

“LEVERAGING GREEN HRM FOR SCOR-13–BASED SUPPLY CHAIN PERFORMANCE: THE MEDIATING ROLE OF GREEN SUPPLY CHAIN INTEGRATION UNDER TECHNOLOGICAL UNCERTAINTY—A DYNAMIC CAPABILITY AND INFORMATION PROCESSING PERSPECTIVE”

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Abstract

This study investigates the impact of Green Human Resource Management (GHRM) on Supply Chain Performance (SCP), with Green Supply Chain Integration (GSCI) as a mediator and Technological Uncertainty (TU) as a moderator, in Pakistan’s manufacturing sector. Drawing on the Dynamic Capability View and Information Processing Theory, the study examines how internal green capabilities translate into superior supply chain outcomes. Using survey data and structural equation modeling, the findings reveal that GHRM significantly enhances both GSCI ($\beta = 0.844, p < 0.001$) and SCP ($\beta = 0.367, p < 0.001$), while GSCI positively affects SCP ($\beta = 0.308, p < 0.001$), confirming its mediating role. TU also positively influences SCP ($\beta = 0.167, p < 0.001$) but negatively moderates the GSCI–SCP relationship ($\beta = -0.116, p = 0.003$), indicating boundary conditions under technological volatility. The study contributes by positioning GHRM as a dynamic capability, integrating DCV and IPT in green supply chain research, and providing empirical evidence from a developing economy. Practical implications emphasize sustainable HR practices and adaptive integration strategies.

1.0 INTRODUCTION

The imperative for sustainable business practices has increasingly reshaped strategic priorities across global industries. Environmental concerns, regulatory pressures, and stakeholder expectations have driven firms to embed environmentally responsible practices within their organizational processes, particularly through Green Human Resource Management (GHRM).

GHRM extends traditional human resource practices by aligning recruitment, training, performance management, and employee engagement with environmental objectives, thereby cultivating a workforce capable of supporting sustainability goals and enhancing organizational outcomes (Waheed & Akhtar, 2025). Empirical research demonstrates that

GHRM contributes positively to firm performance and fosters the successful adoption of green initiatives, often mediated by complementary organizational practices (Jawaad et al., 2022; Waheed & Akhtar, 2025).

In parallel, *Green Supply Chain Integration* (GSCI) has emerged as a critical mechanism for operationalizing sustainability within supply chains by coordinating environmental practices across internal functions and external partners. Integration of green practices—such as eco-design, green purchasing, and information sharing—has been linked to improved operational and environmental performance, particularly in manufacturing contexts where environmental impact is significant (PubMed et al., 2017; Riaz et al., 2020). Additionally, research from Pakistan finds that deeper integration of green supply chain practices correlates with enhanced competitive advantage and organizational performance (Jawaad et al., 2022; Riaz et al., 2020).

Dynamic Capabilities View (DCV) posits that firms achieve sustainable competitive advantage by developing, integrating, and reconfiguring internal and external competencies in response to rapidly changing environments (Teece et al., 1997; Singh et al., 2018). DCV has been used to explain how supply chain capabilities and integration practices contribute to firm performance under conditions of uncertainty and change. *Information Processing Theory* (IPT) highlights the importance of aligning a firm's information processing capacity with the complexity of its environment, whereby effective information flows and integration enhance decision-making and operational performance in uncertain conditions (Galbraith, 1973; Yan et al., 2024). IPT has been applied to supply chain contexts to explain how information sharing and integration reduce uncertainty and improve coordination among supply chain partners.

Despite growing evidence on GHRM and GSCI's benefits, **the interplay between green HR practices, supply chain integration, and performance outcomes under technological uncertainty remains underexplored** within emerging economies such as Pakistan. Technological uncertainty—characterized by rapid technological change and unpredictable innovation trajectories—can exacerbate information processing demands and challenge firms' adaptive

capabilities. Thus, investigating how GHRM facilitates GSCI to improve supply chain performance under technological uncertainty offers both theoretical and practical significance.

Grounded in DCV and IPT, this study develops and tests a comprehensive model linking Green HRM practices to Green Supply Chain Integration and supply chain performance, while accounting for the moderating influence of technological uncertainty. By situating this investigation within Pakistan's manufacturing sector, this research contributes to sustainability and supply chain literature and provides actionable insights for practitioners striving to balance environmental goals with competitive performance.

1.1 Problem Statement

Despite increasing recognition of the strategic role of Green Human Resource Management (GHRM) and Green Supply Chain Integration (GSCI), firms in emerging economies, particularly Pakistan, face significant challenges in leveraging these practices to enhance supply chain performance. Manufacturing organizations often operate under **technological uncertainty**, where rapid changes in technology create unpredictability in processes, operations, and coordination across the supply chain (Yan et al., 2024). While prior research indicates that GHRM positively influences organizational sustainability and GSCI enhances operational efficiency (Waheed & Akhtar, 2025; Riaz et al., 2020), the mechanisms through which GHRM drives GSCI and, consequently, supply chain performance, remain underexplored. Moreover, the moderating role of technological uncertainty how it may strengthen or weaken these relationships—has received limited attention, particularly in the context of Pakistan's manufacturing sector. This research addresses this gap by examining the pathways through which GHRM influences GSCI and supply chain performance under technological uncertainty, providing both theoretical and practical insights.

1.2 Research Objectives

This study aims to:

1. Investigate the direct impact of Green Human Resource Management practices on Green Supply Chain Integration in Pakistan's manufacturing sector.

2. Examine the effect of Green Supply Chain Integration on supply chain performance.
3. Assess the mediating role of Green Supply Chain Integration in the relationship between Green HRM and supply chain performance.
4. Evaluate the moderating effect of technological uncertainty on the relationship between Green Supply Chain Integration and supply chain performance.

2.0 Literature Review:

2.1 Green HRM

A large number of firms consider GHRM as vital for supporting environmental sustainability (Vidal-Salazar et al., 2012). Renwick (2004) argued that the concept of green HRM emerged after a number of studies on the same subject.

GHRM is a procedure of generating an eco-friendly manpower team that promotes an environment friendly culture in organizations. (Sheikh et al, 2019). GHRM has evolved as a new theme in human resources function (Zaid et al. 2018)

To achieve environmental sustainability GHRM practices is driving force Daily, Bonnie F.; Huang, (2001). GHRM practices is a bundle of activities lie GRS, GT and GEE according to AMO theory (Appelbaum et Al 2000)

2.2 GSCMI

GSCI is the level of strategic relationship between a firm and its external stakeholder as well its internal routines to fulfill environmental requirements. (Chen et al., 2017; Yang et al., 2020)

SCMI enables the capability of decision makers to ensure integration between companies' internal and external stakeholders to obtain competitive advantage (Xu et al., 2013)

There are type three GSCI, internal integration, Supplier integration and customer integration (Song et al., 2017). GII ensures efficiency through production schedules, demand forecast and linkage with external stakeholders. (Wong, et al (2011).

SI also termed as backward integration ensures proper and smooth flow of raw materials, while GCI also termed as forward integration entails connections with customers to make long term strategic relations with customer (Flynn et al., 2010)

XU (10) stated that GSCI leads to flexible deliveries which lead to competitive advantage.

GSI enables a firm to establish a trustworthy relationship with supplier. (Kong et al., 2020).

One of the major objectives of GSI is enabling green purchases (Zhu et al., 2012)

Coordinating customer to know their environmental demands and needs a firm must plan jointly to achieve environmental objectives. (Du et al., 2018).

2.3 Performance

Supply chain performance is the backbone of the organizational performance, especially in changing environments that are characterized by uncertainty (Ayoub & Abdallah, 2019). The success of supply chains raises the competitive standing and is thus a major management concern (Attia, 2016). It is widely understood as the capability to address the needs of the customers about their quality, costs and responsiveness (Chen et al., 2004). On the same note, Green and Inman (2005) emphasize that performance involves provision of the right items and services at proper amounts, at proper place and at the lowest possible cost to the ultimate customers.

Supply chain performance refers to the extent to which a firm's supply chain achieves superior outcomes in terms of reliability, responsiveness, agility, cost efficiency, and asset utilization. Drawing on the SCOR model (Version 13), supply chain performance is conceptualized as a multidimensional, score-based construct reflecting both operational and strategic effectiveness.

Supply chain performance can therefore be perceived as the ability to deliver quality products and services on a sustained basis, at the right quantity and amount based on the set time lines, at a competitive price.

Score 13 is a comprehensive framework for evaluating supply chain performance, encompassing multiple dimensions such as reliability, responsiveness, agility, cost efficiency, and asset management efficiency. Unlike single-metric assessments, score 13 provides a structured approach that allows firms to measure both operational and strategic outcomes, offering insights into strengths and areas for improvement across supply chain functions.

Reliability, as measured in Score 13, emphasizes the consistency of fulfilling customer orders and maintaining quality standards and speed of adapting.

For Pakistani manufacturers, this is critical due to frequent logistical constraints and supply variability. Responsiveness evaluates the speed and effectiveness with which firms adapt to changing market demands, an essential factor in a dynamic and competitive manufacturing environment. Agility, another dimension of Score 13, captures the flexibility of firms to adjust production, inventory, and distribution strategies in response to unexpected changes, such as raw material shortages or sudden shifts in export demand.

Cost efficiency and asset management efficiency, also integral to Score 13, provide insights into the judicious use of resources and the ability to minimize operational costs without compromising service quality. By adopting this comprehensive scoring system, Pakistani manufacturing firms can benchmark their supply chain processes, identify critical gaps, and implement targeted improvements. Over time, score 13 enables managers to enhance not only operational performance but also strategic decision-making, ultimately improving competitiveness both locally and internationally.

Score 13-Based Supply Chain Performance and Its Integration with Green Practices

In the context of Pakistan's manufacturing sector, score 13 is particularly relevant due to frequent supply disruptions, fluctuating demand, and technological constraints. Reliability ensures consistent fulfillment of orders despite logistical challenges, responsiveness allows firms to quickly adjust to changing customer requirements, and agility helps manage sudden shifts in production or distribution. Similarly, cost efficiency and effective resource management are critical for maintaining competitiveness in a market characterized by resource constraints and cost-sensitive operations. By adopting Score 13, Pakistani manufacturers can benchmark performance, identify operational gaps, and implement targeted improvements that enhance both short-term efficiency and long-term strategic outcomes.

The integration of Green Supply Chain practices (GSCI) further enhances the relevance of Score 13. GSCI emphasizes environmentally responsible coordination across procurement, production, and distribution processes. When combined with Green HRM initiatives—such as employee training,

engagement, and awareness programs—GSCI positively influences supply chain performance across all Score 13 dimensions. Employees trained in sustainable practices contribute to more reliable, responsive, and agile operations while supporting cost and resource efficiency through waste reduction and optimized processes. Therefore, aligning Green HRM and GSCI with supply chain operations not only strengthens environmental sustainability but also improves operational and strategic performance, as captured by Score 13 metrics.

2.4 Moderating Role of Technological Uncertainty

Technological uncertainty refers to the degree of unpredictability associated with rapid technological changes, innovation pace, and the adoption of new production and information technologies within an industry. In manufacturing sectors of emerging economies such as Pakistan, frequent technological changes intensify information processing requirements and increase coordination complexity across supply chain partners.

From the perspective of **Information Processing Theory (IPT)**, high technological uncertainty elevates information processing needs, making integration mechanisms essential for achieving superior performance (Galbraith, 1974). Green Supply Chain Integration (GSCI) enhances real-time information sharing, joint environmental planning, and collaborative decision-making, thereby enabling firms to cope more effectively with technological turbulence.

Similarly, the **Dynamic Capabilities View (DCV)** suggests that under conditions of technological uncertainty, firms must continuously reconfigure resources and capabilities to maintain competitiveness (Teece, 2007). GSCI represents a dynamic capability that allows organizations to realign green practices, technologies, and processes across the supply chain, thereby strengthening supply chain reliability, responsiveness, agility, and cost efficiency as captured by the **SCOR-13 performance dimensions**.

When technological uncertainty is high, the positive impact of GSCI on supply chain performance is expected to be stronger because integrated supply chains can better absorb technological shocks, coordinate technological upgrades, and respond

rapidly to environmental and market changes. Conversely, under low technological uncertainty, the performance benefits of GSCI may be relatively weaker due to reduced information and coordination demands.

2.5 Theoretical Foundations

2.5.1 Dynamic Capabilities View (DCV)

Dynamic Capabilities View explains that firms achieve superior performance by **sensing, seizing, and reconfiguring internal and external resources** in response to environmental changes (Teece, 2007). In the context of green practices:

- **Green HRM** (training, recruitment, rewards for sustainability) builds **organizational capabilities** to promote environmental objectives.
- These capabilities enable firms to **integrate environmental practices across the supply chain**, i.e., **Green Supply Chain Integration (GSCI)**.
- Integration requires continuous **adaptation, coordination, and reconfiguration** of processes with suppliers and customers to align with sustainability goals.

Recent studies argue that green integration enables firms to continuously realign supply chain resources, thereby enhancing supply chain performance under environmental uncertainty (Han & Huo, 2020; Low & Hashim, 2025).

DCV logic: Green HRM develops dynamic capabilities → GSCI becomes a higher-order capability → prepares the organization to achieve superior supply chain performance.

2.5.2 Information Processing Theory (IPT)

According to Information Processing Theory, supply chains that integrate environmental and operational information across suppliers and customers can process information more effectively, reduce uncertainty, and improve decision-making. Consequently, green supply chain integration enhances score-based supply chain performance by enabling firms to coordinate processes, respond to variability, and achieve operational and sustainability targets.

IPT complements DCV by explaining **how GSCI improves performance outcomes**. The theory asserts:

- Organizations need to process information to reduce uncertainty and improve decision-making (Galbraith, 1973).
- **GSCI increases information flow** across the supply chain, including sustainability data, supplier environmental compliance, and customer requirements.
- Enhanced information processing reduces operational uncertainty and enables **better coordination, timely decisions, and responsiveness**.
- This translates into **score-based supply chain performance**: reliability, flexibility, cost efficiency, and sustainability outcomes.

IPT logic: GSCI improves the firm's information processing capacity → reduces uncertainty → enhances supply chain performance.

Green HRM alone cannot directly improve supply chain performance. Its impact is realized through GSCI, which acts both as a dynamic capability (DCV) and an information processing mechanism (IPT), linking human resource practices to measurable performance outcomes.

3.0 Hypothesis development:

3.1 GHRM and Green SCI:

When HRM practices are aligned to specifically promote cooperation with customers and suppliers, employees are more motivated to address wider environmental issues. (Green et al., Yu et al., 2017). Longoni et al. (2018) found support for the positive association between GHRM practices and external GSCM; however, they only considered suppliers in measuring external GSCM. Zaid et al. (2018) found that GHRM positively affected external GSCM practices, based on measuring external GSCM as a composite construct combining buyers and suppliers.

3.1.1 Green training: GT not only enables GCI but also facilitates GSI. GT enables knowledge and skill needed for solving problems related to customers and supplier.

3.3.1.2 Green Motivation:

Using RBV (Barney, 2001) and AMO (Appelbaum et al., 2000), we expect that firms that value worth of its human capital (S.K. Singh, et al. 2020) will attempt to institutionalize GHRM for the week of motivating

and providing opportunities to GHRM to leverage their potentialities for GSCI

3.3.1.3 Green employee involvement (GEE):

Sila (2007) stated that GEE is a strong force for persistent progression.

3.2 Impact of Green HRM and Green SCI

The **Dynamic Capabilities View (DCV)** explains that firms achieve superior performance by **sensing, seizing, and reconfiguring resources** in response to environmental changes (Peteraf, & Leih, 2016). In the context of sustainability, **Green HRM practices** including environmentally focused recruitment, training, performance appraisal, and reward systems—develop employees' knowledge, skills, and motivation to support environmental initiatives (Redman, & Maguire, 2013). These practices enable organizations to **integrate green principles across their supply chains**, enhancing collaboration with suppliers and customers and ensuring alignment with sustainability objectives.

Hypothesis 1 (H1): Green HRM practices are positively associated with Green Supply Chain Integration.

3.2 Impact of Green Supply Chain Integration on Supply chain performance:

Information Processing Theory (IPT) posits that organizations need to **process and share information effectively** to reduce uncertainty and improve decision-making (Galbraith, 1973; Tatikonda & Montoya-Weiss, 2001). In a green supply chain context, **Green Supply Chain Integration (GSCI)** enhances the firm's ability to collect, process, and communicate environmental and operational information with upstream suppliers and downstream customers (Dubey, Gunasekaran, Childe, Papadopoulos, & Roubaud, 2017). Improved information flow allows for **timely and informed decision-making**, better coordination, and effective implementation of sustainable practices, ultimately improving **score-based supply chain performance** such as reliability, flexibility, cost efficiency, and sustainability outcomes.

Green Integration and Score-Based Supply Chain Performance

Green integration emphasizes embedding environmental practices across internal functions, suppliers, and customers to enhance supply chain effectiveness. **Green internal integration** aligns environmental objectives within procurement, production, logistics, and quality management, enabling firms, through the **Dynamic Capability View (DCV)**, to reconfigure routines and processes in response to environmental and operational changes. This enhances coordination, reliability, and responsiveness, core elements of score-based supply chain performance.

Green supplier integration fosters collaboration with upstream partners through joint planning, information sharing, and green sourcing. DCV highlights this as an externally oriented capability that allows firms to sense environmental risks and seize eco-efficiency opportunities. **Information Processing Theory (IPT)** underscores that effective communication and data exchange with suppliers reduce uncertainty and improve input quality and delivery reliability.

Green customer integration involves collaborating with customers to meet environmental requirements and support sustainable products and reverse logistics. By sensing evolving market demands (DCV) and ensuring timely information flow (IPT), firms improve responsiveness, service quality, and market effectiveness. Collectively, these green integration practices are expected to enhance score-based supply chain performance.

Hypothesis 2 (H2): Green Supply Chain Integration is positively associated with score-based Supply Chain Performance.

3.3 Mediation Role of Green Supply Chain Integration

While Green HRM develops the firm's dynamic capabilities, its effect on performance is **realized through Green Supply Chain Integration**. GSCI serves a **dual role** in linking HR practices to performance:

1. **DCV perspective:** It acts as a higher-order capability that reconfigures and aligns internal and external processes with

environmental objectives (Teece, 2007; Wu, 2013).

2. **IPT perspective:** It enhances information processing across the supply chain, reducing uncertainty and improving operational and environmental decision-making, which positively affects measurable performance outcomes (Flynn, Huo, & Zhao, 2010; Wong, Boon & Wong, 2011).

3.4.1 Technological uncertainties:

Technological uncertainties means unpredictability of product and process Wong *et al.*, (2015) Due to vigorous and manifested aspects of technology, uncertainty in technology will have an adverse impact on different industries (Narayanan *et al.*, (2015) When stakeholders in a SC experience technological uncertainties SCI has capacity to cooperate which in turns increases firm’ capability for performance (Lai *et al.*, 2015)

Hypothesis 3 (H3): Green Supply Chain Integration mediates the relationship between Green HRM and score-based Supply Chain Performance.

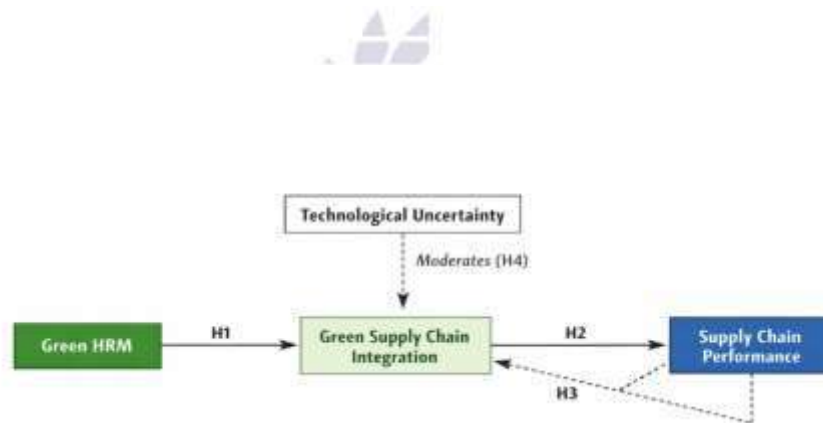
3.4. Uncertainty as moderator

Technology uncertainty or complexity may strengthen the positive impact of GSCI on supply chain performance, as higher uncertainty increases the need for effective information processing (Galbraith, 1973; Sousa & Voss, 2008).

High level of technological uncertainty impact more on SCI as compared to low level of technological uncertainty. Therefore, we assume that effect of technology on SCI would be different at different levels of technology.

Hypothesis 4 (H4): The positive relationship between GSCI and score-based Supply Chain Performance is stronger under high technological uncertainty.

Conceptual Model



Control variables:

Firm size and firm age will be used as control variable. Since large firms have more funds, it is easy to implement GSCI (Du *et al.*, 2018). Also, the age of firm also has significant impact on performance as older firms seemed to less efficient (Van Doorn *et al.*, 2013).

4.0 Research Methodology

4.1 Research Design

This study employs a **quantitative, cross-sectional research design** to examine the relationships between Green Human Resource Management (GHRM), Green Supply Chain Integration (GSCI), Technological Uncertainty (TU), and Supply Chain Performance (SCP) in the manufacturing sector of

Pakistan. A **survey-based approach** was adopted to collect primary data, enabling the investigation of causal relationships among the study variables. The study applies the **Dynamic Capability View (DCV)** and **Information Processing Theory (IPT)** as theoretical foundations to conceptualize how organizational capabilities and information processing mechanisms influence supply chain performance in environmentally conscious settings.

4.2 Population and Sampling

The population of the study includes **manufacturing firms in Pakistan**, particularly those engaged in supply chain activities. To ensure relevance, only firms actively participating in the supply chain network were considered. A **purposive sampling technique** was employed, targeting supply chain managers, HR managers, and other relevant professionals with a minimum of **three years of experience** in their respective firms. The final sample comprised **235 respondents**, ensuring sufficient statistical power for structural equation modeling (SEM) analysis.

4.3 Data Collection & Measurement Scales:

Data were collected using a **structured questionnaire**, adapted from established scales in prior literature:

- **GHRM:** Measured using items adapted from Daily et al. (2012) and one additional item from (Jabbour, 2015), Five items proposed by Pinzone et al. (2016) and Masri and Jaaron (2017) were adapted to measure green employee involvement (EEN).
- focusing on environmentally-oriented HR practices such as green recruitment, training, and performance management. Here we used GHRM as a multidimensional second order construct.
- **GSCI:** Measured using items adapted from Green internal integration (Vachon & Klassen, 2008; Wu, 2013). Green supplier integration (Vachon & Klassen, 2008; Wu, 2013). Green customer integration (Vachon & Klassen, 2008; Wu, 2013). Green Supply chain integration is also used a second order construct.

Technological Uncertainty (TU): Measured using items adapted from Technological uncertainty questions were selected from Flynn et al.'s study

(Flynn et al., 2016), capturing the perceived unpredictability in technology.

Supply Chain Performance (SCP): Assessed using SCOR 13-based metrics, including agility, cost efficiency, asset management efficiency, and responsiveness **Özden Özkanlısoy & Füsün Bulutlar (2023)** developed and validated a comprehensive SCOR v13.0-based supply chain performance scale, covering key performance dimensions such as reliability, responsiveness, agility, cost, and asset management efficiency.

A **five-point Likert scale** (1 = strongly disagree, 5 = strongly agree) was used for all items.

4.4 Measures and Instrument Reliability

The reliability and validity of the instrument were assessed through **Cronbach's alpha**, **composite reliability**, and **average variance extracted (AVE)**. Items with low loadings (<0.60) were removed to ensure **construct validity**, and **discriminant validity** was confirmed using the **Fornell-Larcker criterion**.

4.5 Data Analysis Techniques

The study employs **Partial Least Squares Structural Equation Modeling (PLS-SEM)** using **SmartPLS 4** to test the hypothesized relationships. PLS-SEM was chosen due to its suitability for complex models with mediating and moderating effects and its robustness to non-normal data distributions. The following steps were undertaken:

1. **Measurement Model Assessment:** Evaluated internal consistency, convergent validity, and discriminant validity.
2. **Structural Model Assessment:** Tested the direct, indirect (mediating), and moderating relationships.
3. **Bootstrapping (5,000 resamples):** Used to assess the significance of path coefficients.
4. **Control Variables:** Firm size and industry type were included as control variables to account for potential confounding effects.

4.6 Ethical Considerations

Respondents were assured of **anonymity and confidentiality**, and participation was voluntary. Informed consent was obtained before survey administration. Data were used solely for research

purposes, in accordance with ethical research standards.

5.0 Analysis & Interpretations:

5.1 Psychometric analysis:

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
SCP	0.940	0.941	0.954	0.806

The reliability and convergent validity results for the construct **Supply Chain Performance (SCP)** indicate a very strong measurement quality.

Cronbach's alpha for SCP is **0.940**, which is well above the commonly accepted threshold of 0.70. This shows a high level of internal consistency among the items used to measure supply chain performance, suggesting that the indicators reliably capture the same underlying concept.

Composite reliability further confirms this consistency. The value of **rho_a** and **rho_c** both exceed the recommended minimum level of 0.70. These results indicate that the construct demonstrates excellent reliability and that the indicators jointly provide a stable and consistent measurement of SCP.

The **Average Variance Extracted (AVE)** for SCP is **0.806**, which is substantially higher than the minimum acceptable value of 0.50. This implies that more than 80 percent of the variance in the observed indicators is explained by the SCP construct itself rather than by measurement error. Hence, strong convergent validity is established.

Overall, the results confirm that the SCP construct is both highly reliable and valid, making it suitable for further structural model analysis and hypothesis testing.

5.2 Discriminant Validity

Fornell and Larcker

	GHRM	GSCI	SCP	TU
GHRM	0.860			
GSCI	0.844	0.870		
SCP	0.827	0.856	0.878	
TU	0.780	0.784	0.811	0.854

Discriminant validity was assessed using the **Fornell-Larcker criterion**, where the square root of the Average Variance Extracted (AVE) for each construct is compared with its correlations with other constructs. Discriminant validity is established when

the diagonal values are greater than the corresponding off-diagonal correlations.

The results based on the Fornell-Larcker criterion confirm that all constructs in the model demonstrate satisfactory discriminant validity, as each construct is more strongly related to its own measures than to those of other constructs.

5.3 Correlation

	Agility	Asset Management	Cost efficiency	GHRM	GSCI	Reliability	Responsiveness	TU	TU x GSCI
Agility	1.000								
Asset Management		1.000							
Efficiency	0.727		1.000						

Cost efficiency	0.666	0.862	1.000						
GHRM	0.827	0.797	0.731	1.000					
GSCI	0.818	0.780	0.725	0.844	1.000				
Reliability	0.834	0.716	0.675	0.785	0.823	1.000			
Responsiveness	0.851	0.745	0.687	0.836	0.827	0.804	1.000		
TU	0.755	0.716	0.692	0.780	0.784	0.745	0.728	1.000	
TU x GSCI	-0.744	-0.761	-0.685	-0.789	-0.838	-0.769	-0.762	-0.705	1.000

The correlation matrix provides insight into the relationships among the key variables in this study, including supply chain performance dimensions (Agility, Asset Management Efficiency, Cost Efficiency, Reliability, Responsiveness), Green Human Resource Management (GHRM), Green Supply Chain Integration (GSCI), Technological Uncertainty (TU), and the interaction term (TU × GSCI).

The correlations indicate strong positive relationships among HR practices, supply chain

integration, and performance dimensions, supporting the theoretical model. The negative correlations of the interaction term align with the finding that technological uncertainty weakens the benefits of GSCI on performance. Overall, the table confirms the expected associations and provides preliminary evidence supporting the hypothesized relationships.

Model Evaluation:

Explanatory Power- R- Square

	R-square	R-square adjusted
GSCI	0.712	0.711
SCP	0.871	0.869

The coefficient of determination (R²) values indicate a strong explanatory power of the model for both endogenous constructs.

For **Green Supply Chain Integration (GSCI)**, the R-square value is **0.712**, with an adjusted R-square of **0.711**. This means that approximately 71 percent of the variance in GSCI is explained by its predictor(s) in the model. The very small difference between R-square and adjusted R-square suggests that the model

is well specified and not inflated by unnecessary predictors.

In the case of **Supply Chain Performance (SCP)**, the R-square value is **0.871**, while the adjusted R-square is **0.869**. This indicates that about 87 percent of the variance in supply chain performance is accounted for by the explanatory variables included in the model. Such a high value reflects a strong predictive capability and suggests that the model effectively captures the key drivers of SCP.

5.5 VIF (Collinearity)

	VIF
Agility	4.810
Asset Management Efficiency	4.860
Cost efficiency	4.002
GHRM	1.000

GSCI	1.000
Reliability	3.866
Responsiveness	4.412
TU	1.000
TU x GSCI	1.000

Variance Inflation Factor (VIF) values were examined to assess the presence of multicollinearity among the predictor variables. VIF indicates the extent to which the variance of an estimated coefficient is inflated due to correlation with other predictors. As a general rule, VIF values below 5 suggest that multicollinearity is not a serious concern.

The VIF values for the supply chain performance dimensions—**agility (4.810)**, **asset management efficiency (4.860)**, **cost efficiency (4.002)**, **reliability (3.866)**, and **responsiveness (4.412)**—all remain below

the critical threshold of 5. Although some values are relatively high, they are still within acceptable limits, indicating manageable levels of correlation among these indicators. The VIF values for **GHRM**, **GSCI**, **Technological Uncertainty (TU)**, and the interaction term **TU × GSCI** are all **1.000**, which reflects the absence of multicollinearity for these constructs. This suggests that these predictors are statistically independent and do not overlap excessively in explaining the variance of the dependent variables.

5.6 Model fit Indices

	Saturated model	Estimated model
SRMR	0.045	0.060
d_ ULS	0.072	0.129
d_ G	0.125	0.199
Chi-square	248.493	297.247
NFI	0.916	0.900

Model fit was evaluated using multiple goodness-of-fit indicators for both the **saturated model** and the **estimated model**, providing a comprehensive assessment of how well the proposed model represents the observed data.

The **Standardized Root Mean Square Residual (SRMR)** values are **0.045** for the saturated model and **0.060** for the estimated model. Both values are below the recommended cutoff of 0.08, indicating a good overall fit and suggesting that the discrepancies between the observed and predicted correlations are minimal.

The **d_ ULS** and **d_ G** values increase slightly from the saturated model (0.072 and 0.125, respectively) to the estimated model (0.129 and 0.199). This increase is expected because the estimated model imposes structural constraints. Despite this increase, the values remain within acceptable limits, indicating that the model does not suffer from serious misspecification.

The **chi-square** statistic rises from **248.493** in the saturated model to **297.247** in the estimated model. This increase reflects the restrictions introduced in the estimated model compared to the saturated one. In PLS-SEM, chi-square is sensitive to sample size and is therefore interpreted cautiously; the observed values do not suggest a problematic fit.

Finally, the **Normed Fit Index (NFI)** values are **0.916** for the saturated model and **0.900** for the estimated model. Both exceed the commonly accepted threshold of 0.90, indicating that the proposed model explains the data substantially better than a null model.

Taken together, these fit indices demonstrate that the estimated model shows an acceptable to good overall fit, supporting the adequacy of the proposed measurement and structural relationships for further interpretation and hypothesis testing.

Hypothesis testing

Hypothesis	Path Coefficient	Original sample (O)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	Decision
H1	GHRM -> GSCI	0.844	0.021	40.853	0.000	Accepted
H2	GHRM -> SCP	0.367	0.063	5.861	0.000	Accepted
H3	GSCI -> SCP	0.308	0.051	5.991	0.000	Accepted
H4	TU -> SCP	0.167	0.046	3.639	0.000	Accepted
H5	TU x GSCI -> SCP	-0.116	0.038	3.017	0.003	Rejected

Hypotheses were evaluated based on the sign of the path coefficient, the t-statistics, and the associated p-values. A hypothesis is considered **supported** when the relationship is statistically significant ($p < 0.05$) and the direction of the effect is theoretically consistent.

H1 (GHRM → GSCI)

The path coefficient is positive and very strong ($\beta = 0.844$). The t-value (40.853) far exceeds the critical value, and the p-value is below 0.001. This provides very strong statistical evidence in support of H1. Therefore, **H1 is accepted**.

H2 (GHRM → SCP)

The relationship between GHRM and SCP is positive ($\beta = 0.367$) and statistically significant, with a t-value of 5.861 and a p-value below 0.001. This indicates that green HR practices directly enhance supply chain performance. Hence, **H2 is accepted**.

H3 (GSCI → SCP)

The path coefficient for GSCI to SCP is positive ($\beta = 0.308$) and significant. The t-statistic (5.991) and p-value (< 0.001) confirm strong empirical support. Accordingly, **H3 is accepted**.

H4 (TU → SCP)

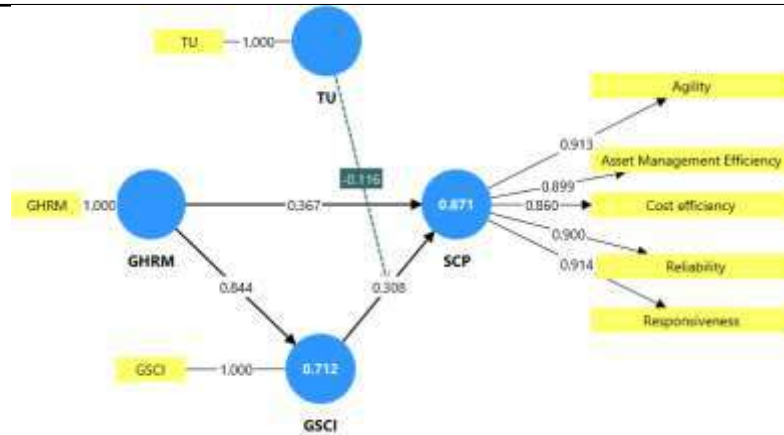
Technological uncertainty shows a positive and significant effect on SCP ($\beta = 0.167$). The t-value of 3.639 and a p-value below 0.001 indicate that the relationship is statistically meaningful. Thus, **H4 is accepted**.

H5 (TU × GSCI → SCP)

The interaction effect is statistically significant ($t = 3.017, p = 0.003$); however, the path coefficient is **negative** ($\beta = -0.116$). If H5 was hypothesized as a positive moderating effect, this result contradicts the expected direction. Therefore, despite being statistically significant, the hypothesis is **not supported in the proposed direction**. Hence, **H5 is rejected**.

Summary of hypothesis testing

H1, H2, H3, and H4 are **accepted**, as their relationships are positive and statistically significant. H5 is **rejected** due to the negative sign of the interaction effect, which does not align with the hypothesized moderation direction.



6.0 Discussion and Conclusions

This study examined the influence of **Green Human Resource Management (GHRM)** on **Supply Chain Performance (SCP)**, with **Green Supply Chain Integration (GSCI)** as an explanatory mechanism and **Technological Uncertainty (TU)** as a contextual factor in Pakistan’s manufacturing sector. Anchored in the **Dynamic Capability View (DCV)** and **Information Processing Theory (IPT)**, the findings offer robust empirical evidence on how internal green capabilities are translated into external supply chain outcomes.

The results indicate that GHRM exerts a strong and positive effect on GSCI, suggesting that environmentally oriented HR practices enhance employees’ skills, motivation, and alignment with organizational sustainability objectives, which in turn facilitate closer coordination with supply chain partners. From a DCV perspective, this finding highlights GHRM as a firm-level capability that supports the reconfiguration of routines and inter-organizational processes in response to environmental demands.

The direct relationship between GHRM and SCP further demonstrates that green HR practices contribute to performance outcomes independently of supply chain integration. This underscores the strategic role of human capital in improving supply chain efficiency, responsiveness, and reliability, particularly in emerging market contexts where operational constraints are more pronounced.

Consistent with IPT, GSCI shows a significant positive association with SCP. Integrated green supply chains appear better able to process complex information related to environmental requirements, coordination, and compliance, leading to improved performance outcomes. This finding reinforces the view that integration enhances information quality and decision effectiveness across supply chain partners.

Technological uncertainty exhibits a positive direct effect on SCP, implying that firms operating in volatile technological environments may adopt more adaptive and proactive approaches that ultimately enhance performance. However, the interaction between TU and GSCI is negative, indicating that high levels of technological uncertainty weaken the positive impact of supply chain integration on performance. This suggests that under conditions of rapid technological change, the coordination and information processing demands of green integration may exceed firms’ absorptive and managerial capacities, thereby reducing its effectiveness. This result highlights an important boundary condition in the GSCI–performance relationship.

Overall, the model demonstrates substantial explanatory power, with high variance explained in both GSCI and SCP, and satisfactory reliability, validity, and model fit. These results confirm the robustness of the proposed framework and support the complementary use of DCV and IPT in explaining green supply chain performance.

6.1 Theoretical Contributions

This study contributes to the green supply chain literature in three key ways. First, it empirically

positions **GHRM as a dynamic capability**, extending DCV by linking internal green HR systems with external supply chain integration and performance. Second, it advances IPT by demonstrating that while integration enhances performance through improved information processing, its effectiveness is contingent on environmental conditions such as technological uncertainty. Third, by focusing on Pakistan's manufacturing sector, the study enriches the limited empirical evidence from developing economies, offering insights into sustainability practices under institutional and technological constraints.

6.2 Managerial Implications

For managers, the findings emphasize the importance of embedding environmental objectives within HR systems rather than treating sustainability as an operational add-on. Green recruitment, training, and performance management can strengthen supply chain integration and directly enhance performance. Managers should also recognize that while supply chain integration is beneficial, its implementation under high technological uncertainty requires flexible coordination structures, digital readiness, and continuous capability development to avoid performance erosion.

6.3 Limitations and Future Research

This study has certain limitations. The cross-sectional design restricts causal inference, and future research could adopt longitudinal approaches to capture dynamic capability development over time. The focus on a single country and sector may limit generalizability, suggesting the need for comparative studies across institutional and industrial contexts. Future research may also examine additional boundary conditions, such as environmental regulation intensity or digital maturity, to further clarify the contingencies affecting green supply chain integration.

6.4 Conclusion

This study demonstrates that **Green Human Resource Management and Green Supply Chain Integration are critical drivers of supply chain performance**, while technological uncertainty shapes the conditions under which integration is most effective. By integrating DCV and IPT, the findings

offer a nuanced understanding of how internal green capabilities translate into external performance outcomes, contributing both theoretically and practically to the green supply chain management literature.

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