental spheres are interdependent within the supply chain ecosystem (Kamalahmadi & Parast, 2016). These interactions can lead to unexpected disruptions or failures in the supply chain. Currently, long-term financial viability across all industries cannot be achieved solely by operating a green-conscious firm, despite companies' inherent benefits from implementing sustainable supply chain strategies (Lee et al., 2024; Mathivathanan et al., 2017).

The conception and operationalization of green supply chain integration (GSCI) are ambiguous and inconsistent, lacking empirical evidence regarding its impact on performance. Nevertheless, certain scholars have acknowledged the importance of GSCI and examined its performance implications (Han & Huo, 2020; Y. Song et al., 2017; C. W. Y. Wong et al., 2018). Han and Huo (2020) develop a theoretical framework for GSCI by utilizing the SCI literature and the natural resource-based view (NRBV) as an integrative approach to explain their study. They subsequently investigate the influence of various GSCI factors on sustainable performance, encompassing environmental, social, and economic dimensions. Numerous leading corporations and supply chains have prioritized sustainability, positioning it as a new strategic lever (Kang, 2018). This critical performance element has not been explored in previous GSCI studies. Earlier research on general supply

chain management (GSCM) has concentrated on its impact on economic or environmental performance (Golicic & Smith, 2013; Li et al., 2016; H. Zhang & Yang, 2016).

Green innovation (GInv) remains a vital solution for addressing the growing environmental issues, strict regulations, and increased stakeholder demands (Lin & Chen, 2017; Tang et al., 2018). Furthermore, businesses must adapt to changing times as the external environment and business landscape constantly evolve, highlighting significant environmental challenges. Consequently, this new reality has sparked a widespread desire among companies to enhance their green impact (Malik et al., 2020).

Several studies have emphasized the influence of green supply chain integration (GSCI) on variables such as uncertainty (C. Y. Wong et al., 2020), sustainable performance (Han & Huo, 2020), green innovation (Wu, 2013), financial performance (Kong et al., 2021), environmental impact, and cost performance (C. Y. Wong et al., 2020). However, research regarding the impact of green supply chain integration on sustainable supply chain performance and green innovation within established agro-based firms remains insufficient.

According to Aydiner et al. (2020), managers face pressure to adjust their companies' operations to adapt to evolving technology, the complexities of the supply chain, and changing customer demands. Consequently, supply chain management poses a significant challenge in the current environment, particularly for enterprises involved in agro-manufacturing products. Although studies (Kong et al., 2020; C. Y. Wong et al., 2020; B. Zhang et al., 2022) have shown the direct effects of GSCI on GInv, research has not yet demonstrated how these variables influence SSCP and the resulting indirect effects on the performance of the sustainable supply chain. This study's most significant finding and uniqueness is that green innovation and green value co-creation play a crucial and substantial role in the relationship between green sustainable supply chain performance and green supply chain integration. Notably, no empirical research distinguishes and combines the mediating and moderating effects of green innovation and green value co-creation in examining the impacts of GSCI.

The model and its relevance to companies in emerging economies further demonstrate the originality of this research. This study examines the reasons for corporate green activities and contributes to developing the natural resource-based view (NRBV) theory. Additionally, this paper investigates how GSCI and GInv support enterprises, particularly in emerging nations such as Nigeria, in achieving sustainable supply chain performance by addressing a knowledge gap in understanding how green value co-creation and green innovation mediate the connection between GSCI and SSCP.

2. Theoretical Framework

2.1. Natural Resource-Based View (NRBV)

The natural resource-based view (NRBV), which extends Hart's (1995) resource-based view, posits that a firm's competitive advantage arises from its relationship with its environment. NRBV focuses on a firm's resources, skills, and goals combined for operations with a sustainability perspective (Olaleye et al., 2023). Therefore, a company can utilize NRBV to determine its sustainability. The "natural resource-based view" (NRBV) has remained relevant lately and has multiple ties to competitiveness (Aribaba et al., 2019; McDougall, 2018; Olaleye, 2023). The necessity to investigate the existing situation regarding NRBV resource availability is one of several relevant issues that arise.

Hart outlined three environmental tactics for a corporation within his natural resource-based view (NRBV): preventing pollution, stewarding products, and developing sustainably. These plans align with the objectives of GSCI, which focus on reducing the company's material and emissions waste.

Businesses can achieve their shared strategic objectives by integrating their systems, which allow suppliers, customers, and internal departments to access and share the same data and resources. By doing so, businesses can better meet their green and sustainable development goals and enhance their core competitiveness, as operational activities and products have a reduced environmental impact (Wu, 2013). Various manufacturing contexts have demonstrated that GSCI can improve social and environmental performance by decreasing energy consumption and pollution.

2.2. Green Innovation (GInv)

Green innovation refers to "the creation, adoption, or use of a new product, production process, service, management, or business method that is unique to the organization that creates or adopts it and that, throughout its life cycle, reduces environmental risk, pollution, and other negative effects of resource use (including energy use) compared to relevant alternatives" (Arfi et al., 2018, p. 211; Ma et al., 2022, p. 583). Novitasari and Agustia (2023) assert that green innovation encompasses software and hardware improvements aimed at making products and processes more environmentally friendly and monitoring the environmental impact of businesses.

Companies that make sustainability claims are now entangled with environmental concerns. To maintain their social legitimacy, businesses need to find new ways to reduce their adverse environmental effect and, ideally, make a positive difference (Huang & Li, 2017). Furthermore, green innovation is defined as "innovation that enables the reduction in adverse environmental impacts" (Soewarno et al., 2019).

GInv is based on a theory that originates from the resource-based view and is also grounded in the NRBV (Appannan et al., 2020; Yang et al., 2022). The NRBV suggests that a company's competitive advantages arise from its inherent strategic strengths, which shape its strategy, decisions, and interactions with external parties. Recently, Mishra and Yadav (2021) proposed the NRBV theory as a framework for prioritizing environmental considerations in business decision making and promoting sustainable growth to address contemporary environmental challenges.

2.3. Green Supply Chain Integration (GSCI)

"Green supply chain integration" (GSCI) refers to the extent of collaboration and coordination among suppliers and producers aimed at mitigating environmental impacts (Lo et al., 2018; Kong et al., 2020). GSCI emphasizes the importance of green collaboration in achieving sustainable goals that benefit all stakeholders (Mao et al., 2017; Yu et al., 2014).

Lo et al. (2018) and Lo (2015) suggest that businesses can gain economic benefits from green supply chain integration (GSCI) by strengthening relationships with their supply chain partners, facilitating information sharing, and promoting environmentally friendly activities. This, in turn, can reduce operating costs, provide businesses with a competitive advantage, and ultimately enhance their bottom line. GSCI collaborates with major suppliers to exchange environmental information and develop solutions to environmental challenges. By aligning their environmental strategies with the GSCI mechanism, businesses can improve their environmental performance and achieve their strategic objectives (Li et al., 2020). Manufacturing companies have begun systematically integrating their supply chains to maximize consumer value and benefit all parties involved (Zhao et al., 2018).

2.4. Green Value Co-Creation (GVCc)

This paper acknowledges Ranjan and Read's (2016) definition of value co-creation and introduces an innovative idea termed green value co-creation. This research defines GVCc as the process by which a company and its affiliates work together to create value through

environmental efforts during the production or consumption stages. Value co-creation involves businesses and their stakeholders forming unique and strategic partnerships. These partnerships make it easier for corporations to manage innovation and value creation, which reduces the differences between firms. The desire to contribute to environmental preservation is a significant impetus for innovation, corporate growth, and economic profit (Olaleye et al., 2024; Walley & Whitehead, 1994). Hence, businesses must adopt a more ecologically concerned mindset.

Companies may encounter challenges when entering new markets due to the stringent environmental requirements of adopting green initiatives (Barrett, 1991). Firms participate in global value chains (GVCs) by collaborating with other organizations at various stages of production and consumption, both directly and indirectly, to generate value (Ranjan & Read, 2016).

2.5. Sustainable Supply Chain Performance

Sustainable supply chain performance (SSCP) is crucial for firms, as it facilitates strategy creation, implementation, and oversight (Mathivathanan et al., 2017). As supply networks expand, monitoring these aspects becomes increasingly challenging. The economic, environmental, and social dimensions of sustainability should be integrated into sustainable supply chains (Yildiz Çankaya & Sezen, 2019).

When examining the impact of supplier and business operations on the environment, environmental performance focuses on reducing waste, minimizing resource consumption, and mitigating the overall environmental footprint of supply chains (Zaid et al., 2018). Human capital and social performance include respect for community rights, satisfactory working conditions, diversity, equity, and skill enhancement. Paulraj et al. (2017) assert that social and environmental initiatives positively influence economic performance, particularly in sales growth and profitability. These activities enhance consumer satisfaction and loyalty, increasing sales and profitability. Green et al. (2012) argue that customer service quality, accessibility, overall capacity, and response time are key determinants of a supply chain's sustainable economic performance.

2.6. Green Supply Chain Integration and Sustainable Supply Chain Performance

Studies have noted that GSCI is a method that enables individuals in the supply chain to collaborate and ensure that information and goods flow smoothly (Nurmilaakso, 2008; Yu et al., 2013; Hussein Zolait et al., 2010). The objective is to provide clients with optimal value at the most competitive price and advantageous location.

According to El-Kassar and Singh (2019), consumers have expressed a growing interest in "green" products due to increased environmental awareness. As a result, businesses are under pressure to develop sustainable products and adopt eco-friendly practices to meet consumer demand, produce durable goods, and maintain a competitive edge. Therefore, companies gain an edge over their rivals when they innovate with new and improved products, which boosts performance and SSCP.

Han and Huo (2020) underscore how to be green by investigating the impact of GSCI on sustainable performance via three dimensions: economic, social, and environmental sustainability. This study evaluates a theoretical model employing data from 206 Chinese companies through structural equation modeling with maximum-likelihood estimation. It was discovered that the dimensions of GSCI, green supplier integration (GSI), and green customer integration (GCI) are contingent upon green internal integration and social and environmental performance. At the same time, GSI and GCI positively correlate with economic and social performance.

Numerous studies have investigated the impact of GSCI on performance with inconsistent results (Y. Song et al., 2017; C. W. Y. Wong et al., 2018). According to Y. Song et al. (2017), all three GSCI dimensions exhibit a favorable link with economic performance, but C. W. Y. Wong et al. (2018) found no such correlation. C. W. Y. Wong et al. (2018) is the sole study investigating the impact of GSCI on ecological efficiency. Their investigation indicates that integrating green consumers and suppliers does not influence environmental performance. This literature evaluation indicates that the advantages of GSCI require additional investigation.

Eco-friendly approaches enhance process innovation by eliminating detrimental chemicals and optimizing resource use, improving environmental performance. Concerns exist that the company's product range may encompass safe and hazardous solutions, diminishing its beneficial environmental impact and leading to undesirable results (Tariq et al., 2019). Thus, the researcher infers the following:

H1. *GSCI significantly positively influences sustainable supply chain performance.*

2.7. Green Supply Chain Integration, Green Innovation, and Sustainable Supply Chain Performance

GSCI signifies collaboration between businesses and suppliers, emphasizing the enhancement of cooperation and the promotion of green innovation through effective environmental management practices. This approach mitigates negative environmental impacts and improves environmental performance to create more sustainable products (Soewarno et al., 2019; Zhou et al., 2020). Applying and implementing GSCI within a company's supply chain boosts its developmental momentum and competitiveness. Enhanced environmental performance and innovative capabilities, particularly in green innovation, can be achieved through a more comprehensive approach to supply chain management. When collaborating in an integrated supply chain, businesses can share information on green innovations (Melander & Pazirandeh, 2019).

GSCI can enhance SCI's environmental aspects by evaluating the ecological impacts of new business initiatives (Silva et al., 2019; Wu, 2013). It investigates how supply chain partners collaborate to tackle environmental issues, share information, and develop practical solutions. This collaboration is essential for businesses to thrive over the long term while reducing their environmental impact at every stage (Tantayanubutr & Panjakajornsak, 2017).

Considering all factors, GSCI can enhance sustainable performance by addressing environmental challenges associated with SCI, fostering innovation, expanding the company's life cycle perspective, and attracting new customers while meeting existing needs (Lo & Shiah, 2016; Murfield & Tate, 2017). However, resources that span organizational and functional barriers are essential for GI to operate effectively. Wang's (2019) research indicates that green organizational culture and green performance are somewhat mediated by green innovation (GInv). Cai et al. (2020) assert that enterprises must collaborate with supply chain partners to implement the GSCI model. Wu (2013), Dangelico (2016), and Effendi et al. (2021) all establish that integration and innovation are interconnected; nevertheless, GSCI provides options for resource acquisition and utilization.

Abbas et al. (2022) discovered that GI enhances organizational performance by being a constructive mediator between GSCI and performance in the manufacturing industry. The findings augment knowledge regarding GSCI and GI, facilitating strategic planning for an organization's IT department to achieve performance objectives. C. Y. Wong et al. (2020) assert that GSCM promotes GInv by incorporating suppliers and customers. This integration occurs through information exchange, collaborative problem solving, and the mitigation of uncertainty. Consequently, the subsequent hypothesis is posited:

H2. *GSCI has a positive and significant influence on GInv.*

H3. *GInv mediates the relationship between green supply chain integration and sustainable supply chain performance.*

2.8. Moderating Role of Green Value Co-Creation

To meet stakeholders' demands in a timely and competitive manner while also addressing current environmental issues, it is now evident that firms must involve their suppliers in the value-creation process. Prior studies (Choi et al., 2018; Y. Song et al., 2017) have shown that suppliers play a crucial role in developing eco-friendly products, enhancing performance, and creating competitive advantages. Engaging customers in sustainability issues, also known as "green customers", is important, as this creates a value-added phenomenon for greening and achieving sustainable performance within the supply chain system.

H4. *Green value co-creation moderates the relationship between green supply chain integration and sustainable supply chain performance.*

Based on the formulated research hypotheses, the following research model was proposed and depicted in Figure 1.

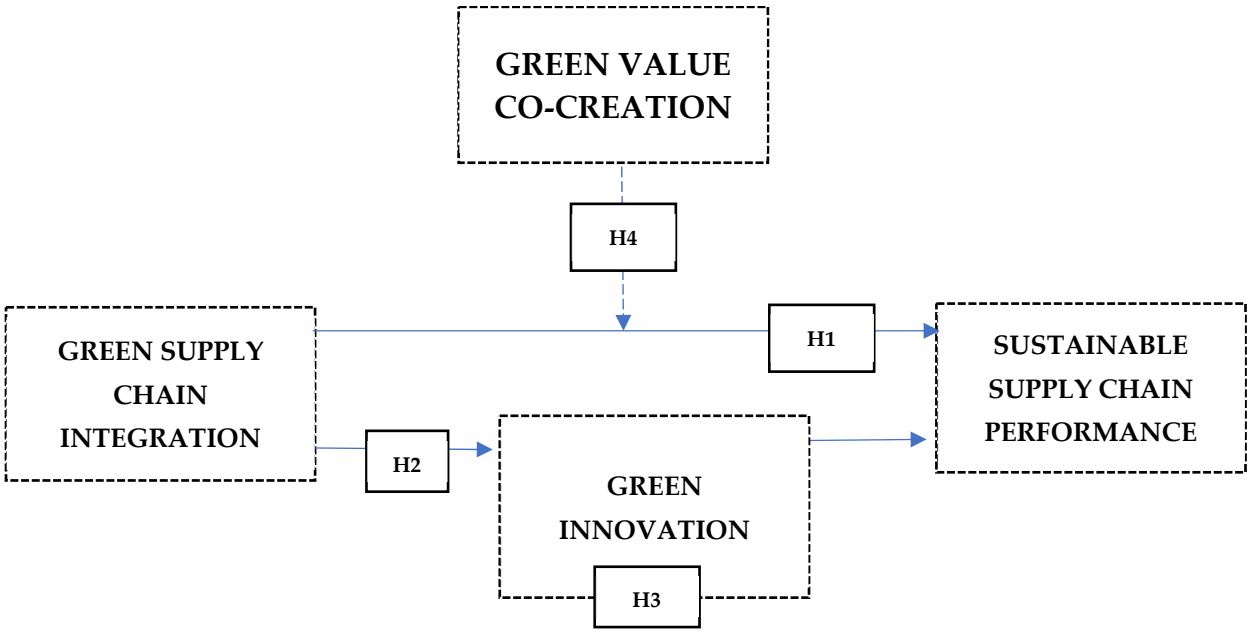


Figure 1. Research Model.

3. Materials and Methods

3.1. The Participants and Sampling Procedures

This study primarily relies on methodologies that have proven effective in previous research. The studies by Olaleye et al. (2021) and Siddiqi et al. (2025) are grounded in a positivist philosophy and utilize quantitative methodologies. This research gathers data from individuals employed by or overseeing publicly traded agro-allied enterprises in Nigeria. The National Bureau of Statistics (NBS) classifies the agro-allied industry into four main sectors: food and beverage, textiles, garments and footwear, wood and wood products, and pulp, paper, and paper products. A survey-based methodology is specifically

employed to gather extensive data on the interrelationship among GInv, GSCI, SSCP, and GVCc.

The most efficient method for reaching the Chief Executive Officers and General Managers of specified agro-based manufacturing businesses for the survey was through email invitations. We distributed two reminders every fortnight to enhance participants' engagement. The research focused on Sectional Managers and supply chain management personnel due to their presumed extensive knowledge of green economy concepts, such as green innovation, green value co-creation, and GSCI.

This study randomly selected ten firms from a directory of NSE-quoted entities in agro-based sectors that met its criteria, employing a convenience sampling strategy, an effective method for data selection that enhances data integrity and quality. A total of 317 out of 500 workers in the chosen agro-allied enterprises voluntarily participated, illustrating their autonomy and capacity to decline without repercussions. Participants were duly informed that their responses were solely for research purposes and were assured data confidentiality. Consequently, questionnaires were fully disseminated upon obtaining participants' consent.

Data were collected using a two-stage self-report survey and a time-lagged research design to mitigate the bottleneck of standard method variance. The survey was conducted over two weeks and consisted of two segments each. At the outset (period 1), participants were asked about green innovation, green supply chain integration, and basic demographic information. Two weeks later, participants were asked to evaluate their perspectives on sustainable supply chain performance and green value co-creation in the second data collection phase.

Initially, 342 of the 500 employees expressed their opinions. The next step involved removing outliers and compiling 317 valid, fully completed surveys, resulting in an overall response rate of 63.4%. Table 1 presents key information from the data sample. Men represented 62.5% of the 198 respondents, while women accounted for 37.5%, totaling 119 individuals. Furthermore, the study participants encompassed a range of ages, from youth to adulthood, demonstrating a uniform distribution among the respondents. Out of the total responses, 29 (9.1%) were from individuals aged 18–30, 68 (21.5%) from those aged 31–40, 121 (38.2%) from the 41–50 age group, and 99 (31.2%) from individuals over 50 years of age. Descriptive statistics indicate that 194 participants, representing 61.2% of the total, held a bachelor's degree or higher, making it the most common educational attainment among the participants. The second prevalent category comprises individuals with a diploma or equivalent, while the remaining 10.1% hold postgraduate degrees. Ultimately, 33.4% of employees have more than six years of tenure in their current positions, while 12.6% have less than three years. Additionally, 46.4% had held their positions for four to six years, and 7.6% had been in their roles for less than a year.

Table 1. Demographics.

Measures	Items	Frequency	Percentage (%)
Gender	Male	198	62.5
	Female	119	37.5
Age	18–30	29	9.1
	31–40	68	21.5
	41–50	121	38.2
	50 and above	99	31.2
Education	Diploma	91	28.7
	University degree	194	61.2
	Postgraduate degree	32	10.1

Table 1. *Cont.*

Measures	Items	Frequency	Percentage (%)
Job Tenure	Less than a year	24	7.6
	1–3 years	40	12.6
	4–6 years	147	46.4
	Over 6 years	106	33.4

3.2. Ethical Considerations

The Federal University Oye-Ekiti, Department of Business Administration Ethical Review Committee approved the study. The ethical approval number is 2024/REC/BAM/0101. Institutional ethical declaration policies dictated that all research involving human subjects be conducted. All participants in the study provided their informed consent.

3.3. Measures and Analysis

All measurements were adapted to the study and evaluated using a 7-point Likert scale (see Appendix A). Gunasekaran et al. (2017) and Bag et al. (2020) offer eight statements to assess SSCP. Furthermore, a 6-item scale from W. Song and Yu's (2018) research was used to rate green innovation, as cited by Yousaf (2021). A 3-item scale based on Albinsson et al.'s (2016) work was used to evaluate green value co-creation. Moreover, GSCI comprises three dimensions, each containing five statements adapted from Wu (2013) and Y. Song et al. (2017).

The partial least squares structural equation modeling (PLS-SEM) was employed to evaluate hypotheses using SmartPLS version 4. The PLS-SEM, known to be a predictive analysis, was preferred over covariance-based structural equation modeling (CB-SEM) because it is a variance-based SEM, which is more accessible as it does not have to meet all the strict criteria of CB-SEM. Furthermore, it is essential to address causality problems related to latent variables when assumptions are not satisfied in CB-SEM, including working principle to minimize error terms and optimization of explained variance of the endogenous variable (Astrachan et al., 2014; Cepeda-Carrion et al., 2019; Fauzi, 2022). Hence, it is primarily used for composite variables, measuring theoretical concepts with multiple items and interval scales. Meanwhile, the structural and measurement models were evaluated using bootstrapping techniques, including confidence intervals, t-statistics, *p*-values, path coefficients, and assessing the study hypotheses.

4. Results

This study evaluated the measurement model by analyzing the discriminant and convergent validity, as well as the reliability of the scales. All results are presented in Table 2. This research assessed the validity of the tools. Both the composite reliability (CR) and Cronbach's Alpha coefficient exceed 0.7, which is deemed an acceptable threshold (Hair et al., 2021). This figure demonstrates the accuracy of the scales. The variance inflation factor (VIF) was used to determine the likelihood of multicollinearity and overall methodological bias. Hair et al. (2021) indicate that VIF values below 3.0 suggest minimal multicollinearity and standard method bias. No methodological bias or multicollinearity is evident, as indicated by the VIF scores, which range from 1.068 to 2.927 for all questions.

The square root of the average variance extracted (AVE), along with factor loadings and AVE, was employed to assess convergent validity in this study. The results indicate convergent validity when loadings exceed 0.7, and AVE surpasses 0.5. Fornell and Larcker's (1981) criteria were utilized to confirm the validity of the discriminant analysis test. The square root of the AVE and the correlations between latent variables were used for this purpose. The square root of a latent variable's average variance extracted (AVE) must not

be less than its correlation with any other latent variable. Henseler et al. (2015) also applied the Fornell and Larcker (1981) criterion rather than the "heterotrait–monotrait" (HTMT) correlation ratio. Tables 3 and 4 illustrate that the HTMT values of the model components were below 0.9, indicating strong discriminant validity.

Table 2. Factor loading, AVE, and reliability of variables.

Latent Variables	Loadings (λ)	CA	rho_A	CR	AVE
GREEN INNOVATION	**GInv**	0.949	0.954	0.959	0.798
GInv1	0.865 ***				
GInv2	0.894 ***				
GInv3	0.926 ***				
GInv4	0.925 ***				
GInv5	0.899 ***				
GInv6	0.848 ***				
GREEN SUPPLY CHAIN INTEGRATION	**GSCI**	0.956	0.958	0.961	0.623
Green Internal Integration	**GII**	0.905	0.907	0.930	0.725
GI1	0.837 ***				
GI2	0.869 ***				
GI3	0.890 ***				
GI4	0.826 ***				
GI5	0.835 ***				
Green Customer Integration	**GCI**	0.926	0.928	0.944	0.773
GCI1	0.818 ***				
GCI2	0.869 ***				
GCI3	0.920 ***				
GCI4	0.902 ***				
GCI5	0.883 ***				
Green Supplier Integration	**GCI**	0.914	0.919	0.936	0.746
GSI1	0.874 ***				
GSI2	0.750 ***				
GSI3	0.884 ***				
GSI4	0.912 ***				
GSI5	0.889 ***				
GREEN VALUE CO-CREATION	**GVCc**	0.908	0.939	0.941	0.842
GVCc1	0.940 ***				
GVCc2	0.892 ***				
GVCc3	0.920 ***				
SUSTAINABLE SUPPLY CHAIN PERFORMANCE	**SSCP**	0.938	0.943	0.950	0.733
SSCP1	0.918 ***				
SSCP2	0.900 ***				
SSCP3	0.854 ***				
SSCP4	-				
SSCP5	0.727 ***				
SSCP6	0.765 ***				
SSCP7	0.901 ***				
SSCP8	0.908 ***				

Note: χ^2 = 2031.73; NFI = 0.906; SRMR = 0.0513. - deleted due to poor loadings, *** denoted loadings are above 0.7.

Table 3. Discriminant validity of variables (Fornell–Larcker criterion).

Constructs	1	2	3	4
1. Green Innovation (GInv)	**0.893**			
2. Green Supply Chain Integration (GSCI)	0.210	**0.789**		
3. Green Value Co-creation (GVCc)	0.809	0.199	**0.917**	
4. Sustainable Supply Chain Performance (SSCP)	0.404	0.210	0.300	**0.856**

Note: Values in bold format are the square root of the AVE, placed above their inter-construct correlation.

Table 4. Discriminant validity of variables (HTMT ratio).

Constructs	1	2	3	4
1. Green Innovation (GInv)				
2. Green Supply Chain Integration (GSCI)	0.220			
3. Green Value Co-creation (GVCc)	0.880	0.211		
4. Sustainable Supply Chain Performance (SSCP)	0.421	0.220	0.312	

Structural Model Evaluation

The PLS-SEM results for bootstrapping are presented in Figure 2 below. The results of the bootstrapping analysis are shown in Table 5 to evaluate the research hypotheses and structural framework. The research hypothesis appears to have been confirmed as valid. The assertion that GSCI and SSCP have a positive and significant connection is supported by the finding for H1 (β = 0.154, t = 2.819). The results for H2 (β = 0.210, t = 3.496, $p < 0.001$) indicate that GSCM and GInv are positively and significantly linked. We assessed the degree of influence of each independent variable on the dependent variable using Cohen's effect size measure, also known as f-square (Cohen, 1988). The results are shown in Table 5 and demonstrate that GSCI had a negligible effect on both SSCP (effect size $0.02 \leq f^2 = 0.028 < 0.15$) and GInv (effect size $0.02 \leq f^2 = 0.046 < 0.15$). The GSCI-SSCP path is slightly affected by GVCc (effect size, $f^2 = 0.26$, less than 0.15), indicating additional limitations.

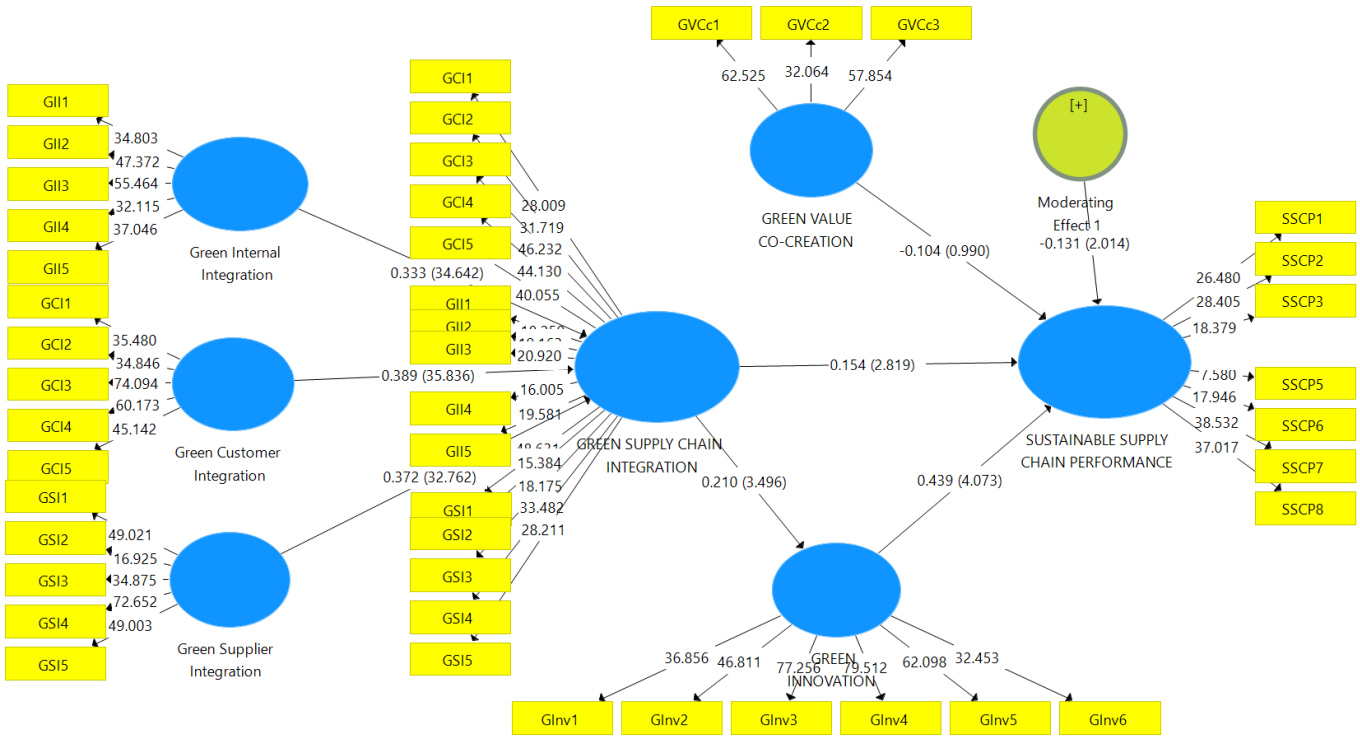


Figure 2. Path analysis.

Table 5. Hypothesis testing.

	Parameters	β	SE	t-Value	*p*-Value	R^2	F^2	Decision
				Direct effects				
H1	GSCI → SSCP	0.154	0.055	2.819	0.005	0.202	0.028	S
H2	GSCI → GInv	0.210	0.060	3.496	0.001	0.344	0.046	S
				Indirect effects				
H3	GSCI → GInv → SSCP	0.092	0.037	2.480	0.013	PM		S
H4	GVCc _MOD_GSCI → SSCP	−0.131	0.065	2.014	0.045	0.026		S

Key: SE, standard error; PM, partial mediation; S, significant.

In addition to the bootstrapping analysis results, VAF was utilized to investigate GInv's role as a mediator in the relationship between GSCI and SSCP. The evidence from the data indicates that GInv mediates the connection between GSCI and SSCP. It can be concluded from these results that (β = 0.092, t = 2.48, $p < 0.001$). Subsequently, the mediation hypotheses were tested with 5000 bootstrap samples (see Table 6). The indirect effect of GSCI on sustainable supply chain performance through green innovation was significant (effect = 0.092, 95% CI [0.058, 0.266]), thus supporting Hypothesis 3. However, the findings revealed a 95% confidence interval (CI) that did not include zero and a smaller 2.5% confidence interval (CI), aligning with the third hypothesis (H3). Despite the negative value, it was ascertained that green value co-creation diminished the correlation between GSCI and SSCP (β = −0.131, t = 2.014, $p < 0.001$). Accordingly, the findings corroborated the validity of H4.

Table 6. Mediation analysis.

Path	95% Confidence Interval				
	Indirect Effect	**SE**	**Lower**	**Upper**	**Direct Effect**
GSCI → GInv → SSCP	0.092	0.037	0.058	0.266	0.246 ***

Note: 5000 bootstrap samples. Abbreviations: GSCI, green supply chain integration; GInv, green innovation; SSCP, sustainable supply chain performance. *** $p < 0.001$.

5. Discussion

Due to increased awareness among governments, customers, and public authorities, businesses must integrate sustainability concerns into their strategies and supply chains. The connection between GSCI, GInv, and GVCc is the focal point of this study, exploring sustainability and green supply chain management. Hypothesis 1 (H1) indicates a strong positive correlation between GSCI and SSCP. Meanwhile, several studies have identified a positive correlation between GSCI and sustainable performance, including those by Zhu et al. (2012), Suheil (2015), and Omara et al. (2019).Manufacturing firms can enhance their corporate sustainability performance by using green management practices and pursuing collaborative initiatives with key supply chain partners.

Furthermore, previous research (Hussein Zolait et al., 2010) supports this finding. This outcome illustrates the rationale behind manufacturing organizations' diligent efforts to link their supply chains, enhancing consumer value and benefiting all stakeholders (Zhao et al., 2018). According to Wolf (2011), the literature on supply chain integration and green supply chain management (GSCM) constitutes the most critical components of green supply chain integration (GSCI). Consequently, it deepens our understanding of the measures that can be implemented to make supply chains more ecologically sustainable and assesses the impact of these measures on overall sustainability performance.

GSCI has a positive and advantageous effect on GInv (β = 0.210; p = 0.001), hence supporting H2. Previous studies (C. Y. Wong et al., 2020; Lo & Shiah, 2016; Murfield & Tate, 2017) demonstrate that collaboration among supply chain stakeholders enables the development of innovative strategies to meet demand while addressing environmental concerns through applying the best environmental management approaches. Green innovation is crucial for identifying methods to improve environmental performance by advancing sustainable products and processes. According to the NRBV theory (Zhou et al., 2020), meaningful integration grounded in sustainability principles can enhance embeddedness. This may result in collaborative efforts across groups to identify innovative, eco-friendly methods (Melander & Pazirandeh, 2019; Soewarno et al., 2019). Research indicates that consumers exert more pressure on agro-based enterprises to invest more in innovation via green supply chain integration. Wu (2013) argues that integrating green supply chains is crucial for developing new eco-friendly products and processes. Du et al. (2018) and C. W. Y. Wong et al. (2012) are among the researchers endorsing GSCI as an effective platform for green innovation.

The findings indicate that GInv influences the nexus between GSCI and sustained supply chain performance (H3). The results demonstrate that GInv can significantly affect GSCI, improving supply chain performance, as Abbas et al. (2022) asserted. Mao et al. (2017) and Yu et al. (2014) conducted studies highlighting the significance of green collaboration in achieving universally beneficial sustainability objectives. The GSCI further substantiates this assertion. According to Afum et al. (2020), their findings have important implications for managers of small- and medium-sized manufacturing firms (SMEs) in Ghana and other sub-Saharan African nations. These findings will enable manufacturing business managers to invest more effectively in GMPs and establish strong connections with environmentally focused supply chain partners to achieve sustainable performance targets. Finally, Abbas et al. (2022) also identify the firm's GInv as a mediator between GSCI and organizational performance, emphasizing that by adopting GI principles, supply chain partners can achieve their corporate social responsibility and sustainable development objectives with green organizational integration.

The fourth hypothesis (H4) asserts that GVCc modifies the relationship between GSCI and SSCP. This emphasizes that promoting environmental sustainability aligns with ethical business practices and collaborative value creation. Integrating eco-friendly concepts into corporate operations is vital. Companies may face challenges when entering new markets due to the strict environmental regulations they must adhere to while implementing green initiatives (Barrett, 1991). Ranjan and Read (2016) contend that in GVCs, firms collaborate with other entities to generate value at different stages of production and consumption. This partnership can be direct or indirect, involving the exchange of environmental concepts and engagement at various phases of production or consumption. The primary determinant of success for organizations in providing products and services is value co-creation, attained when several stakeholders throughout the supply chain forge a collaborative connection. This enables organizations to collaboratively achieve strategic advantages and enhance their operational efficiency, economic performance, and service efficacy (Butler & Batt, 2014; Gummesson et al., 2010).

5.1. Theoretical Contributions

From the standpoint of the SDGs, this study enhances supply chain management in several diverse areas. The development began with a theoretical model incorporating SSCP, green value co-creation, GInv, and GSCI. With its theoretical and empirical evidence on the links between GSCI, green innovations, and SSCP, this study makes a significant contribution. Based on the NRBV theory, this paper provides a scientific explanation for

some problems in the literature that lead to apathy toward investing in green supply chain integration and green innovation. This study demonstrates that agro-based enterprises can benefit from being ecologically responsible through shared practices in the supply chain. A key aspect of the study's uniqueness is that it addresses a paradigm previously neglected in research: the moderating effect of GVCc.

5.2. Practical Implications

Leaders of industries and organizations can apply our research findings in practice. First, the fact that GVCc acts as a mediator in this relationship indicates that it can either amplify or mitigate the effects of GSCI. This adds to what is already known about how green value co-creation can affect SSCP. Meanwhile, eco-conscious manufacturers have shifted their focus from conventional supply chain integration to GSCI. The supply chain stands to benefit from environmental initiatives, and there has been a corresponding increase in emphasis on sustainability, which is attributed to this trend (Jawaad & Zafar, 2020). In addition to making performance more sustainable, the results showed that GSCI values green supply chain management solutions that account for all environmental impacts and resource use. Furthermore, this suggests that firms could enhance their sustainability through performance-driven green innovation. To counteract disruptions, firms can proactively strengthen and integrate their supply chains. Therefore, resilience is crucial for greening, and achieving sustainability requires a balanced integration of innovative skills. Finally, this research significantly contributes to how GInv impacts the relationship between organizations' improved SSCP and the incorporation of green technologies into their business models.

5.3. Limitations and Suggestions for Future Research

Initially, this study may still encounter common method bias due to its reliance on self-reported data despite employing a two-stage survey to mitigate standard method variance. To address these issues, the researcher delineated the questions and reinforced the instructions to enhance the likelihood of honest responses. Consequently, self-report measures remain a significant issue in our investigation. Cross-sectional research design requires careful consideration when assessing causal correlations between GSCI and SSCP. Longitudinal research methods would provide more solid evidence about what causes what and better illustrate how greening and sustainability outcomes evolve. Moreover, the sample size is often limited. As part of the Sustainable Development Goals (SDGs), further research could be conducted to gather information from a broader range of countries and industries. Social, cultural, political, and economic factors significantly impact agro-allied businesses and related industries' environmental concerns. Researchers must meticulously evaluate contextual influences. Further studies may investigate how organizational culture, supply chain resilience, corporate social responsibility (CSR) programs, the complementary effects of green product and process innovation, as well as the three components of sustainable integration (customer, supplier, and internal) impact the sustainable performance of the supply chains of agro-based manufacturing companies.

6. Conclusions

The present research underscores the significance of green supply chain integration as a crucial component in attaining sustainable supply chain performance within specific agro-allied enterprises in Nigeria. This analysis considers intervening factors that positively influence the relationship between GSCI and SSCP. In this context, the current findings illustrate how the presence of GSCI can be assessed in conjunction with green innovation, as it fosters sustainable performance within the supply chain framework. Integrating

sustainability into business processes can give organizations a competitive advantage and enhance their overall sustainability. This study is based on the belief that integrating green supply chains and co-creating green value is one of an organization's essential needs. While it may seem challenging for organizations to remain operational, as their success relies heavily on their activities, businesses can improve their sustainable supply chain performance by gaining insights into green innovation and implementing value-creation strategies. This article demonstrates how agro-based manufacturing firms and their management can foster green innovation and performance through supply chain collaboration, offering valuable insights for enhancing sustainability in the agro-allied industry and economy. Notably, the current research contributes to the literature on green management, where NRBV is a key resource and can interact with sustainable supply chain performance. Regarding the progress of theoretical frameworks, green supply chain integration (GSCI) has been examined more thoroughly by incorporating the natural resource-based view (NRBV) theory. This integration enhances empirical research in sustainability by adopting a more comprehensive approach to a coherent industry engaged in the GSCI strategy, culminating in developing a conceptual alternative presented as a structural model.

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Informed Consent Statement: All participants provided informed consent before participating in the study.

Data Availability Statement: The data supporting this study's findings are available on request from the corresponding author. Due to restrictions, the data are not publicly available but can be available upon reasonable request.

Conflicts of Interest: The author declares no conflicts of interest.

Appendix A. Measurement Items

Appendix A.1. Green Supply Chain Integration (GSCI)

A. Green internal integration.

- GII1: Cross-functional cooperation for environmental improvements.
- GII2: Environmental issues are well communicated among departments.
- GII3: Environmental knowledge is accumulated and shared across departments.
- GII4: An environmental management system exists.

B. Green customer integration

- GCI1: Achieving environmental goals through joint planning with major customers.
- GCI2: Cooperating with major customers to reduce the environmental impact of our products.

GCI3: Cooperating with major customers for cleaner production, green packaging, or other environmental activities.
GCI4: Collaborating with major customers to implement the environmental management system.
GCI5: Implementing environmental audit for major customers' internal management.

C. Green supplier integration

GSI1: Collaborating with a major supplier to set up environmental goals.
GSI2: Implementing environmental audit for major supplier's internal management.
GSI3: Providing major suppliers with environmental design requirements related to design specifications and cleaner production technology.
GSI4: Requiring major suppliers to implement environmental management or obtain third-party certification of environmental management system.
GSI5: Selecting suppliers according to environmental criteria.

Appendix A.2. Green Value Co-Creation (GVCc)

1. Our organization facilitates the customer deciding how they want to receive the service/product offering.
2. The customer has many options to choose how they experience the service/product offering.
3. It is easy for the customer to receive the service/product offering when, where, and how they wants it.

Appendix A.3. Green Innovation (GInv)

1. Our organization chooses the materials of the product that produce the least amount of pollution for conducting the product development or design.
2. Our organization uses the least amount of materials to comprise the product for conducting the product development or design.
3. Our organization would circumspectly deliberate whether the product is easy to recycle, reuse, and decompose for conducting the product development or design.
4. The manufacturing process of the organization reduces the consumption of water, electricity, coal, or oil.
5. The manufacturing process of the organization effectively reduces the emission of hazardous substances or waste.
6. The manufacturing process of the organization reduces the use of raw material.

Appendix A.4. Sustainable Supply Chain Performance (SSCP)

1. Our organization has visibility of supply chain dynamics in the network.
2. Risks in the supply network are managed proactively by our organization.
3. Our organization has proper control over supply chain costs.
4. Wastages in our supply chain network have been reduced significantly.
5. Our organization's primary supply chain can supply final customers with timely complete orders.
6. Our organization can adhere to environmental standards as per customer requirement.
7. Our organization has minimized buffer stocks at all levels throughout the supply chain.
8. Our organization's supply chain can respond faster than competitors in a volatile business environment.

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