

Innovation performance in manufacturing SMEs: the influence of green management and digital orientation

Desempeño innovador en las pymes manufactureras: la influencia de la gestión verde y la orientación digital

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Abstract: This study examines the relationship between digital orientation, green management, and innovation performance in Latin American manufacturing SMEs. The data were collected between February and May 2022 by the Ibero-American SME Observatory (ISO), and the analysis employed partial least squares structural equation modeling (PLS-SEM), based on data from 4270 manufacturing SMEs in Latin America. The results showed that digital orientation is positively and significantly related to innovation performance, and that green management significantly and positively mediates that relationship. Nevertheless, the size of this mediating effect is relatively small compared to the direct effects. These findings are particularly relevant for manufacturing SMEs in emerging Latin American countries, which must confront modern challenges related to digitalization and environmental management while maintaining a market presence through valuable strategic capabilities, such as innovation. The results can also inform public policymakers.

Keywords: Green management, innovation performance, SMEs, digitalization.

Resumen: Este estudio examina la relación entre orientación digital, gestión verde y el desempeño innovador en pequeñas y medianas empresas (pymes) manufactureras Latinoamericanas. Los datos analizados se recolectaron entre febrero y mayo 2022 por el Observatorio de las Pymes, los mismos fueron analizados utilizando modelos de ecuaciones estructurales por mínimos cuadrados parciales (PLS-SEM), con datos de 4270 pymes manufactureras de Latinoamérica. Los resultados muestran que la gestión verde media la relación entre orientación digital y desempeño innovador, lo que implica que el efecto de la orientación digital sobre el desempeño innovador se potencia a través de la gestión verde. Los resultados son relevantes para las pymes manufactureras de países emergentes de Latinoamérica, que deben enfrentar los retos modernos de digitalización y gestión verde y mantenerse en el mercado a través de recursos valiosos como la innovación. Estos resultados también son relevantes para creadores de política pública.

Palabras clave: Gestión verde, desempeño innovador, pymes, digitalización.

1. Introduction

Small and Medium-sized Enterprises (SMEs) are currently facing major challenges in configuring their resources and capabilities in a comprehensive manner to operate in a dynamic environment, while also considering the need to develop competitive advantages (Barney, 2001). Key among these challenges is business digitalization, driven by growing demands for data availability, and by the need to keep pace with globalization and rapid technological change (Füller et al., 2022; McAfee & Brynjolfsson, 2012). At the same time, environmental pressures require the implementation of Green Management (GM), referring to practices systematically employed by firms and their suppliers to protect, preserve and restore the environment. GM typically addresses issues such as carbon emissions, the use of natural resources, waste, water and energy management, recycling, and many other concerns (OECD, 2024; Ambec & Lanoie, 2008; Shu et al., 2020).

In this article, we conceptualize digitalization as the use of digital technologies to generate information with the aim of reviewing intra- and inter-organizational decision-making processes and structures (Holmström et al., 2019; Lafuente & Sallan, 2024). A related concept that is gaining momentum is Digital Orientation (DO), defined as “an organization’s guiding principle to pursue digital technology-enabled opportunities to achieve competitive advantage. It encompasses the dimensions of digital technology scope, digital capabilities, digital ecosystem coordination, and digital architecture configuration” (Kindermann et al., 2021).

There is evidence that DO with green characteristics improves Innovation Performance (IP) when mediated by digital business models, reflected in benefits such as reduced transaction costs, improved operational efficiency, and integration with partners in the green digital ecosystem, in areas such as digital technology and green innovation (Yin et al., 2024). Moreover, DO drives firms’ operational efficiency and promotes sustainability through green-oriented innovations (Ning et al., 2023). It also contributes to the generation of more solid competitive advantages when directed toward green innovation (Le et al., 2024).

Additionally, recent evidence highlights that digital technologies and Artificial Intelligence (AI) platforms are reshaping collaboration patterns and enabling new forms of strategic ecosystems, which help firms overcome resource and institutional constraints (Vaillant et al., 2025). Likewise, studies show that digital competencies disrupt traditional co-innovation configurations, making vertical (value chain) and horizontal (industry) collaborations more optimal than institutional ones, while institutional partnerships remain essential for firms with lower digital capabilities (Lafuente et al., 2023).

Although prior research has shown that digitalization drives innovation (Martínez-Falcó et al. 2024; Rojas-Cabezas et al., 2026) and that green management enhances performance (Wei & Sun, 2021), both phenomena are often examined in isolation. This fragmentation limits the understanding of the potential synergies that may emerge when digital and green strategies are jointly implemented in SMEs (Xie et al., 2022; Bag et al., 2022). Then, given the increasing convergence between digitalization and sustainability, it is pertinent to ask: Does digital orientation act as a catalyst for green management to enhance firm performance? While the effect of digital orientation on innovation and that of green management on performance have been individually examined (Yin et al., 2024; Kindermann et al., 2021), their combined impact remains underexplored, despite calls for integrating digital and green strategies to strengthen innovation outcomes (Bag et al., 2022; Al Halbusi et al., 2023)

This gap is particularly significant in emerging economies and the manufacturing sector. On the one hand, in emerging economies, particularly in Latin America, SMEs face additional structural challenges, such as institutional voids, limited access to financing, and technological gaps, which increase the complexity of simultaneously advancing digital transformation and sustainability initiatives (Rojas-Cabezas et al., 2024a; Sabando-Vera et al., 2025). On the other hand, the manufacturing sector both contributes significantly to gross domestic product and generates high environmental impacts in the Latin American region (Sabando-Vera et al., 2025).

In this context, examining DO and its relationship with GM in Latin America is particularly relevant, given the heterogeneous institutional environments across the region and the significant gaps and lags in its digital ecosystem (Acs et al., 2022). Although there is marked internal heterogeneity (with countries such as Chile, Costa Rica, and Uruguay exhibiting relatively stronger performance), the region remains behind the United States and Canada, where digital ecosystems are more mature and follow different configuration priorities (Acs et al., 2022).

Furthermore, Acs et al. (2022) indicate that in Latin America, the digital ecosystem is primarily driven by entrepreneurship in digital technologies and by dynamics associated with digital platforms, rather than by a consolidated digital citizenship and well-established regulatory structures, as observed in the United States and Canada. This configuration places greater responsibility on firms to develop digital capabilities internally to respond to market demands, and manufacturing SMEs are no exception.

Overlooking this interrelation is not only an academic shortcoming but also undermines the ability of firms and policymakers to design practical innovation and sustainability strategies. Consequently, it remains unclear how digital orientation can leverage green management to foster improved innovation outcomes.

Consequently, the analysis of the relationship between DO and performance can generate strategic alternatives to address modern environmental (Zhang et al., 2025) and that digital strategic orientation is positively associated with innovation-related challenges (Yin et al., 2024). The mere use of digital technologies is now a necessary condition for businesses but is not sufficient to ensure success. Hence the relevance of DO (Kindermann et al., 2021). Although empirical evidence has linked digital green strategic orientation to IP (Khin & Ho, 2020; Yin et al., 2024) and to sustainable performance (Zhang et al., 2025), the effect of GM as a mediating mechanism in this relationship, and specifically in manufacturing SMEs in developing countries, remains a highly topical line of inquiry, given the potential role of the manufacturing sector with regard to environmental impact.

Although some studies link digitalization and green management to innovation performance and corporate outcomes in general (Zhou & Zhao, 2025; AlKoliby et al., 2024), empirical research jointly analyzing the relationship between DO and IP, and particularly the mediating role of GM, in manufacturing SMEs remains limited. To address this gap, our investigation seeks to answer the following research questions: Does digital orientation have a positive association with SMEs' innovation performance? Does green management mediate the relationship between digital orientation and innovation performance?

The study is based on a dataset collected by the Iberoamerican SME Observatory (ISO). The final sample includes information on 4270 manufacturing SMEs across 16 Latin American countries, and the analysis is based on a partial least squares structural equation modeling (PLS-SEM) approach. The empirical results confirm that DO is positively related to the IP of the analyzed SMEs, and that GM positively mediates this relationship. Albeit modest, this effect is statistically significant.

This study contributes to the literature by extending research on DO from a firm-level perspective, specifically within manufacturing SMEs. While studies such as Acs et al. (2022) analyze the digital ecosystem at the country level -identifying differences and gaps from a macro and institutional perspective- the present research adopts a micro-level approach focused on firms' internal capabilities. Additionally, the study extends the analysis of DO to the green management dimension in a context characterized by structural constraints and weaknesses in the digital ecosystem, thereby providing new insights into the mechanisms through which digital orientation influences innovation performance under conditions of resource scarcity (Sabando-Vera et al., 2025).

From a practical perspective, this study offers relevant implications for managers and decision-makers in manufacturing SMEs, as well as for public policymakers interested in promoting sustainable development in Latin America. The findings suggest that DO is a strategic tool with positive effects on innovation performance, and that green management operates as a mediating mechanism in this relationship, despite the absence of strong green policies and persistent inequalities in digital infrastructure (Acs et al., 2022). Accordingly, firms can implement digital capabilities at the organizational level to complement broader public policy initiatives in both digital and environmental domains.

The remainder of this paper is structured as follows: Section 2 presents the literature review and hypotheses, Section 3 describes the methodology used in the empirical analysis, Section 4 analyzes the results, Section 5 contains the discussion, and Section 6 concludes with the key findings and suggestions for future research.

2. Literature Review

According to the resource-based view of the firm (RBV), competitiveness is determined by the possession of resources and the ability to transform them into capabilities (Wernerfelt, 1984; Barney, 1991, 2001) that are unique due to differentiating characteristics such as durability, transferability, replicability and transparency (Wernerfelt, 1984). Modern challenges facing firms, such as sustainability, digitalization and globalization, among others, demand not only the development of competitive advantages, but also their adequate configuration to shield the firm against imitation (Warner & Wager, 2019).

Digital Orientation (DO) can generate valuable, inimitable and non-substitutable capabilities that enable firms to acquire and leverage strategic resources through the use of technologies such as big data and automation, among many others, as this enhances strategic decision-making (McAfee & Brynjolfsson, 2012) and strengthens knowledge absorption (Cohen & Levinthal, 1990) by facilitating data collection and structuring (Kindermann et al., 2021).

Meanwhile, Green Management (GM) helps minimize a company's environmental footprint and promotes sustainability through practices such as the development of eco-friendly products, more efficient and responsible resource use, recycling, and optimized consumption of raw materials (Peng & Li 2008; Shu et al., 2016). In addition to its ecological benefits, environmental innovation is positively recognized and rewarded by capital markets, resulting in higher company valuations and improved financial metrics such as returns on assets (ROA) and investment (ROI). Evidence also shows that GM positively influences Innovation Performance (IP) (Rojas-Cabezas et al., 2024b) by fostering a culture of proactivity and strategic foresight, as well as creating barriers to entry for potential competitors (Farza et al., 2021). In short, GM contributes to sustained competitive advantage.

2.1 Digital Orientation and Innovation Performance of SMEs

DO facilitates smoother access to various innovation resources (Ning et al., 2023) through the adoption and integration of digital tools, platforms and processes, such as Enterprise Resource Planning (ERP) systems, big data analytics software, robotics and the Internet of Things (Kindermann et al., 2021). This boosts a firm's ability to respond to environmental changes and hence enables faster strategic reconfiguration and business model redesign (Warner & Wager, 2019), among other aspects.

Firms with stronger DO demonstrate positive effects on sustainable corporate performance as they enjoy broader and faster access to information across all activities (Le et al., 2024). This also benefits green innovation, with Yin et al. (2024) confirming that a green DO tends to be reflected in a firm's green digital innovation, mediated by green business model innovation.

DO has also been shown to significantly improve Innovation Performance (IP) through various mechanisms, such as knowledge-sharing processes. For instance, Martínez Falcó et al. (2024) conclude that digitalization streamlines processes and enables more efficient knowledge management, thereby facilitating innovation and improving IP. Increased investment in R&D strengthens the relationship between DO and IP by allowing firms to leverage their digital infrastructure to improve innovation (Guo et al., 2023; Zhao et al., 2024).

Recent studies have shown that the relationship between DO and IP is contingent upon firm-level resources and capabilities. For instance, funding capacity allows firms to leverage digitalization for costly and uncertain innovation processes, while environmental awareness enhances transparency and corporate responsibility, reinforcing sustainable innovation outcomes (An et al., 2024). Likewise, absorptive capacity enables firms to acquire and apply

external knowledge more effectively, thereby amplifying the positive effect of DO on IP (Ning et al., 2023). These mechanisms underline that DO is not only a technical resource but also a strategic capability that, when combined with other organizational factors, drives superior innovation performance.

Other studies have confirmed a significant positive relationship between DO and corporate innovation and also found that the presence of female executives moderates this relationship (Zhou & Zhao, 2025). In this case, DO enhances information gathering and processing, stimulates cultural change toward innovation, and reduces information asymmetry with investors, all of which improve access to funding and foster greater investment in innovation. DO has also been studied as a mediator between the digital economy and green innovation. For example, Qiao et al. (2024) find that the digital economy, understood as the level of digital development in the broader macroeconomic context, enables firms in more digitally developed regions to exhibit greater DO, thus improving their ability to innovate sustainably.

DO has also been studied as a mechanism linking knowledge management and innovation in green products and processes. Vo-Thai and Tran (2025) concluded that it facilitates innovation by improving knowledge management, reducing barriers, developing technological capabilities and transforming organizational culture. It also mediates the relationship between the external digital environment and the innovative capacity of firms.

The existing scientific evidence indicates that DO facilitates strategic reconfiguration and fosters innovation in products, processes, and business models. Accordingly, and based on prior empirical findings, the following hypothesis is proposed.

H1: Digital orientation is positively related to the innovation performance of manufacturing SMEs

2.2 The Mediating Effect of Green Management on the Relationship between Digital Orientation and Innovation Performance of SMEs

GM has previously been studied as a source of competitive advantage. In this regard, Ambec and Lanoie (2008) identify several benefits of GM, such as access to differentiated markets (via product differentiation) and process optimization (through process innovation). This is because companies that adopt GM not only comply with environmental standards but also transform their operations, products and processes, thereby increasing both their innovation (Rojas-Cabezas et al., 2024b; Núñez et al., 2025) and their financial performance (Castillo-Esparza et al., 2024).

Ren et al. (2022) also find that environmental management mechanisms can drive technological innovation and improve firm performance. For instance, they observe that emissions trading systems require companies to meet strict emissions limits, which call for investments in areas such as emission-reduction technologies, optimization of resource efficiency, and digital monitoring of environmental metrics.

Green process and product innovations can increase a firm's market competitiveness while contributing to the sustainable development of society (Lafuente & Vaillant, 2023; Wang et al., 2024), yielding measurable benefits such as low-cost competitive advantages and differentiation (Liao, 2016; Lin et al., 2013). In this regard, financial and innovation performance have both been studied as outcomes of GM implementation (Shu et al., 2020). However, the effect on innovation performance tends to be stronger than that on financial performance, due to the costs associated with green practices (Shu et al., 2020).

Meanwhile, Qiao et al. (2024) found and analyzed a positive relationship between digitalization and green innovation, showing that digitalization enhances both financial resources and the informational environment for innovation. However, digitalization alone is not sufficient. A study conducted in China using fuzzy-set Qualitative Comparative Analysis (fsQCA) determined that the presence of green conditions (such as investment in environmental innovation) moderates the impact of digitalization on innovation (Yan & Wang 2024).

Digital orientation enhances firms' ability to manage environmental challenges by providing real-time information, facilitating the adoption of eco-efficient technologies, and strengthening the integration of knowledge into green innovation processes (Wei & Sun, 2021; Vo-Thai & Tran 2025). However, evidence shows that digitalization alone is insufficient; firms' environmental awareness, along with financing capacity, plays a critical role in transforming digital resources into higher-quality green innovations (An et al., 2024).

Overall, the literature suggests that digital resources, although essential, must be complemented by proactive environmental practices to realize their innovative potential fully. In this sense, GM acts as a strategic mechanism that channels the benefits of digital orientation into more sustainable and high-quality innovation outcomes. Considering the above, we propose the following hypothesis:

H2: Green management positively mediates the relationship between digital orientation and innovation performance in manufacturing SMEs.

3. Methodology

3.1 Sample and Data

This study draws on data collected in 2022 by the ISO, a nonprofit private organization made up of 153 Ibero-American universities from 22 countries (see <https://faedpyme.es/> for further information). Data were gathered from SMEs using a stratified sampling approach based on three criteria: sector, size and country (García et al., 2022). Population sizes for each stratum were taken from the official statistical sources of each participating country. The survey instrument was administered to SME managers via an online platform, supplemented with telephone follow-ups. The overall sampling error was 1.1% at a 95% confidence level (García et al., 2022).

A total of 16,454 managers completed the questionnaire. However, this article focuses exclusively on manufacturing SMEs. The final sample included 4270 valid responses.

Of the final sample, 60% were men and 40% women, and 61.9% held a university degree. In terms of firm size, 47.5% were microenterprises, 32.9% were small businesses, and 18.6% were medium-sized. The geographic distribution of the sample was as follows: Mexico 20.3%, Central America 12.8%, South America 65.9%, and the Caribbean 0.9%.

3.2 Variables

The first part of the questionnaire collected general company information, and the remaining items addressed the key study variables. Constructs and indicators were measured on a 5-point Likert scale ranging from “not important” (1) to “very important” (5). All scales were developed by ISO based on the academic literature (García et al., 2022). Table 1 provides a description of the constructs and their associated indicators.

Endogenous latent variables.—Innovation Performance (IP): This latent variable is defined as innovation in both products and processes. Product innovation includes improvements to existing products/services as well as the launch of new offerings and services (OECD/Eurostat, 2018). Process innovation, meanwhile, refers to improvements in production methods and the acquisition of new technologies and equipment. The construct is measured using four items aligned with the Oslo Manual. Green Management (GM): This is defined as activities related to waste, energy, water and packaging management, among others (Ambec & Lanoie, 2008; Shu et al., 2020). We employ the ISO scale, which considers elements consistent with this conceptualization.

Exogenous latent variable.—Digital Orientation (DO): This refers to the use of digital technologies within the firm and encompasses all efforts to develop and maintain routines that leverage human capital and knowledge assets (Kindermann et al., 2021). This includes the use of big data, machine learning and similar. Again, we employ the ISO scale, which considers elements consistent with this conceptualization. It is important to emphasize that in this study, DO is conceptualized as a strategic orientation rather than as the mere adoption of digital technologies. In line with Kindermann et al. (2021), DO reflects a firm's willingness to identify, integrate, and leverage digital technologies in order to generate value through data utilization, process automation, and related benefits that support strategic decision-making. From a resource-based view (RBV) perspective, DO constitutes an organizational capability that goes beyond the isolated implementation of technologies. For this reason, various technologies (e.g., artificial intelligence, robotics, Internet of Things) are integrated into a single latent construct.

Control variables.—To isolate the effect of the core variables and improve internal validity, the model includes two control variables, namely firm size, measured by number of employees (Harymawan, 2018), and firm age (Vithessonthi & Tongurai, 2015; Ezzi & Jarboui, 2016). Larger firms tend to have greater bargaining power and more resources for innovation-based competitive advantages (Gopalakrishnan & Bierly, 2006). In turn, older firms have been observed to have accumulated more knowledge over time, which often leads to greater innovative activity than younger firms (López-Fernández et al., 2016). The effects of GM on performance may also vary depending on firm age (Neumann, 2021).

3.3 Method

To test the proposed hypotheses, we used partial least squares structural equation modeling (PLS-SEM). This is a more flexible methodology, as it does not require assumptions about data distribution. It uses a predictive causal model that is especially well-suited to the study of phenomena in the social sciences, exploratory studies, and the analysis of secondary or archival data, among others (Hair et al., 2018). As an additional justification for using PLS-SEM, the Shapiro–Wilk test was applied to the construct indicators, yielding values below 0.05 (González-Estrada & Cosmes, 2019). Given the presence of multivariate non-normality in the model data, the use of PLS-SEM is confirmed. To test the hypotheses, we applied the bootstrapping technique with 5,000 subsamples, which involves the replacement of missing values with the mean and a two-tailed test.

The software used to conduct the analysis was SmartPLS 4. The unidimensionality and reliability of the data were analyzed using the composite reliability (CR) and average variance extracted (AVE) indices. In all cases, both indices exceeded the evaluation criteria of 0.7 for CR (Dijkstra & Henseler, 2015) and 0.5 for AVE (Hair et al., 2018). Convergent validity indicates the extent to which a construct converges to explain the variance of its items. As shown in Table 1, all values are within the recommended threshold, which indicates internal consistency reliability and convergent validity (Hair et al., 2014).

To assess discriminant validity, which is the extent to which the constructs differ from one another, the criterion proposed by Fornell and Larcker (1981) was used, which indicates that the square root of the AVE of each construct (diagonal elements of the matrix) must be greater than the absolute value of its correlations with other constructs (off-diagonal elements), as shown in Table 2. All constructs met this criterion, suggesting that the indicators share more variance with their respective constructs than with other constructs. The Heterotrait-Monotrait Ratio of Correlations (HTMT) was also used to assess discriminant validity (Henseler et al., 2009). An HTMT value above 0.85 represents a discriminant validity issue. As shown in Table 3, all HTMT values for the constructs were below this figure. In sum, the tests performed suggest that discriminant validity is not an issue in this study.

4. Empirical Results

4.1 Measurement Model

The validity and internal reliability of the reflective measurement model were assessed by analyzing the outer loadings of the indicators on their respective constructs. These loadings reflect the proportion of indicator variance explained by the construct. According to Henseler et al. (2009) and Hair et al. (2018), a loading of ≥ 0.708 is considered acceptable, as it indicates that the construct explains at least 50% of the variance of the indicator. Nonetheless, one item with a loading of 0.685 was retained, given that the associated construct had an AVE > 0.50 and CR > 0.70 . The specific results of the loadings can be found in Table 1.

To evaluate internal consistency, Cronbach's alpha and CR were analyzed. Both metrics reflect the reliability of the construct, that is, whether the indicators adequately measure the same latent concept. As shown in Table 1, all constructs obtained alpha values between 0.70 and 0.95, which is considered acceptable (Henseler et al., 2009). Likewise, CR values also exceeded 0.70, meeting the criteria established by Dijkstra and Henseler (2015).

Regarding construct validity, both convergent and discriminant validity were examined (Henseler et al., 2009). Convergent validity was assessed using the average variance extracted (AVE), which reflects the proportion of variance explained by the construct relative to the total variance of its indicators. According to Hair et al. (2018), an AVE above 0.50 is acceptable. In this study, all constructs reached this threshold. In addition, convergent validity was also supported by the observation that the AVE for each latent variable was greater than the squared correlations with other latent variables, indicating that the constructs share more variance with their own indicators than with those of other constructs.

To assess discriminant validity, two complementary approaches were applied. First, the Fornell–Larcker criterion was used, which compares the square root of the AVE of each construct with its correlations with other constructs. Second, the HTMT (Heterotrait–Monotrait Ratio of Correlations) index proposed by Henseler et al. (2009) was used, with a threshold of < 0.90 . The results of both analyses are presented in Table 3 and suggest that the model satisfies the discriminant validity criteria.

In summary, all reliability and validity indices for the reflective measurement model fall within the recommended thresholds, supporting the internal consistency, convergent validity, and discriminant validity of the constructs (Hair et al., 2014).

Table 1: Reliability and validity indices of scales

Construct	Items	Loadings	Cronbach's Alpha	CR	AVE
Digital Orientation	ERP (Enterprise Resource Planning) systems	0.775	0.890	0.916	0.647
	Corporate intranet	0.822			
	Cybersecurity services	0.816			
	Big data and data analytics software	0.870			
	Robotics and sensors	0.795			
	Localization, Internet of Things	0.741			
Green Management	Environmental criteria in supplier selection	0.788	0.911	0.930	0.656
	Environmental criteria in plastic and derivative packaging management	0.812			
	Environmental criteria in process design	0.873			
	Environmental criteria in energy management	0.862			
	Environmental criteria in water management	0.851			
	Environmental criteria in waste management	0.781			
	Environmental certifications (e.g., ISO 14001/EMAS)	0.685			

Construct	Items	Loadings	Cronbach's Alpha	CR	AVE
Innovation Performance	Changes or improvements to existing products/services	0.844	0.848	0.898	0.688
	Launch of new products/services	0.830			
	Changes or improvements to production processes	0.871			
	Acquisition of new capital equipment	0.769			

4.2 Bias Control

To ensure the quality of the measurement instrument, ISO conducted a pre-test of the questionnaire with a small group of participants, which served to verify the clarity and comprehension of the items. Participants were assured of the confidentiality and anonymity of their responses as a means to reduce social desirability bias. To increase motivation and engagement, participants were offered an aggregated report of the survey results.

A test for common method variance (CMV) was conducted to detect potential response distortions resulting from the data collection method (Podsakoff et al., 2024). For this, a Full Collinearity test was performed, as shown in Table 1, analyzing the VIF values for the latent variables in the model, where a VIF greater than 3.3 suggests the presence of CMV. None of the constructs had a VIF above 3.3, which suggests that there is no evidence of CMV. Harman’s single-factor test was also applied. Using this technique, the variables were included in an Exploratory Factor Analysis (EFA), and the “non-rotated factorial solution” was examined to determine whether the variance in the data was attributable to a single factor. The resulting variance under Harman’s test was 0.358, which is below the 0.50 threshold, indicating that common method bias does not have a significant impact (Kock, 2015).

Table 2: Discriminant validity (Fornell-Larcker Criterion)

	Innovation Performance	Digital Orientation	Green Management
Innovation Performance	0.829		
Digital Orientation	0.280	0.804	
Green Management	0.400	0.413	0.810

Table 3: Discriminant Validity (Heterotrait Ratio, HTMT)

	Innovation Performance	Digital Orientation	Green Management
Innovation Performance			
Digital Orientation	0.319		
Green Management	0.452	0.451	

4.3 Structural Model Evaluation and Hypothesis Testing

To evaluate the structural model, bootstrapping with 5.000 resamples was conducted to analyze the model’s predictive capacity and the relationships between the constructs. The analysis included a review of the collinearity, magnitude and significance of the path coefficients, the coefficient of determination (R²), the effect size (f²), and the predictive relevance (Q²).

First, collinearity was assessed using variance inflation factor (VIF) values. As shown in Table 4, all VIF values are below the threshold of 3.3 proposed by Kock (2015), indicating that collinearity does not pose a significant threat among the model’s exogenous constructs.

Regarding the hypotheses, the bootstrapping results showed that DO is positively and significantly related to IP ($\beta = 0.14$; $t = 9.168$; $p < 0.001$), thus supporting Hypothesis 1. To evaluate Hypothesis 2, the mediating effect of GM was analyzed using the bootstrapping procedure, which is considered the most robust approach for testing mediation in PLS-SEM (Hair et al., 2014). As shown in Table 5, the results confirm that GM significantly and positively mediates the relationship between DO and IP ($\beta = 0.142$; $t = 16.149$; $p < 0.001$), thus confirming Hypothesis 2. However, the size of this mediating effect is relatively small compared to the direct effects, which suggests that its practical significance should be interpreted with caution.

As for the control variables, the results indicate that firm age has a significant effect on IP, with older firms exhibiting lower IP. In contrast, firm size did not have a significant effect.

The coefficient of determination (R^2) indicates that the model explains 17.9% of the variance in innovation performance, which represents an acceptable level of explanatory power. Furthermore, the predictive relevance analysis (Q^2) yielded values greater than zero for all dependent variables, suggesting that the model has acceptable predictive capability (Hair et al., 2014).

Finally, the effect size (f^2) analysis revealed that DO has a moderate effect on IP ($f^2 = 0.205$), while GM has a small effect ($f^2 = 0.118$), in accordance with the interpretation criteria proposed by Hair et al. (2018).

Table 4: Structural relationships and hypothesis testing

	Coefficients (β)	Standard deviation	VIF	t-value	R-square	Decision
A -> IP	-0.06	0.015	1.127	3.931**		
S -> IP	0.019	0.014	1.262	1.378		
DO -> IP	0.140	0.015	1.340	9.168**	0.179	H1: Supported
DO -> GM	0.413	0.013	1.000	31.358**	0.170	
GM -> IP	0.343	0.017	1.203	20.117**		

Note 1: OD: Digital Orientation; GM: Green Management; DI: Innovation Performance; A: Age; S: Size

Note 2: VIF<5: * $p < 0.005$; ** $p < 0.001$

Table 5: Mediation effect testing

	Coefficients (β)	Standard deviation	t-value	Decision
DO -> GM -> IP	0.142	0.009	16.149	H2: Supported

Note 1: OD: Digital Orientation; GM: Green Management; DI: Innovation Performance

Note 2: * $p < 0.005$; ** $p < 0.001$

5. Discussion

The results show that digital orientation is positively and significantly related to innovation performance. At the same time, green management acts as a mediating mechanism in this relationship, albeit with a more negligible effect than the direct impact of DO. These findings are consistent with prior research indicating that firms with higher levels of DO develop capabilities that foster product and process innovation, for example, by strengthening organizational learning and integrating external knowledge (Kindermann et al., 2021; Wang et al., 2024). Moreover, technologies such as the Internet of Things (IoT), sensors, and artificial intelligence enable the generation of real-time data that supports the identification of innovation opportunities and activities.

These results can be further interpreted through the framework proposed by Nambisan et al. (2017), who argue that innovation in digital environments is open, dynamic, and continuously evolving. One of their key propositions suggests that digitalization enables dynamic problem–solution matching. In this sense, digital orientation equips manufacturing SMEs with flexible, data-driven capabilities that allow them to identify and address complex challenges, including those related to environmental issues.

The evidence from this study confirms that digital orientation and green management, when combined, have a significant impact on innovation performance in manufacturing SMEs. This finding aligns with prior research, which shows that digitalization drives green innovation by enhancing absorptive capacity and resource integration, while also highlighting the need for greater conceptual clarity regarding the role of digital transformation in reshaping business models (Rojas-Segura et al., 2023).

This finding is consistent with recent discussions on the configuration of digital ecosystems and platform economies, which highlight the need for SMEs to embed digitalization within broader institutional and policy frameworks that support competitiveness and sustainability (Lafuente et al., 2023). Thus, our results reinforce the idea that digital orientation not only improves operational efficiency but also constitutes a key catalyst for environmentally responsible innovation practices.

In this sense, DO equips firms to identify and combine “problems/needs” with “solutions/technologies”; GM introduces environmental criteria that reconfigure those matches (which solutions are accepted or discarded and how they are implemented); and IP emerges from the sequence of these matchings as they are made and remade over time. This mechanism is consistent with recent views of dynamic problem–solution matching in digital innovation (Nambisan et al., 2017). In this regard, our evidence suggests that DO allows firms to respond to environmental and institutional pressures through green innovations, using resources such as IoT, big data and artificial intelligence to identify changes in regulations, as well as consumer tastes and preferences, thereby providing valuable information for making timely strategic decisions on matters such as green products, environmentally friendly processes, reduction of water usage, waste minimization, and even supplier requirements (Zhang et al., 2025).

The results of our study can also be connected to the idea that DO endows firms with critical resources for monitoring their own management practices, in waste reduction, for example. While this is likely aimed at operational efficiency, at the same time it may also raise awareness of the firm’s environmental footprint, as companies with a strong green DO can plan and implement digital technologies not only to be more efficient but also to achieve environmental goals, such as emissions reductions (Yin et al., 2024).

Similarly, the evidence from our article could be interpreted through the work of Li et al. (2022), who used clustering, decision trees and data mining to analyze the influence of different configurations of enterprise digitalization on green IP. They found that advanced digitalization positively impacts green innovation through more efficient communication, more effective knowledge integration, and lower innovation implementation costs.

Finally, the results allow us to nuance the debate on contextual contingencies. While research in developed economies has shown that technological turbulence amplifies the positive effect of digital orientation on environmental performance (Bendig et al., 2023), evidence from China indicates that digitalization does not automatically ensure sustainable performance, as it depends on institutional factors and firms’ commitment to the green agenda (Yin et al., 2024). In this sense, our study contributes to demonstrating that, despite resource scarcity and structural vulnerabilities, the combination of digital and environmental capabilities provides a strategic pathway to strengthen innovation and sustainable competitiveness in Latin America. This finding also responds to recent calls to clarify conceptual and theoretical frameworks on digital transformation (Rojas-Segura et al., 2023) and to rethink innovation management in an increasingly digital world (Nambisan et al., 2017).

6. Conclusions, Implications, Limitations and Future Research Directions

6.1 Concluding Remarks

This study sets out to address two research questions: (1) Does digital orientation (DO) positively influence innovation performance (IP) in manufacturing SMEs in Latin America? and (2) Does green management (GM) mediate the relationship

between DO and IP? The empirical results provide evidence of a direct, positive, and significant relationship between DO and IP, as well as a positive mediating relationship of GM between these variables. The mediating role, although significant, exhibits only a moderate effect, which warrants a careful interpretation of its implications for managerial practice.

The development of new green products and processes as well as the improvement of existing ones contributes not only to reducing a firm's carbon footprint but also to lowering capital costs. Moreover, such innovation can enhance market positioning by attracting environmentally conscious consumers and strengthening long-term customer relationships, given the growing attention to corporate environmental performance.

In Resource-Based View (RBV) terms, the combination of DO (data, platforms, analytics) and GM (environmental routines, metrics, and standards) constitutes valuable, rare, inimitable, and organized resources and capabilities. GM's mediation suggests an integrative capability that transforms digital assets into innovation, generating returns that are difficult to replicate. (Barney, 1991).

6.2 Implications

Our findings also provide theoretical insight into the importance of these initiatives, especially for Latin American SMEs. The results reinforce the notion that implementing DO and green practices leads to better IP, while also contributing to environmental sustainability and enhancing firm reputation (Maldonado-Guzmán & Pinzón-Castro, 2022). GM emerges as a solution for SMEs not only because it improves environmental performance (Rehman et al., 2021), but also because it simultaneously fosters the development of new products and processes that meet the expectations of a segment of the population that evaluates companies' environmental behavior and seeks green products and services. This, in turn, promotes customer loyalty (Meng et al., 2016) by enabling product differentiation (Ambec & Lanoie, 2008).

The mechanism is consistent with the logic of problem–solution matching in digital innovation: DO identifies needs and technologies; GM introduces environmental criteria that reconfigure those matches; and IP emerges from their iteration over time (Nambisan et al., 2017). Moreover, integrating IoT and smart, connected products activates data feedback loops that improve design decisions, enable cleaner processes, and enhance traceability, reinforcing the DO, GM, and IP link (Porter & Heppelmann, 2014; Lafuente & Sallan, 2024).

These benefits are not automatic. Zhao et al. (2024) demonstrate that the green payoff of digitalization primarily materializes under supportive institutional conditions, stricter environmental regulations and disclosure, higher marketization, and digital infrastructure, as well as when firms actively commit resources to the green agenda; in weaker settings, the effect attenuates. This situation may be related to the moderate size of the mediating effect of green management observed in our results, given that the study covers multiple countries, each of which may exhibit different levels of commitment to the green agenda.

These results are relevant not only for managers of manufacturing SMEs, but also for public policymakers, since both GM and DO promote firm competitiveness. DO and GM should be incorporated into the strategic planning of any firm or nation, especially those in emerging markets that face diverse and complex challenges in both domestic and international contexts. Undoubtedly, globalization demands that firms modernize and gain access to real-time information to make timely strategic adjustments. As we have seen, DO is a strategic ally in generating and sharing information that creates competitive advantages through innovation.

Although the results show positive effects of digital orientation on innovation performance, mediated by green management, in Latin American manufacturing SMEs, it is important to acknowledge that the region faces significant delays in developing its digital ecosystem and pronounced heterogeneity across countries (Acs et al., 2022). In this context, policymakers are encouraged to design initiatives tailored to each country's specific conditions, focusing on strengthening the weakest components of their digital ecosystems rather than applying uniform digital policies across the region.

The empirical results lead us to recommend that manufacturing SMEs integrate DO into their strategies, as it facilitates the processing of high-quality real-time information and promotes the development of new or improved products and processes. GM is also recommended as a strategic element that enhances the relationship between DO and IP. The use of IoT, sensors, robotics and similar technologies generate key data that can lead to the implementation of green activities such as waste reduction, environmental criteria in process design and redesign, and water management, among others, which in turn can lead to the development of green products or more efficient processes. All of this helps firms to create competitive advantages.

For example, one of the firms participating in this study, Kemical, a manufacturing SME located in Costa Rica, reported the adoption of digital systems for real-time monitoring of energy consumption, implemented alongside the installation of solar panels that have supplied more than 80% of its electricity needs since 2020. This case illustrates how digital orientation (through the use of monitoring technologies) enables green management practices (tracking the use of renewable energy and energy consumption), which in turn enhance innovation performance by generating eco-efficient processes and new organizational routines that strengthen both environmental and economic outcomes. The literature shows that digitalization provides the data infrastructure and connectivity (sensors/smart connected products) that transform day-to-day operating decisions and processes, creating feedback loops for improvement and traceability, the basis for those green routines. As a result, the firm innovates.

Environmental challenges related to the conservation and restoration of ecosystems and biodiversity cannot be ignored. Today more than ever, companies are being monitored by stakeholders for their environmental footprint, a further reason to implement green practices. Finally, by jointly analyzing the relationship between DO, GM and IP, we show that GM is an important mechanism for strengthening the effect of DO on IP.

6.3 Limitations and Future Research Directions

Like any study, this one is not without limitations. First, the degree of digital or technological maturity of the firms was not considered, even though this could influence innovation outcomes. Second, causal factors related to the implementation of green practices, such as country-specific legal or cultural aspects, were also not considered. Third, the absence of longitudinal data limits the possibility of studying the evolution of these constructs over time.

Future research could include variables related to firms' degree of digital orientation, as well as regulatory factors or public policies that promote green practices and digitalization. Longitudinal studies could also be conducted to examine how the constructs interact over time and explore the costs associated with implementing green practices.

Declaration of Generative AI and AI-assisted Technologies

The authors utilized Chat Generative Pre-Trained Transformer (ChatGPT) and Grammarly to enhance readability and language. Additionally, the author utilized ChatGPT to search for relevant literature while revising the manuscript. After using these tools, the author reviewed, edited, and took full responsibility for publishing the content.

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