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Green Supply Chain Management and Performance: Roles of Agility, Resilience, and Big Data Analytics

Gestión de la cadena de suministro verde y desempeño: agilidad, resiliencia y *big data*

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Abstract

Keywords:
Sustainability; agility; financial performance; resilience; big data.

Green supply chain management has emerged as a key strategy for manufacturing firms seeking to balance environmental responsibility and economic performance, particularly in emerging economies. This study examines how green supply chain management practices relate to perceived environmental and financial performance in Mexican manufacturing firms, considering the mediating roles of supply chain agility and resilience and the moderating role of big data analytics capabilities. Data were collected through a survey of 270 manufacturing firms in Mexico and analyzed using partial least squares structural equation modeling. Findings indicate that green supply chain management is positively associated with both performance dimensions. Supply chain agility and resilience partially mediate these relationships, while big data analytics capabilities strengthen the association with environmental performance but not with financial performance. The results clarify how sustainability initiatives operate under enabling organizational capabilities in an emerging economy context.

Resumen

Palabras clave:
Sostenibilidad; agilidad; desempeño financiero; resiliencia; big data.

La gestión de la cadena de suministro verde se ha consolidado como una estrategia clave para que las empresas manufactureras equilibren la responsabilidad ambiental y el desempeño económico, especialmente en economías emergentes. Este estudio analiza cómo las prácticas de gestión de la cadena de suministro verde se relacionan con el desempeño ambiental y financiero percibido en empresas manufactureras mexicanas, considerando los roles mediadores de la agilidad y la resiliencia de la cadena de suministro, así como el papel moderador de las capacidades de analítica de big data. Se recopilaron datos mediante una encuesta aplicada a 270 empresas manufactureras en México y se analizaron mediante modelado de ecuaciones estructurales por mínimos cuadrados parciales. Los resultados indican asociaciones positivas con ambos desempeños. La agilidad y la resiliencia median parcialmente estas relaciones, mientras que la analítica de big data fortalece la asociación con el desempeño ambiental, pero no con el financiero.

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Introduction

Global supply chains account for a substantial share of carbon emissions and environmental degradation in manufacturing (Bové & Swartz, 2016). These challenges highlight the urgency of reconciling environmental responsibility with economic performance. Manufacturing firms face increasing pressure to meet corporate social responsibility expectations and comply with regulatory and market demands for sustainability (Alkandi *et al.*, 2024; Shafique *et al.*, 2017). In response, many organizations have adopted green supply chain management (GSCM) practices aimed at reducing environmental impact while improving competitiveness and financial outcomes (Begen *et al.*, 2016; Kouhizadeh & Sarkis, 2018).

Mexico reflects both the opportunities and constraints of emerging economies. While practices such as eco-design, green purchasing, and environmental management are increasingly adopted, collaboration with suppliers and customers remains limited due to weak regulatory enforcement, fragmented supply chains, and restricted institutional financing (Wu *et al.*, 2022). These contextual constraints suggest that the effectiveness of GSCM in delivering environmental and financial benefits depends on the presence of enabling organizational capabilities.

Despite the growing adoption of GSCM practices, manufacturing firms continue to face tensions between cost efficiency and environmental responsibility. The pursuit of productivity and lower production costs often leads to environmental externalities such as pollution and inefficient resource use (Zeng *et al.*, 2022). These pressures increase stakeholder scrutiny and complicate the alignment between sustainability objectives and performance goals (Sarkis, 2020; Zhu *et al.*, 2005).

Empirical findings on the performance outcomes of GSCM remain inconsistent. While some studies report positive environmental effects with limited or no financial gains (Younis *et al.*, 2016; Zeng *et al.*, 2022), others suggest that internal green practices and institutional pressures may even constrain short-term financial performance (Agyabeng-Mensah *et al.*, 2020; Ahmed *et al.*, 2020). These mixed results raise a critical question: why does the relationship between green supply chain management and organizational performance vary across contexts, and what mechanisms may help explain this divergence?

Dynamic capabilities theory and the resource-based view offer a useful lens to explain these inconsistencies. From a dynamic capabilities perspective, supply chain agility and resilience function as enabling mechanisms that allow firms to sense environmental pressures, reconfigure resources, and adapt processes in response to green initiatives. Although these capabilities are theoretically central, their mediating role in GSCM research remains underexplored. Emerging evidence suggests that agility and resilience can develop through GSCM adoption (Dubey *et al.*, 2015; Ghaderi *et al.*, 2024), yet further empirical validation in manufacturing contexts is needed.

Building on the resource-based view and dynamic capabilities theory, this study conceptualizes green supply chain management practices and big data analytics as strategic resources, while supply chain agility and resilience are treated as dynamic capabilities that enable firms to translate sustainability initiatives into performance outcomes.

Stakeholder and institutional perspectives further emphasize the role of external pressures, such as regulatory demands and customer expectations, in driving the adoption of sustainability practices, particularly in emerging economies (Ahmed *et al.*, 2020; Zailani *et al.*, 2012; Zhu *et al.*, 2005). These external forces interact with internal capabilities to shape how effectively GSCM translates into environmental and financial outcomes. Integrating these perspectives, this study develops an analytical framework to examine how and under what conditions GSCM contributes to performance in Mexican manufacturing firms, a context characterized by institutional constraints and resource limitations.

This study extends prior research by examining the mediating roles of supply chain agility and resilience as dynamic capabilities linking GSCM to organizational performance, and by incorporating big data analytics as a moderating technological enabler. Accordingly, the objective is to analyze how green supply chain management practices relate to environmental and financial performance in Mexican manufacturing firms under these enabling conditions.

By integrating dynamic capabilities and technological enablers, this study advances understanding of how GSCM translates into environmental and financial performance in emerging economy contexts.

Literature review

Hypotheses development

Green supply chain management (GSCM) has been widely recognized as a strategic approach to improve both environmental performance and competitiveness across supply networks (Ageron *et al.*, 2012; Alkandi *et al.*, 2024). By integrating environmental considerations into procurement, production, and distribution processes, firms seek to reduce resource consumption and environmental impact while strengthening collaborative relationships within the supply chain.

Despite the growing adoption of GSCM practices, empirical evidence regarding their environmental benefits remains mixed. While some studies report positive effects on environmental performance, others find weak or statistically insignificant relationships (De Giovanni, 2012; Yang *et al.*, 2013; Zailani *et al.*, 2012). Such inconsistencies create uncertainty for manufacturing firms, particularly concerning externally oriented practices such as supplier and customer collaboration (Alkandi *et al.*, 2024).

Much of the literature treats GSCM as an aggregated construct, without distinguishing among specific practices and their differentiated environmental effects (De Giovanni, 2012; Diabat *et al.*, 2014; Yang *et al.*, 2013). Stakeholder theory provides a useful lens to interpret these mixed findings, as regulatory and market pressures may prompt firms to adopt green practices even when performance outcomes remain uncertain (Freeman, 1984; Zailani *et al.*, 2012; Zhu *et al.*, 2005). Based on the above, the following hypothesis is proposed:

H1: Green supply chain management practices positively influence environmental performance.

Beyond environmental protection, GSCM practices aim to improve resource efficiency, reduce operational costs, and enhance overall organizational performance. Prior research suggests that these practices influence economic, environmental, and operational outcomes simultaneously (Geng *et al.*, 2017).

Empirical evidence indicates that GSCM practices enhance environmental management capabilities and contribute to competitive advantage and long-term financial sustainability (Choi & Hwang, 2015; Geng *et al.*, 2017; Khan & Qianli, 2017).

The effectiveness of GSCM adoption depends on organizational capabilities that embed sustainability into core operations (Kuei *et al.*, 2008). From a resource-based view, such practices can function as strategic resources when effectively integrated, supporting cost efficiency and improved financial performance (Barney, 1991).

Firms that effectively integrate GSCM practices into their operations are better positioned to convert environmental initiatives into operational efficiencies and competitive advantages, leading to improved financial performance. Accordingly, the following hypothesis is proposed:

H2: Green supply chain management positively influences firm performance.

Recent research has begun to examine the contribution of GSCM to dynamic capabilities, particularly supply chain agility. Agility reflects a firm's ability to respond effectively to market volatility, environmental disruptions, and changing customer demands (Fasan *et al.*, 2021). By fostering coordination and real-time information exchange across supply networks, GSCM practices may enhance responsiveness and operational flexibility, thereby supporting the development of supply chain agility (Akram *et al.*, 2024; Beske *et al.*, 2014).

Dynamic capabilities theory posits that competitive advantage arises from a firm's ability to reconfigure and adapt resources in dynamic environments (Teece, 2007). GSCM initiatives require environmental scanning, process redesign, and supply chain collaboration, which enhance responsiveness and flexibility. From this perspective, GSCM can be expected to positively contribute to the development of supply chain agility. Based on the above, the following hypothesis is proposed:

H3: Green supply chain management positively influences supply chain agility.

Supply chain resilience refers to the ability to endure, adapt to, and recover from disruptions (Pettit *et al.*, 2010). In turbulent environments, characterized by regulatory change and market volatility, resilience becomes critical for maintaining business continuity. Empirical evidence suggests that green operational practices enhance firms' capacity to manage risks and reduce vulnerability to disruptions (Govindan *et al.*, 2014; Harland *et al.*, 2019; Sarkis, 2020). From this perspective, GSCM may contribute positively to the development of supply chain resilience.

From a dynamic capabilities perspective, supply chain resilience reflects a firm's ability to reconfigure and realign supply chain resources under environmental volatility (Teece, 2007). GSCM practices enhance structural flexibility and reduce dependence on critical inputs, thereby strengthening organizational resilience (Negri *et al.*, 2021; Pettit *et al.*, 2010).

Empirical evidence indicates that GSCM practices support risk mitigation and long-term continuity by enhancing firms' ability to adapt to disruptions (Ghaderi *et al.*, 2024). From a dynamic capabilities perspective, GSCM thus functions as a strategic facilitator of supply chain resilience in uncertain environments (Beske *et al.*, 2014). Based on the above, the following hypothesis is proposed:

H4: Green supply chain management positively influences supply chain resilience.

Firms lacking sufficient internal capabilities may struggle to sustain green initiatives under operational pressure, limiting environmental benefits (De Giovanni, 2012; Yang *et al.*, 2013). In contrast, organizations with stronger adaptive capacities operating in uncertain environments are more likely to maintain environmentally responsible practices and achieve superior environmental performance (Harland *et al.*, 2019; Sarkis, 2020).

From a dynamic capabilities perspective, supply chain resilience strengthens the relationship between GSCM and environmental performance by enabling firms to anticipate and adapt to disruptions (Govindan *et al.*, 2014). While GSCM establishes environmentally sustainable practices, resilience ensures their continuity under adverse conditions. Firms with higher resilience are therefore better positioned to sustain the environmental benefits derived from GSCM initiatives. Based on the above, the following hypothesis is proposed:

H5: Supply chain resilience mediates the relationship between green supply chain management practices and environmental performance.

Although GSCM is widely recognized as a driver of organizational performance, its financial impact often depends on contextual conditions. Prior research shows that green practices can reduce costs and improve efficiency (Choi & Hwang, 2015; Khan & Qianli, 2017), yet these benefits may be limited in unstable environments, unless they are supported by adaptive organizational capabilities.

In this regard, the relationship between GSCM and performance is shaped by strategic supply chain capabilities, particularly resilience. Empirical research indicates that resilience enhances the effectiveness of GSCM practices and supports more stable performance outcomes (Ghaderi *et al.*, 2024; Hu *et al.*, 2023; Negri *et al.*, 2021). Firms that embed resilience into their green initiatives are therefore better positioned to manage costs, maintain operational stability, and respond effectively to disruptions.

From a dynamic capabilities perspective, resilience functions as a strategic capability that enables firms to sustain financial performance by mitigating disruption-related costs and ensuring supply continuity. Accordingly, resilience acts as a key mediating mechanism through which GSCM practices translate into improved financial outcomes.

H6: Supply chain resilience is an intermediate between the firm performance and green supply chain management practices.

Although GSCM is generally associated with improved environmental performance, empirical findings remain mixed (Alkandi *et al.*, 2024; Zailani *et al.*, 2012). These inconsistencies suggest that environmental benefits depend on firms' operational competencies and their ability to respond effectively to market volatility (Carter *et al.*, 2000).

Speaking of which, agile supply chains help organizations to better position themselves in order to convert green initiatives into a real and positive difference in their environmental performance (Batool *et al.*, 2025; Hu *et al.*, 2023).

From a dynamic capabilities perspective, supply chain agility enhances the effectiveness of GSCM by enabling real-time adaptation to market and regulatory changes, thereby strengthening environmental performance.

H7: The supply chain agility mediates the relationship between the practices of green supply chain management and environmental performance.

Although prior research highlights the performance benefits of GSCM (Choi & Hwang, 2015; Khan & Qianli, 2017), its effectiveness in dynamic environments depends on supportive operational capabilities. Supply chain agility enables firms to respond to market volatility and sustain environmentally responsible operations (Fasan *et al.*, 2021; Hu *et al.*, 2023).

Prior research suggests that GSCM practices enhance supply chain agility, which in turn strengthens firms' ability to capture the performance benefits of green initiatives (Batool *et al.*, 2025; Dubey *et al.*, 2015; Fernando & Saththasivam, 2017).

Agility can be conceptualized as a higher-order dynamic capability that enables firms to align green supply chain management efforts with changing market demands and environmental discontinuities, thereby enhancing operational efficiency and competitiveness (Beske *et al.*, 2014; Teece, 2007). While GSCM practices provide the strategic foundation for sustainability, agility allows firms to translate these initiatives into tangible performance outcomes by accelerating operational adjustments and resource reallocation.

H8: Supply chain agility mediates between the green supply chain management practices and the performance of the firm.

Big data analytics (BDA) has emerged as a strategic capability that enables data-driven, real-time, and predictive decision-making in supply chains (Wamba *et al.*, 2017). By enhancing visibility, detecting inefficiencies, and improving sustainability monitoring, BDA can strengthen the environmental impact of GSCM practices (Bag *et al.*, 2020; Fasan *et al.*, 2021). Firms with well-developed analytics capabilities are therefore better positioned to translate green initiatives into improved environmental performance. Accordingly, the positive relationship between GSCM and environmental performance is expected to be stronger in organizations with advanced big data analytics capabilities.

From the resource-based view (RBV), big data analytics constitutes a valuable, scarce, inimitable, and non-substitutable (VRIN) resource that enhances firms' predictive capabilities and operational transparency (Barney, 1991). As such, analytics capabilities complement GSCM practices by improving sustainability monitoring and strengthening their environmental performance outcomes.

H9: Big data analytics mediate between the relationship of green supply chain management and environmental performance.

Although GSCM is associated with improved firm performance (Choi & Hwang, 2015; Khan & Qianli, 2017), the strength of this relationship may depend on complementary technological capabilities. Big data analytics enhances firms' ability to transform green initiatives into measurable performance outcomes by generating real-time insights and supporting strategic decision-making.

Big data analytics further supports the GSCM practice by increasing visibility, responsiveness, and data-driven decision-making throughout the supply network to improve the implementation and the strategic fit of practices. Embracing it as a part of green supply chain initiatives, big data analytics allows enterprises to pursue cost-reduction opportunities, along with resource optimization, and to discover inefficiencies in a more efficient manner (Dubey *et al.*, 2015; Wamba *et al.*, 2017). These competences make green practices have higher returns in terms of finance and operating in dynamic or complex supply environment. Big data analytics may impose warnings in times when the demand of customers is elevated and when the threat is involved regarding suppliers, enabling business to balance sustainability efforts and more comprehensive business objectives of profitability and competitiveness (Bag *et al.*, 2020). Other things unchanged, therefore, performance gains of GSCM are less likely to be realized in low big data analytics potential firms, compared to high big data analytics potential firms that are more likely to convert environmental strategies to economic gain (Fasan *et al.*, 2021).

H10: Big data analytics moderates the relationship between green supply chain management practices and firm performance.

Materials and methods

This study employed a quantitative research design to investigate the impact of Green Supply Chain Management (GSCM) practices on environmental and financial performance, with particular emphasis on the mediating roles of supply chain agility and supply chain resilience, as well as the moderating effect of big data analytics capabilities. A cross-sectional approach was adopted to examine the relationships among variables and assess their statistical significance.

The target population consisted of manufacturing enterprises operating in Mexico across diverse sectors, including textiles, sports, leather, and sugar. The inclusion of multiple industries aimed to enhance the generalizability of the findings. Data were collected using a convenience sampling strategy, targeting firms that were accessible and willing to participate. While this approach facilitated data collection from a broad range of organizations, it may also involve self-selection bias, as firms with greater interest or engagement in GSCM practices may have been more inclined to respond. Consequently, the sample may overrepresent organizations already involved in environmental initiatives, potentially strengthening the observed relationships among the study variables.

Data were gathered through an online survey distributed via Facebook groups related to the manufacturing sector, as well as LinkedIn, WhatsApp, and email channels (Table 1). A total of 297 responses were received, of which 27 were incomplete and excluded. The final sample comprised 270 valid questionnaires. Firm size was included as a control variable, given that larger firms may possess greater resources to implement GSCM practices and improve performance outcomes.

Table 1. Demographical details.

Participants	Description	Frequency	Percentage
Gender of the Participants	Male	174	64.4
	Female	96	35.5
Total Participants		270	100
Age of the Participants	25 to 30	60	22.22
	31 to 35	66	24.44
	36 to 40	83	30.74
	Above 41	61	22.59
Total Participants		270	100
Education of the Participants	Undergraduate	51	18.88
	Graduate	131	48.51
	Postgraduate	88	32.59
Total Participants		270	100
Industry Sector of the Participants	Surgical	19	7.03
	Textile	35	12.96
	Sports	22	8.01
	Leather	31	11.48
	Sugar	23	8.51
	Others	140	51.85
Total Participants		270	100
Job experience of the Participants	<5	88	32.59
	6 > 9	119	44.07
	10 > 14	40	14.81
	Above 14 years	23	8.5
Total Participants		270	100

The questionnaire consisted of standardized measurement scales using a five-point Likert scale, ranging from 1 (“Strongly disagree”) to 5 (“Strongly agree”). The instrument measured Green Supply Chain Management practices, supply chain agility, supply chain resilience, big data analytics capabilities, environmental performance, and financial performance.

Content validity and measurement development

Content validity was ensured through the use and adaptation of measurement scales previously validated in the literature. All items were derived from well-established studies to ensure that the full conceptual domain of each construct was adequately represented. The selected indicators were reviewed to confirm their alignment with the theoretical definitions of the constructs and their relevance to the context of Mexican manufacturing firms. This process ensured that all relevant dimensions associated with GSCM, agility, resilience, big data analytics, and organizational performance were systematically covered.

Specifically, GSCM practices were measured using twelve items adapted from Renaldo & Augustine (2022), while environmental and financial performance were assessed using six items from the same source. Supply chain agility was measured using five items adapted from Ghaderi *et al.* (2024) and Dubey *et al.* (2015), and supply chain resilience was evaluated using five items based on Ghaderi *et al.* (2024). Big data analytics capabilities were measured using three items adapted from Venkatesh *et al.* (2003). Minor wording adjustments were made to ensure clarity and contextual relevance, without altering the original meaning of the items.

It is important to note that the performance variables in this study were measured based on respondents' perceptions. Although perceptual measures are widely used in supply chain and management research, they may introduce response bias, particularly in areas such as financial performance, where respondents' knowledge may vary depending on their organizational role. Therefore, the findings should be interpreted with caution, acknowledging that the results reflect perceived rather than objective organizational performance.

Data analysis

The data analysis was conducted using SmartPLS 4 to implement variance-based structural equation modeling (PLS-SEM) (Ringle *et al.*, 2015). The PLS-SEM approach was selected due to its suitability for complex models, non-normal data distributions, and relatively small sample sizes (Chin *et al.*, 2008; Marcoulides, 1998). The analysis followed a two-stage procedure. First, the measurement model was evaluated by examining indicator reliability, construct reliability, and convergent and discriminant validity. Second, the structural model was assessed to test the hypothesized relationships among constructs, including the mediating effects of supply chain agility and resilience, as well as the moderating role of big data analytics capabilities.

PLS-SEM offers flexibility in estimating latent variable scores, strong predictive power, and robustness when modeling complex relationships. This technique has been widely applied in prior research across multiple fields, including marketing, human resource management, information systems, and green supply chain management (Dubey *et al.*, 2015; Hair *et al.*, 2011; Hair *et al.*, 2012; Ringle *et al.*, 2020).

Results

Measurement model

Measurement models describe the degree, ability, and stability of the latent constructs (Mardani *et al.*, 2020). According to Kenny (2015), a measurement model has to be created before the causal pathways within the structural model are investigated. To measure the measurement model, we evaluated the convergent and discriminant validity. The measurement model includes the unidirectional causal relationship that exists between each underlying idea and the observable variable associated with it.

Convergent validity

Convergent validity is defined as the degree to which various variables employed in a study to measure the same variables are consistent (Hair *et al.*, 2021). Convergent validity is examined through item component loading, Cronbach alpha measurement, average extracted variance (AEV) measurement, and composite reliability (CR) measurement (Murtagh & Heck, 2012). The findings indicate that the factor loading of each item is 0.7 or more, Cronbach Alpha is beyond the range of 0.60, all the variable average variance extracted (AVE) values are greater than 0.5 and composite reliability (CR) is greater than 0.7. Therefore, Table 2 shows that convergent validity in the analysis of the scale was established (Murtagh & Heck, 2012).

Table 1. Convergent validity.

Items	Factor Loading	Cronbach's alpha	Composite reliability	Average variance extracted
GSCM2	0.762	0.849	0.892	0.625
GSCM3	0.801			
GSCM4	0.847			
GSCM5	0.819			
EP1	0.807	0.778	0.857	0.601
EP2	0.790			
EP3	0.720			
EP5	0.781			
FP1	0.751	0.788	0.863	0.612
FP2	0.791			
FP4	0.821			
FP5	0.762			
GSCR1	0.772	0.701	0.807	0.515
GSCR3	0.789			
GSCR4	0.725			
GSCR5	0.764			
GSCA1	0.765	0.836	0.884	0.605
GSCA2	0.791			
GSCA3	0.818			
GSCA4	0.713			
GSCA5	0.799			

Note. AVE = Average Variance Extracted; CR = Composite Reliability.
Source: Author's own elaboration.

Discriminant validity

The degree to which items distinguish or isolate ideas is called discriminant validity. Two approaches are employed in the current research to test discriminant validity: Fornell-Larcker criterion and the Heterotrait-Monotrait ratio (HTMT) (Foliente & Becker, 2001). Table 3 shows that the square root of the mean variance extracted is larger than the interrelationships among the constructs (Fornell & Larcker, 1981).

Table 2. Fornell-Larcker criterion.

	Environmental Performance	Financial Performance	SCA	GSCM	SCR
Environmental Performance	0.775				
Financial Performance	0.348	0.782			
Supply Chain Agility	0.557	0.432	0.778		
GSCM	0.732	0.393	0.552	0.790	
Supply Chain Resilience	0.537	0.316	0.354	0.471	0.718

Source: Author's own elaboration.

With regard to the heterotrait-monotrait ratio (HTMT) criterion, Table 4 shows that the HTMT values ranged between 0.432 and 0.895, and all of them did not exceed the 0.90 threshold, as indicated by (Henseler *et al.*, 2016).

Table 4: HTMT Approach

	Environmental Performance	Financial Performance	SCA	GSCM	SCR
Environmental Performance					
Financial Performance	0.443				
Supply Chain Agility	0.688	0.533			
GSCM	0.895	0.479	0.653		
Supply Chain Resilience	0.703	0.432	0.454	0.601	

Note. HTMT = Heterotrait-Monotrait Ratio of Correlations. Values below 0.90 indicate discriminant validity.
Source: Author's own elaboration.

In order to assess the predictive performance of the structural model, we have computed the coefficient of determination, also known as R2. R2 explained the degree to which the predictor variables explain the variability (Barclay *et al.*, 1995). The values of R2 were plotted in Figure 1 below. Environmental performance shows a value of R2 of 0.661, whereas financial performance shows a value of R2 of 0.258. The findings provide evidence to suggest that the synergistic effect of three elements of GSCM practices, SC resilience, and SC agility can account 66.1 and 23.5 percent of the environmental performance and financial performance, respectively. Hair *et al.* (2021) state that the R2 values should be 0.10 or higher to determine whether the variance explained by a particular endogenous concept is satisfactory.

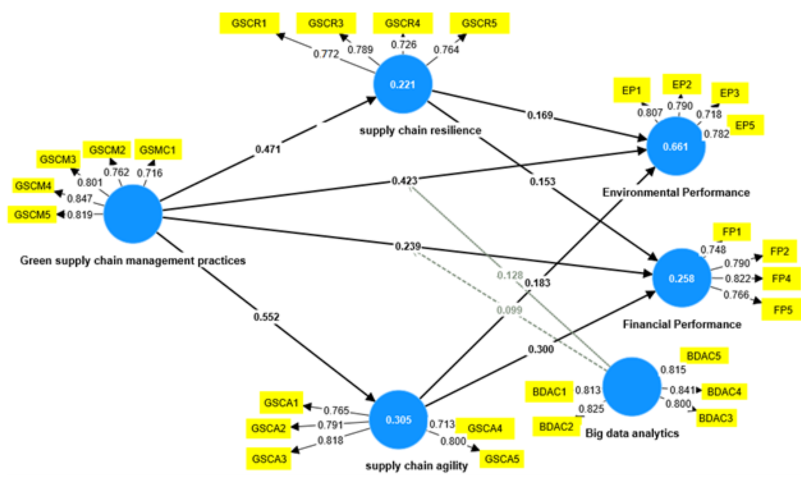

Figure 1. Analysis of structured modelling.
Source: Author's own elaboration.

F^2 is the value of the change in R^2, given by exclusion of an external variable to the model. In the PLS path analysis model, we determine the change in the square of the correlation coefficient to determine whether the omission of an independent variable has significant influence on the value of the dependent variable. According to Cohen (2013), F^2 of 0.35, 0.15, and 0.02 means that the structural influence of the predictor variable is large, moderate, and low, respectively. The Table 5 results indicated that the effect size of F^2 was between 0.055 and 0.099.

Q^2 tests predictive significance, determining whether a model is useful to predict (a value greater than 0 is evidence of effectiveness). Q^2 proves the predictive importance of the intrinsic elements within the model. Any value of Q^2 past 0 will be a sign that your data has been recreated, and thus the model is predictively relevant. Table 5 shows the Q^2 of every dependent variable of the study with all values exceeding the threshold of 0. SmartPLS 4 evaluates the effectiveness of the proposed framework in general to prove the validity of the research framework. Standardized root mean square residual (SRMR) is adopted, and when it is less than 0.08 then it is adequate (Hu & Bentler, 1998). According to an SRMR score of 0.07, it is a significant mark on the quality of the model.

Table 3.Quality of the structural model.

	Q^2	F^2 Environmental Performance	Financial Performance
Supply Chain Agility	0.294	0.063	0.076
Supply Chain Resilience	0.209	0.099	0.055

Source: Author's own elaboration.

Structural model analysis

Path coefficients under SEM-PLS approach are used to indicate the size and significance of the proposed relationships involving latent components. The route coefficients can be viewed as normalized beta coefficients (Götz *et al.*, 2010). In PLS-SEM, the bootstrapping technique —first presented by Efron (1992)— is frequently employed in order to estimate the *t*-value of the route coefficients and assess the importance of the hypothesized correlations. Statistical evidence confirms the hypothesis with *p*-value of less than 0.05 and *t*-value that has a value greater than 1.96 (Hair *et al.*, 2014).

Table 4. PLS structural model.

Hypothesis	B	(STDEV)	*t* value	*p* values
GSCM Practices -> Environmental Performance	0.423	0.055	7.696	0.000
GSCM Practices -> Financial Performance	0.239	0.103	2.309	0.021
GSCM Practices -> SCA	0.552	0.066	8.330	0.000
GSCM Practices -> SCR	0.471	0.059	8.002	0.000
GSCM Practices -> SCR -> Environmental Performance	0.080	0.022	3.638	0.000
GSCM Practices -> SCR -> Financial Performance	0.072	0.033	2.193	0.029
GSCM Practices -> SCA -> Environmental Performance	0.101	0.043	2.377	0.018
GSCM Practices -> SCA -> Financial Performance	0.166	0.059	2.805	0.005
Big data analytics x GSCM Practices -> Environmental Performance	0.128	0.033	3.838	0.000
Big data analytics x GSCM Practices -> Financial Performance	0.099	0.054	1.824	0.068

Source: Author's own elaboration.

The results of the structural model are given in Table 6, where there is a strong positive correlation between the practice of GSCM and environmental performance (b = 0.423, t = 7.696, p < 0.01). Financial performance was also found to be greatly improved by GSCM (b = 0.239, t = 2.309, p < 0.05). Moreover, GSCM showed a high positive correlation with a supply chain resilience (b = 0.471, t = 8.002, p < 0.05) and supply chain agility (b = 0.552, t = 8.330, p < 0.05). The findings also showed that supply chain resilience had positive impacts on environmental performance (b = 0.169, t = 4.160, p < 0.05) and financial performance (b = 0.153, t = 2.349, p < 0.05). These results highlight the importance of resilience as a positive feedback process of sustainability and economic success. As far as the control variables are concerned, firm size did not show any significant influence on environmental performance (b = 0.280, p = 0.770) or else on financial performance (b = 0.157, p = 0.422).

Mediation analysis

Findings in Table 6 reveal that supply chain resilience is an important mediator between GSCM practices and environmental performance where path coefficient is 0.080, t-value is 3.638, and significance level is less than 0.05. Supply chain resilience also mediates the relationship between GSCM practices and the financial performance with a coefficient of 0.072 and t-value of 2.193, which is statistically significant. It is also shown in the analysis that the mediating role of supply chain agility is equally significant. In the case of relationship between GSCM and environmental performance, the indirect effect had a coefficient of 0.101 with t-value of 2.377, which is significant at the 5% level. Supply chain agility captured the correlation between GSCM and financial performance with an indirect effect of 0.166 and t-value of 2.805, which is a strong piece of evidence to support mediation.

Moderation analysis

Table 6 and Figure 2 show that big data analytics moderates GSCM practices and environmental performance (β = 0.128, t-value = 3.838, p < 0.05). Big data analytics has an insignificant moderation role between GSCM and financial performance (β = 0.099, t-value = 1.824, p > 0.068).

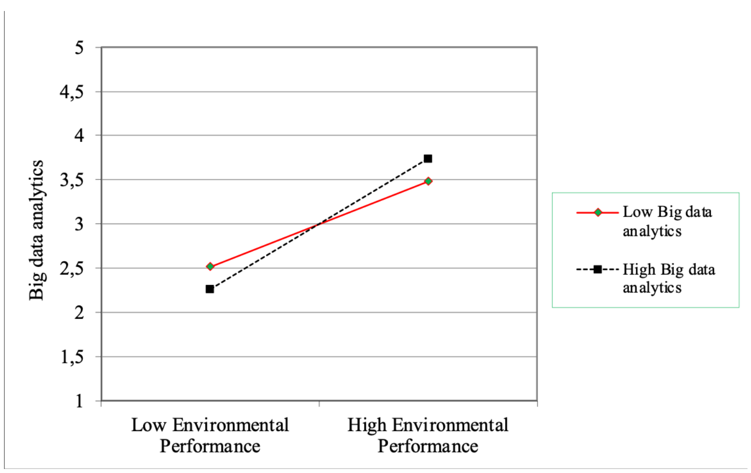

Figure 2. Moderation analysis.
Source: Author's own elaboration.

Discussion

This study investigates the extent to which GSCM influences perceived environmental and financial performance in manufacturing firms, focusing on the Mexican context. Supply chain agility and supply chain resilience are incorporated as mediating mechanisms, and big data analytics as a moderating capability. Drawing on dynamic capabilities theory, the resource-based view, and stakeholder theory, the findings provide both theoretical and practical insights into how green initiatives translate into performance outcomes.

While the relationships examined in this study have been addressed in prior research, the findings extend existing knowledge by demonstrating their combined operation within a mediated–moderation framework in an emerging economy context, where institutional conditions and resource constraints differ from those of developed countries. This integrated perspective helps explain why the outcomes of green supply chain management may vary across contexts and underscores the importance of enabling mechanisms and boundary conditions.

The findings indicate that green supply chain management is positively associated with perceived environmental performance. Firms reporting the implementation of practices related to eco-design, green purchasing, cleaner production, and sustainable logistics also reported perceived reductions in waste, emissions, and resource consumption. These perceptions are consistent with prior empirical evidence highlighting the importance of GSCM for supporting sustainability-oriented outcomes (Choi & Hwang, 2015). In line with dynamic capabilities theory, organizations that develop adaptive capabilities are better positioned to sustain green practices over time, particularly under environmental uncertainty (Teece, 2007). At the same time, stakeholder pressures from regulators, customers, and investors reinforce the strategic relevance of environmental responsibility (Sarkis *et al.*, 2011; Zhu *et al.*, 2005).

Results also indicate a positive association between green supply chain management and perceived financial performance. Although prior studies report mixed findings regarding the financial outcomes of GSCM, the present results suggest that green practices can be translated into perceived financial benefits in terms of efficiency improvements, cost reductions, and enhanced brand value (Geng *et al.*, 2017; Khan & Qianli, 2017). From a resource-based perspective, these perceived benefits support the argument that GSCM may function as a strategic resource, contributing to long-term competitiveness.

It is important to note that financial performance in this study is measured as a perceptual construct based on respondents' assessments rather than objective financial indicators. Accordingly, the findings reflect managerial perceptions of financial outcomes rather than verified accounting data. This perceptual nature of the measurement may partially explain the ambiguity observed in prior empirical studies and why respondents in this study report a generally positive relationship between GSCM and financial performance.

Furthermore, the results show that supply chain agility and resilience act as mediating mechanisms that strengthen the relationship between GSCM and performance outcomes. Cleaner technologies, redesigned processes, and supplier collaboration contribute to more flexible and robust supply chains, enabling firms to respond swiftly to market changes and withstand disruptions (Dubey *et al.*, 2015; Ghaderi *et al.*, 2024). Consistent with dynamic capabilities theory, agile and resilient supply chains facilitate the transformation of sustainability initiatives into perceived environmental and financial gains (Beske *et al.*, 2014).

From a managerial standpoint, the findings provide clear guidance for manufacturing firms that green supply chain management should not be implemented as an isolated environmental initiative, but rather as part of a broader capability-building strategy. Managers in manufacturing firms, particularly in emerging economies, should prioritize the development of supply chain agility and resilience to ensure that green practices translate into tangible performance improvements. Investments in cleaner technologies and sustainable sourcing must be accompanied by organizational flexibility and cross-functional coordination. Furthermore, firms seeking to enhance environmental outcomes should leverage big data analytics to improve visibility, monitoring, and proactive decision-making. However, managers should adopt realistic expectations regarding short-term financial returns, as financial benefits may depend on contextual conditions and longer-term strategic alignment.

Finally, big data analytics strengthens the relationship between GSCM and perceived environmental performance by enabling predictive monitoring and data-driven efficiency improvements (Fasan *et al.*, 2021; Wamba *et al.*, 2017). However, no significant moderating effect is observed for perceived financial performance, suggesting that the financial returns associated with analytics may depend on longer time horizons or specific contextual conditions (Al-Khatib, 2022; Bag *et al.*, 2020).

Conclusion

This study contributes to the literature on sustainable supply chain management by examining how green supply chain management practices are associated with perceived environmental and perceived financial performance through the mediating roles of supply chain agility and resilience, as well as the moderating role of big data analytics capabilities. Drawing on institutional theory, stakeholder theory, and the dynamic capabilities perspective, the study offers a multidimensional framework to understand how external pressures, stakeholder expectations, and internal adaptive capabilities shape sustainability-related performance perceptions in manufacturing firms.

It is important to emphasize that the findings reflect the perceptions of respondents regarding environmental and financial performance rather than objective performance indicators. The measures used capture how employees and managers perceive outcomes such as reductions in waste, emissions, costs, or financial improvements, rather than verified data on emissions, resource consumption, profitability, investment growth, or cash flow. In this sense, the results provide insight into how GSCM initiatives are interpreted and valued within organizations, which may differ from actual performance outcomes measured through hard indicators.

Results suggest that supply chain agility and resilience are perceived not only as desirable attributes but as critical organizational capabilities that enable firms operating in turbulent environments to translate green practices into perceived competitive advantages. Big data analytics is also perceived as an internal enabling resource that supports environmental initiatives through enhanced visibility, predictive capabilities, and process optimization.

However, these findings should be interpreted with caution. Given the use of a convenience sample, a cross-sectional research design, and perceptual measures, the results cannot be generalized beyond the specific context studied. Nevertheless, the study provides relevant empirical evidence from the Mexican manufacturing sector, a context that remains underrepresented in the literature on green supply chain management in emerging economies. Future research should complement perceptual assessments with objective performance indicators and longitudinal designs to further validate and extend these findings.

Limitations and future directions

This research provides useful understanding of the importance of GSCM, supply chain capabilities, and organizational outcomes, but a number of limitations have to be mentioned to place the results in perspective. To begin with, the convenience sampling method applied is practical in terms of data collection, but it brings chances of self-selection biasing. The existing firms, which were already predisposed towards sustainability might have been more willing to join, which may have exaggerated the positive relationship between GSCM, environmental performance, and financial performance. These companies usually have more resources, more precise sustainability practices, more sophisticated digital tools including big data analytics, supply chain agility, and supply chain resilience. As a result, it is possible that the results are not accurate enough to capture the firms that have fewer resources or less conviction to the environment, so the results cannot be generalized to more traditional or resource-limited organizations. Second, the cross-sectional design prevents making causal inferences and cannot reflect the development of the effects of GSCM practices and dynamic capabilities in the course of time. The effects of gradual and cumulative changes on the environment and finances are also likely to vary in the long-term in circumstances of disruption, changing regulations, or market variability. A longitudinal study would be more effective in terms of offering more evidence on the dynamics of GSCM adoption, capability building, and long-term performance.

In future studies, these limitations can be overcome by using probabilistic or stratified random sampling methods to increase representativeness and minimize bias. Longitudinal designs are especially useful in investigating the changes of GSCM practices and their relationships with agility, resilience, and analytics in time of uncertainty. The extension of the model to cover other moderating factors (institutional pressures, organization culture, leadership orientation, etc.) can also provide even better insights into the circumstances in which GSCM proves best. Additionally, industry-specific research, particularly on under-researched sub-sector or on an emerging economy may reveal context-specific differences in adoption and performance. The application of qualitative methods (case studies or interviews) to supplement the quantitative methods would help to deepen the insights since it reflects on the implementation processes, stakeholder relationships, and organizational issues which cannot be entirely reflected in the survey.

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Conflicts of interest

It is declared that there is no conflict of interest related to the publication of this article.

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Questionnaire

This Questionnaire seeks responses for the completion of academic research with the title "The Impact of Green Supply Chain Management on Environmental and Financial Performance in Mexican Manufacturing Firms: A Mediated-Moderation Model" Thank you for taking out time to be part of this research. It is requested to please respond to the questions frankly and honestly as your responses are highly valuable. Your responses will be kept strictly confidential and will be used only for academic purpose.

A. Gender: **1}** Male **2}** Female
B. Work Experience 1}1-3 **2}** 4-10 **3}** 11-20 **4}** 20-30 **5}** Above 30
C. Age (Years): **1}** 23-30 **2}** 31-40 **3}**41-50 **4}**51-60
D. Firm Size: 1} Small 2} Mid 3} Large

Please indicate the extent of agreement with each of the following statements. **(Please tick only one number)**
1=Strongly Disagree **2= Disagree** **3=Neutral** **4= Agree** **5 =Strongly Agree**

Environmental Performance Environmental activities significantly…					
reduced overall costs.	1	2	3	4	5
reduced the lead times.	1	2	3	4	5
improved product/process quality.	1	2	3	4	5
improved reputation of my company.	1	2	3	4	5
reduced waste within the entire value chain process.	1	2	3	4	5
reduced overall costs.	1	2	3	4	5
Financial Performance					
The company experienced an increase in earnings per share	1	2	3	4	5
The company experienced an increase in return on investment	1	2	3	4	5
The company experiences gross profit growth	1	2	3	4	5
The company experiences net profit growth	1	2	3	4	5
The company is experiencing growth in equity					
The company is experiencing asset growth					
Green supply chain agility Our company can…					
Respond more quickly to market green dynamics.	1	2	3	4	5
Respond more quickly to green customer needs.	1	2	3	4	5
Has a suitable infrastructure to respond to the market situation.	1	2	3	4	5
Has a suitable infrastructure to respond to the customers' dynamic needs.	1	2	3	4	5
Meet the customers' green needs.	1	2	3	4	5
Green supply chain resilience Our company…					
Can quickly recover its activities in the event of a service disruption.	1	2	3	4	5
Can adapt to respond positively to operational disruptions.	1	2	3	4	5
Has the appropriate infrastructure for a quick response to environmental disturbances.	1	2	3	4	5

Has a favorable ability to deal with financial consequences after disruptions.	1	2	3	4	5
Has the optimal capacity to deal with the results of disruptions in a positive way.	1	2	3	4	5
Big Data Analytics Use					
Please indicate how often big data analytics tools are used in your organization.	1	2	3	4	5
Please indicate to what extent big data analytics tools are used in your organization.	1	2	3	4	5
On average, please specify the duration to which big data analytics users employ such tools in your organization.	1	2	3	4	5
Green Supply Chain Management					
The company implements green purchases	1	2	3	4	5
The company selects suppliers based on environmental criteria	1	2	3	4	5
The company ensures that the supplier's products do not pollute the environment in the production process	1	2	3	4	5
The company implements green cooperation with customers	1	2	3	4	5
The company applies cross-functional cooperation for environmental improvement	1	2	3	4	5
The company works with suppliers for environmental purposes	1	2	3	4	5
The company implements total quality environmental management	1	2	3	4	5
The company implements environmental compliance and audit program	1	2	3	4	5
The company implements an environmental management system	1	2	3	4	5
The company implements green distribution and packaging	1	2	3	4	5
Product design to reduce material/energy consumption	1	2	3	4	5
Product packaging can be reused for other purposes	1	2	3	4	5