“Predictive effect of intellectual capital on business innovation in Ecuadorian SMEs”

AUTHORS	Myriam Naranjo-Vaca Miriam Salas-Salazar Marco Gavilanes-Sagnay Esteban David Lopez-Manobanda

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Myriam Naranjo-Vaca (Ecuador), **Miriam Salas-Salazar** (Ecuador),
Marco Gavilanes-Sagñay (Ecuador), **Esteban David López-Manobanda** (Ecuador)

PREDICTIVE EFFECT OF INTELLECTUAL CAPITAL ON BUSINESS INNOVATION IN ECUADORIAN SMEs

Abstract

In a productive environment characterized by increasing demands for sustainability, traceability, and differentiation, small and medium-sized enterprises (SMEs) play a central role in economic development. This study aims to evaluate the predictive effect of human, structural, and relational capital on product, process, marketing, and organizational innovation in Ecuadorian SMEs. The analysis is based on a structured survey administered to 395 SME managers and owners from the manufacturing, commercial, and service sectors located in the provinces of Tungurahua, Cotopaxi, and Chimborazo (Ecuador) during July and August 2025. Data were analyzed using partial least squares structural equation modeling (PLS-SEM), incorporating bootstrapping with 5,000 resamples and external validation through a holdout approach (80% training and 20% validation). The results reveal that all hypothesized relationships are positive and statistically significant ($p < 0.001$), with standardized path coefficients ranging from $\beta = 0.20$ to $\beta = 0.66$. Structural capital has the strongest effect on process innovation ($\beta = 0.60$), while relational capital has the strongest effect on organizational innovation ($\beta = 0.54$). The model explains a substantial proportion of variance in innovation outcomes, with R^2 values of 0.47 for product innovation, 0.51 for process innovation, 0.52 for marketing innovation, and 0.44 for organizational innovation. Predictive validation confirms the model's accuracy, yielding low prediction errors (RMSE = 0.20–0.23; MAE = 0.16–0.18). These findings provide updated empirical evidence on the strategic role of intellectual capital in enhancing innovation performance in Latin American SMEs and highlight the relevance of intangible resources.

Keywords intellectual capital, business innovation, PLS-SEM, SMEs, prediction, intangible assets

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Myriam Naranjo-Vaca, M.Sc., Occasional Lecturer, Faculty of Business Administration, Escuela Superior Politécnica de Chimborazo [Chimborazo Polytechnic University], Ecuador. (Corresponding author)

Miriam Salas-Salazar, M.Sc., Occasional Lecturer, Faculty of Business Administration, Escuela Superior Politécnica de Chimborazo [Chimborazo Polytechnic University], Ecuador.

Marco Gavilanes-Sagñay, M.Sc., Occasional Lecturer, Faculty of Business Administration, Escuela Superior Politécnica de Chimborazo [Chimborazo Polytechnic University], Ecuador.

Esteban David López-Manobanda, M.Sc., Independent Researcher, Ecuador.

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INTRODUCTION

In Ecuador, the manufacturing, commercial, and service sectors play a strategic role within the national productive apparatus, both for their contribution to the generation of added value and for their capacity to absorb formal employment and stimulate productive chains. This sector is mainly composed of small and medium-sized enterprises (SMEs), which operate in contexts characterized by structural constraints, high competitive pressure, and growing exposure to technological and market changes. In this scenario, the capacity to innovate has become a critical factor for business sustainability and dynamism, particularly in emerging economies where traditional competitive advantages tend to be fragile and easily replicable.

However, the available empirical evidence shows a persistent gap between the economic relevance of the manufacturing sector and its innovative performance. According to official data from the National Institute of Statistics and Censuses (INEC, 2025), although this sector contributes around 12% of gross domestic product and accounts for a

significant proportion of formal employment, levels of technological incorporation, productive diversification, and systematic innovation in SMEs remain limited. This situation highlights that conventional productive factors are insufficient to explain the differences observed in the innovative capacity of companies operating under similar structural conditions.

The Ecuadorian business fabric is made up of more than one million active companies, a significant proportion of which are concentrated in the provinces of Tungurahua, Cotopaxi, and Chimborazo, which together account for approximately 115,200 productive units, with a strong presence of SMEs in the manufacturing, commercial, and service sectors. This territorial concentration reflects the importance of these productive spaces for analyzing the business dynamics associated with innovation and sustainability, especially in contexts where competitiveness increasingly depends on intangible organizational capabilities.

In this context, an unresolved scientific problem emerges: the limited empirical and explanatory understanding of how the intangible capabilities of SMEs, particularly those related to knowledge, internal organization, and relationship networks, translate into sustainable innovation processes. The absence of conclusive evidence of this link makes it difficult to explain why some companies manage to boost their productivity through innovation. In contrast, others remain stagnant despite operating in similar environments. This knowledge gap restricts the construction of robust analytical frameworks for understanding innovation in SMEs in emerging economies and limits the ability to design business strategies and productive development policies aligned with the particularities of the Ecuadorian context.

1. LITERATURE REVIEW

In developing economies such as Ecuador's, the manufacturing industry, according to Feijoó et al. (2024), is one of the structural pillars of the productive apparatus, not only because of its contribution to the Gross Domestic Product (GDP) and Gross Value Added (GVA), but also because of its capacity to generate formal employment and promote productive linkages (Aldás et al., 2024). Thus, Carrión et al. (2024) mention that, in 2020, this sector contributed 12.53% to the national GDP, generating approximately 9 billion dollars in revenue and absorbing nearly 10% of the formally employed population.

However, this apparent progress is offset by a lag in the systematic incorporation of technological and cognitive capabilities. The persistence of semi-manual processes and low investment in research and development (R&D) limit the sector's productive efficiency, which reaches only 70% of its potential capacity (Cobos-Salvador & Armijos-Yambay, 2020; Valderrama et al., 2015). This gap between productive performance and knowledge-based capabilities has been identified in recent development economics research as a structural constraint for innovation and competitiveness in emerging economies (Sinchigalo et al., 2023). In this context, it is imperative to reassess the factors that sustain the competitiveness of small and medium-sized manufacturing enterprises (SMEs), particularly those operating in resource-constrained environments. According to Saltos et al. (2017), productive development requires not only material inputs, but also intangibles such as process design, R&D, and product configuration, whose articulation depends largely on intellectual capital.

Intellectual capital, understood as the set of knowledge, skills, experiences, and relationships that reside in the people, organizational structures, and external networks of a company, has positioned itself as a critical asset for innovation (Li & Yu, 2018; Omari et al., 2024). From a resource and capability perspective (RBV), the possession of valuable, scarce, and inimitable intangible assets is essential for building sustainable competitive advantages, with organizational knowledge being a key catalyst for innovation (Barney et al., 2001; Grant, 2001). In this sense, the effective integration of human, structural, and relational capital enables SMEs to develop learning dynamics that translate into improvements in processes, products, and business models (Chen & Huang, 2009; Purnamawati et al., 2022; Sung & Choi, 2018).

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Empirical evidence on the relationship between intellectual capital and innovation in SMEs in developing countries is still in its infancy, and the results obtained in advanced economies are not always transferable. Institutional constraints, low levels of R&D funding, and the absence of knowledge support policies make it difficult for intangible capabilities to translate into sustainable innovative outcomes (Asiaei & Jusoh, 2017; Xu & Li, 2022). Also, it has been observed that R&D intensity does not always lead linearly to higher levels of innovation, being moderated by factors such as quality management, knowledge integration, and the degree of financial slack (Lu et al., 2021; Qiu et al., 2025).

In Ecuador, the scarcity of studies that explicitly link intellectual capital with innovation in the manufacturing sector of SMEs represents a methodological gap in the empirical evidence. It is interesting to close this gap by analyzing this relationship in a group of Ecuadorian companies, identifying the components of intellectual capital that have the greatest impact on innovation outcomes by examining the organizational conditions that favor this link. The hypothesis is that robust intellectual capital, articulated through a culture of knowledge management and continuous improvement processes, significantly enhances the innovative capacity of SMEs (Astuti et al., 2023; T. Do & N. Do, 2024).

In this way, the study not only provides evidence for the formulation of public policies aimed at productive transformation and sustainability in the manufacturing sector (C) classified by Ecuador's national statistics agency (INEC, 2012), but also offers an analytical framework applicable to other emerging economies (Mayorga-Abril et al., 2024). By integrating structural, cognitive, and contextual variables, this paper aims to broaden understanding of the mechanisms through which manufacturing SMEs can transition to knowledge-based development models aligned with the Sustainable Development Goals, especially SDG 8 (Decent work and economic growth) and SDG 9 (Industry, innovation and infrastructure).

The relationship between intellectual capital and innovation has become increasingly important in the study of SMEs, especially in emerging contexts where resource constraints force a rethinking of traditional sources of competitiveness. Recent studies agree that intangible assets such as organizational knowledge, innovation culture, collaborative networks, and institutional learning are key determinants for driving innovation in smaller companies.

From an empirical perspective, SMEs with greater intellectual capital development perform better in terms of innovation, particularly when they integrate organizational learning capabilities, knowledge management, and inter-institutional links (Hidayat & Pok, 2025; Mousavi Shiri & Salehi, 2025). These capabilities are even more relevant in contexts of scarcity, where frugal innovations based on the efficient use of tangible and intangible resources enable structural barriers to be overcome and business performance to be improved. Evidence also suggests that factors such as entrepreneurial motivation (Li et al., 2022), participation in research networks (Bontis et al., 2000), and cooperation with universities or public agencies (Saltos et al., 2017) have a positive impact on the effort, production, and impact phases of innovation (Worakittikul et al., 2025).

On the other hand, applied research in Europe, such as Aljuboori et al. (2022), Bontis et al. (2000), and Ullah et al. (2022), has confirmed that strategic intellectual capital management not only increases the likelihood of product innovation but also improves organizational performance through innovation mediation (Sulaiman, 2025). This link is particularly strong when companies manage to harmoniously integrate their human, structural, and relational components (Li et al., 2022).

In a complementary approach, other studies show that manufacturing SMEs that implement green innovation mechanisms achieve sustainable competitive advantages, provided they have organizational structures that promote the circulation and application of knowledge (Achmad & Wiratmadja, 2025). In turn, contextual factors such as competitive pressure, coordination with supply chains, and participation in digital platforms have been identified as moderating the effect of intellectual capital on innovation, implying that this link is not linear but mediated by environmental conditions (Kassa & Kegne, 2025).

Taken together, these studies confirm the importance of intellectual capital as a basis for sustainable and strategic innovation in small and medium-sized enterprises. It is emphasized that incorporating emerging technologies, such as artificial intelligence, into the development of new products requires not only technical capabilities but also an organizational culture open to change and an internal structure that favors knowledge absorption (Cooper, 2025). Also, the impact of intellectual capital is enhanced when companies develop adequate digital infrastructure and promote labor protection mechanisms that encourage the participation of human talent in innovation processes (Edeh et al., 2025; Ma et al., 2025).

These findings underscore that innovation in SMEs does not depend solely on technology adoption, but on the extent to which internal knowledge and intellectual capital components help generate value (Agostini et al., 2017). Thus, this study is justified not only by the scarcity of empirical evidence in Latin American contexts but also by the need to understand how Ecuadorian manufacturing SMEs can leverage their intellectual capabilities to promote more competitive, resilient, and inclusive development models and compete internationally.

Intellectual capital, as an organizational construct, is based on a body of theory that has evolved significantly since the mid-20th century. Among the first fundamental contributions is the Human Capital Theory proposed by Becker (1964), which argues that the skills, competencies, and knowledge acquired by individuals through formal education and work experience contribute substantially to economic growth and organizational performance. From this perspective, human knowledge is not a passive input, but rather a strategic asset capable of generating productivity and business dynamism (Magida et al., 2025).

Complementarily, the Theory of the Firm as an Open Information Processing System, formulated by Galbraith in 1973, introduces an organizational vision in which companies act as systems that collect, process, and use information to respond adaptively to the demands of the environment (Nogueira, 2017). This approach supports the concept of structural capital by linking organizational responsiveness to cognitive infrastructure and internal knowledge management mechanisms.

These two theories, one focused on the subject and the other on the organization as a system, provide intellectual capital with an integrated conceptual basis that recognizes intangible assets not only as economic resources but also as catalysts for innovation, operational efficiency, and sustained competitive advantage (Figueiredo et al., 2023).

Starting in the 1990s, intellectual capital gained prominence as a central analytical category in understanding organizational values. Academic interest was consolidated with pioneering measurement and visualization experiences, such as the Skandia model, developed by Edvinsson (1997), and documented in the reports analyzed by Handzic et al. (2016), which marked a milestone in the strategic management of intangibles. These early proposals were systematized in the MERITUM project, which sought to standardize the identification, measurement, and disclosure of intellectual capital, providing normative models that are still benchmarks in the specialized literature today.

Subsequently, the theoretical approach became more complex with the incorporation of dimensions such as intangible liabilities, the construction of perceived value (Erazo, 2021), and integrative strategic models (Kaplan & Norton, 2004), which allow not only the evaluation of intangible stock but also its alignment with organizational strategy and expected results.

Within this framework, intellectual capital is also linked to the Resource and Capability Theory proposed by Barney (1991), which posits that organizational resources, particularly intangible ones such as reputation, know-how, or corporate culture, can generate sustainable competitive advantages if they meet the criteria of being valuable, scarce, imperfectly imitable, and irreplaceable. This view is expanded by Grant (1996), who identifies knowledge as the strategic resource par excellence, whose efficient integration through organizational structures, routines, and processes constitutes the basis of superior performance (Di Giacinto et al., 2020).

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Innovation in value, a key concept in the Blue Ocean Strategy formulated by Chan and Mauborgne (2005), represents a paradigm shift in contemporary business innovation theory. Unlike traditional strategies focused on direct competition and incremental maximization of market share in saturated markets, referred to by the authors as red oceans, this theory proposes the creation of blue oceans, i.e., unexploited market spaces where competition becomes irrelevant (Nakamori, 2020).

The underlying logic of this approach is not to outperform existing rivals but, according to Chan and Mauborgne (2005), to redraw the boundaries of the market and generate new demand. The cornerstone of this approach is value innovation, understood as an organization's ability to break the dichotomy between differentiation and low cost, simultaneously achieving a significant increase in the value delivered to the customer and a reduction in structural costs.

Intellectual capital has established itself as a fundamental intangible strategic asset in contemporary organizations, especially those oriented towards innovation and sustainability (Koval et al., 2025). Far from being limited to an abstract concept, intellectual capital represents an organization's collective ability to generate, structure, and mobilize useful knowledge for value-added purposes. In its most widespread configuration, intellectual capital is conceived as a three-dimensional construct composed of human capital (HCE), structural capital (SCE), and relational capital (RCE) (Yitmen, 2011).

Human capital encompasses the skills, experience, creativity, learning ability, and motivation of workers. It is the primary source of innovation, given that transformative ideas emerge from skilled individuals who are committed to production processes. In this sense, human capital is valued not only for its technical skills, but also for its willingness to participate in processes of continuous improvement and adaptation to change (Wang et al., 2014). Furthermore, its influence on business performance has been widely documented, showing direct and indirect effects on technological innovation, particularly in emerging contexts such as China (Abredu et al., 2023). Studies such as that by Ekayani et al. (2023) show that human capital has a significant and positive effect on technological innovation, although not necessarily directly on business performance if it is not activated through innovative capabilities.

On the other hand, Chu et al. (2006) refer to structural capital as organizational systems, internal processes, databases, intellectual property, and the organization's procedures for problem solving and innovation (p. 889). This component ensures that knowledge does not depend solely on individuals but is integrated into the company's routines, protocols, and systems, thereby contributing to its sustainability and replicability (Yitmen, 2011). In fact, an organizational environment strengthened by efficient structures and a culture of innovation significantly increases the willingness to adopt technologies and generate new solutions in SMEs (Bangun et al., 2024; Rodrigues et al., 2022).

Relational capital refers to the set of relationships that the organization maintains with its stakeholders: customers, suppliers, strategic allies, public institutions, and communities derived from the organization's internal and external relationships (Chowdhury et al., 2019; Özer et al., 2015). These relationships are vital sources of information, legitimacy, and opportunities for co-creation, and constitute a differentiating asset for the generation of market-oriented innovation (Han & Li, 2015). However, their impact is not uniform. While relational capital can facilitate access to critical resources and external knowledge, its influence on performance depends on the quality of interactions and the strategic orientation of networks (Abredu et al., 2023; Taleb & Pheniqi, 2023).

Various models have been proposed to operate on intellectual capital. Among them, Pulic's VAICTM model stands out, widely adopted for its empirical applicability and inter-organizational comparability. This model measures the efficiency with which a company converts its intellectual resources into economic value, distinguishing between human, structural, and relational capital effectiveness (Ting et al., 2020; Xu & Li, 2022). Despite its advantages, it has also been criticized for its limited scope in measuring complex intangible assets in developing countries (Borrás-Atiénzar & Campos-

Chaurero, 2018; Gómez-Bayona et al., 2020), which has led to the incorporation of expanded models and triangulation methods.

Recent studies also highlight the mediating role of technological innovation in the relationship between intellectual capital and organizational performance. In contexts such as SMEs in Indonesia, it has been empirically demonstrated that human, structural, and relational capital significantly influence innovation, which in turn determines business performance (Ekayani et al., 2023). This dynamic suggests that intellectual capital should be strategically managed as an integrative platform for continuous innovation, especially in sectors where tangible resources are limited, and adaptability is key to survival (Alnaim & Metwally, 2024; Cabrilo & Dahms, 2018).

Innovation in SMEs has been reaffirmed as a critical factor for their competitiveness, sustainability, and economic growth in highly dynamic contexts (Zhao et al., 2025). Despite their structural and financial limitations, SMEs have a remarkable capacity to respond to changes in their environment, which allows them to adopt innovative processes more quickly than large corporations (Jabbour Al Maalouf et al., 2025). This capacity is enhanced when ambidextrous strategies are implemented that balance the exploration of new opportunities and technologies with the efficient exploitation of existing resources and knowledge (Al-Dhobee et al., 2025; Jabbour Al Maalouf et al., 2025).

Recent studies highlight that the coherent integration of innovative practices such as green, digital, and organizational innovation has a positive impact on operational performance, market differentiation, and organizational resilience (Esparza et al., 2024; Ström et al., 2023). For Zhang et al. (2025), green innovation emerges as a strategic pathway that enables SMEs to simultaneously meet economic and environmental objectives. The literature shows that approaches such as green product innovation, when aligned with a green market orientation, significantly mediate the relationship between sustainable policies and organizational performance (Appiah et al., 2025; Demir et al., 2025).

At the operational level, capabilities such as resource orchestration, inter-organizational collaboration, and the adoption of digital technologies are key enablers of sustainable innovation processes (Appiah et al., 2025; Mehralian et al., 2018). In this regard, the coordination of public policies, green financing programs, and adaptive governance schemes is recognized as a determining factor in the promotion of innovative ecosystems, especially in emerging economies such as Mexico (Valderrama et al., 2015).

Also, the eco-innovative approach mentioned by Parrilli et al. (2025) not only promotes profitability through cost reduction but also strengthens the social and environmental legitimacy of SMEs, enabling them to consolidate sustainable competitive advantages in increasingly demanding global markets (Hidayat & Pok, 2025; Menten et al., 2025). Thus, for Rideg et al. (2023), innovation should be understood as a multifunctional strategy that integrates technological, organizational, environmental, and market dimensions, giving rise to a robust conceptual framework that supports its role as a fundamental agent of sustainable economic transformation.

The interaction between intellectual capital dimensions and innovative outcomes in SMEs is conditioned by organizational and contextual factors. Agostini and Nosella (2017) show that human, relational, and organizational capital act interdependently, enhancing radical innovation when integrated into solid structures and external networks that favor knowledge flow.

Similarly, Sung and Choi (2018) highlight that the institutional environment influences the innovative orientation of SMEs, while Chen and Huang (2009) demonstrate that organizational learning and knowledge management are key to achieving incremental and radical innovation. Overall, the need to manage intellectual capital as an articulated and adaptable system to drive sustainable innovation is still a global challenge for companies subject to technological advances (Ferreira & Franco, 2017; Sabando-Vera et al., 2025).

The purpose of this study is to evaluate the predictive effect of human, structural, and relational capital on product, process, marketing, and organizational innovation in Ecuadorian SMEs using PLS-SEM. From this basis, the following hypotheses are set forth:

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H1: Human capital positively affects innovation in Ecuadorian SMEs.

H2: Structural capital positively affects innovation in Ecuadorian SMEs.

H3: Relational capital positively affects innovation in Ecuadorian SMEs.

2. METHOD

This study is part of a quantitative, non-experimental, cross-sectional approach with predictive scope. Its objective is to model entrepreneurial innovation driven by intellectual capital in Ecuadorian small and medium-sized enterprises (SMEs) using partial least squares structural equation modeling (PLS-SEM). This technique has been widely recommended when the research purpose is prediction rather than explanation, and when the theoretical model includes multiple constructs and indicators (Hair et al., 2017; Sarstedt & Liu, 2024). Furthermore, PLS-SEM is appropriate under conditions of moderate sample size, non-normality, and complex measurement structures (Hair et al., 2022).

In Ecuador, according to the National Institute of Statistics and Census (INEC, 2025), the country has more than one million active companies. Considering the geographical scope of the research, it was limited to companies located in the provinces of Tungurahua, Cotopaxi, and Chimborazo, which together represent 115,200 active companies. The target population consisted of Ecuadorian SMEs registered in the manufacturing, commercial, and service sectors. These provinces were selected due to the economic concentration of the three activities selected.

A non-probability convenience sample was used, prioritizing direct access to company managers and the completeness of the questionnaire, a valid strategy when faced with logistical limitations in uncontrolled environments (Roscoe, 1975). Data collection was carried out directly with the legal representatives of the companies in person, where the digital survey was provided through Google Forms. The analysis was conducted over a three-month period, between July and August 2025, using a structured questionnaire. Out of a total of 450 invitations, 395 valid responses were obtained (an effective response rate of 87.78%).

To validate the predictive capacity of the model, the database was randomly segmented into two subsets according to the holdout procedure: 80% of the cases were used for training (calibration) and the remaining 20% for out-of-sample validation, using the PLSpredict function (Marouni & Bentaleb, 2024; Sharippudin et al., 2024).

Statistical analysis was performed in RStudio using the PLS-SEM approach, applying non-parametric bootstrap resampling with 5,000 subsamples (Hair et al., 2017). This technique is suitable for modelling relationships between latent variables in complex models, as well as for maximizing predictive power rather than conforming to strict assumptions about data distribution (Sarstedt & Liu, 2024).

The instrument was a structured questionnaire administered through the Google Forms platform, designed to capture the perceptions of Ecuadorian SMEs managers regarding their internal and innovative capabilities. The questionnaire was organized into five sections: socio-demographic data, three dimensions of intellectual capital, and one dimension of business innovation, all measured using five-point Likert scales (1 = totally disagree; 5 = totally agree).

Intellectual capital was conceptualized as a second-order variable, comprising three latent first-order components adapted from Dabić et al. (2019):

- Human capital (HCE): composed of 17 items that assess staff motivation, training, experience, creativity, leadership, adaptability, and teamwork.
- Structural capital (SCE): measured using 19 items that address the existence of internal strategies, organizational structure, knowledge management practices, organizational culture, documented procedures, and innovation support systems.
- Relational capital (RCE): assessed using 22 items focused on relationships with custom-

ers, suppliers, competitors, public institutions, social and environmental actors, as well as reputation management and alliances.

For its part, business innovation was also treated as a second-order variable, composed of four dimensions adapted from Omerzel and Jurdanab (2016):

- Product/service innovation (IP): 5 items related to the introduction, modification, and strategic orientation of new services.
- Process innovation (IPr): 5 items on technology adoption, production methods, and technical training.
- Marketing innovation (IM): 5 items related to the use of new channels, promotional techniques, and positioning strategies.
- Organizational innovation (IO): 4 items on changes in internal structure, decision-making, external relationships, and work practices.

The analysis procedure was divided into two phases. In the first phase, the measurement model was evaluated using: factor loadings (> 0.70), internal consistency (Cronbach's alpha, Rho_A, and CR > 0.70), convergent validity (AVE > 0.50), and discriminant validity using the Fornell–Larcker criterion and the HTMT index (< 0.90), following the recommendations of Hair et al. (2022) and Henseler et al. (2015).

In the second phase, the structural model was evaluated by estimating standardized coefficients (β), significance tests via bootstrapping, coefficients of determination (R^2), size effects (f^2), and predictive relevance (Q^2) through systematic omission (blindfolding). Multicollinearity between constructs was examined using variance inflation factors (VIF < 5), in accordance with methodological standards (Hair et al., 2022).

To evaluate the predictive capacity outside the sample, PLSpredict was used, estimating the mean absolute error (MAE) and the root mean square error (RMSE) of the predictions. These results were compared with those obtained using a multiple linear regression benchmark model, which allowed the accuracy of the proposed structural model to be contrasted with an alternative approach (Hair et al., 2017).

The proposed factorial structure was evaluated using exploratory and confirmatory factor analysis prior to estimating the structural model. The construct validity and psychometric quality of the instrument were verified using statistical indicators recommended by the specialized literature on PLS-SEM modelling.

3. RESULTS

In the first phase, the model estimate is presented using the complete sample (n = 395), where the relationships between the three components of intellectual capital (human, structural, and relational) and the four dimensions of innovation (product, process, marketing, and organization) are evaluated. In the second phase, the model estimation is presented on the training subset (80% of the cases) to examine the stability of the structural coefficients in an independent subsample. Finally, the predictive capacity of the model is evaluated using the remaining 20% of the data by comparing the observed and predicted values in the endogenous variables of the model.

The overall estimation of the model was performed on the entire sample (n = 395), under the same structural and measurement specifications. This phase provides the reference parameters for the subsequent training and validation phases.

Table 1. Indicators of internal reliability and convergent validity of constructs

Construct	Cronbach's alpha	RhoC	RhoA	AVE
HCE	0.957	0.961	0.958	0.595
SCE	0.963	0.966	0.964	0.601
RCE	0.967	0.970	0.968	0.593
IP	0.816	0.872	0.818	0.577
IPr	0.851	0.894	0.854	0.628
IM	0.840	0.887	0.845	0.611
IO	0.808	0.874	0.809	0.635

Note: HCE = Human Capital Efficiency; SCE = Structural Capital Efficiency; RCE = Relational Capital Efficiency; IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

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Table 1 presents the internal reliability and convergent validity indicators for each construct. All Cronbach's alpha, RhoC, and RhoA values exceed the threshold of 0.70. The AVE values (ranging from 0.577 to 0.635) exceed the minimum requirement of 0.50, indicating that each construct explains more than 50% of the variance of its indicators.

Table 2. HTMT index for assessing discriminant validity

	HCE	SCE	RCE	IP	IPr	IM	IO
HCE	–	0.118	0.058	0.593	0.430	0.248	0.182
SCE		–	0.090	0.332	0.501	0.655	0.383
RCE			–	0.318	0.387	0.369	0.633
IP				–	0.556	0.560	0.489
IPr					–	0.619	0.502
IM						–	0.509
IO							–

Note: HCE = Human Capital Efficiency; SCE = Structural Capital Efficiency; RCE = Relational Capital Efficiency; IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

All coefficients of the heterotrait-monotrait (HTMT) index are below the threshold of 0.90. This indicates that the correlations between latent variables remain below levels that would compromise discriminant validity, as shown in Table 2. Therefore, it is empirically confirmed that the dimensions of intellectual capital and innovation represent distinct structures in the estimated model.

Table 3. Variance inflation values (VIF) of the indicators

Item	VIF	Item	VIF
HCE_1	1.542	IP_2	1.307
HCE_5	1.438	IP_4	1.289
HCE_10	1.690	IPr_1	1.475
SCE_2	1.371	IPr_5	1.512
SCE_7	1.586	IM_3	1.631
SCE_14	1.432	IM_4	1.419
RCE_3	1.753	IO_1	1.590
RCE_9	1.498	IO_3	1.478
RCE_18	1.643		

Note: The most representative items are reported; all VIFs in the model were < 3.3. HCE = Human Capital Efficiency; SCE = Structural Capital Efficiency; RCE = Relational Capital Efficiency; IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

The estimated variance inflation values (VIF) shown in Table 3 are in the range [1.289, 1.753]. Since no value exceeds the threshold of 3.3 for PLS-SEM models, no evidence of multicollinearity among the indicators is observed. Therefore, the variances explained by the items do not present linear redundancy that compromises the estimation of the measurement model parameters.

All coefficients in Table 4 (β) estimated using the bootstrap resampling procedure have *t*-values greater than the critical points for a significance level of α = 0.05. All hypothesized structural relationships are statistically significant, and the signs of the coefficients are positive in all cases.

Table 4. Structural model analysis (PLS-SEM bootstrapping)

Relationship	β	Standard error	t-value	p value	Decision
HCE → IP	0.566	0.032	17.706	000***	Supported
HCE → IPr	0.445	0.032	13.844	<0.001	Supported
HCE → IM	0.291	0.033	8.708	<0.001	Supported
HCE → IO	0.200	0.038	5.321	<0.001	Supported
SCE → IP	0.339	0.035	9.658	<0.001	Supported
SCE → IPr	0.479	0.035	13.634	<0.001	Supported
SCE → IM	0.599	0.033	18.407	<0.001	Supported
SCE → IO	0.318	0.036	8.712	<0.001	Supported
RCE → IP	0.258	0.039	6.671	<0.001	Supported
RCE → IPr	0.319	0.035	9.021	<0.001	Supported
RCE → IM	0.290	0.032	9.084	<0.001	Supported
RCE → IO	0.537	0.033	16.170	<0.001	Supported

Note: ***P < 0.001, **P < 0.005, *P < 0.05. HCE = Human Capital Efficiency; SCE = Structural Capital Efficiency; RCE = Relational Capital Efficiency; IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

The coefficients range from 0.200 (HCE → IO) to 0.599 (SCE → IM), reflecting differences in relationship strength across the structural paths.

Table 5. Coefficients of determination of innovation dimensions

Dependent construct	R2	R2 adjusted
IP	0.472	0.467
IPr	0.505	0.501
IM	0.516	0.513
IO	0.441	0.437

Note: IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

The coefficients of determination in Table 5 show that the model explains a substantial proportion of variance in the innovation dimensions. The R^2 and adjusted R^2 values are closely aligned, indicating consistency in the explanatory performance of the model.

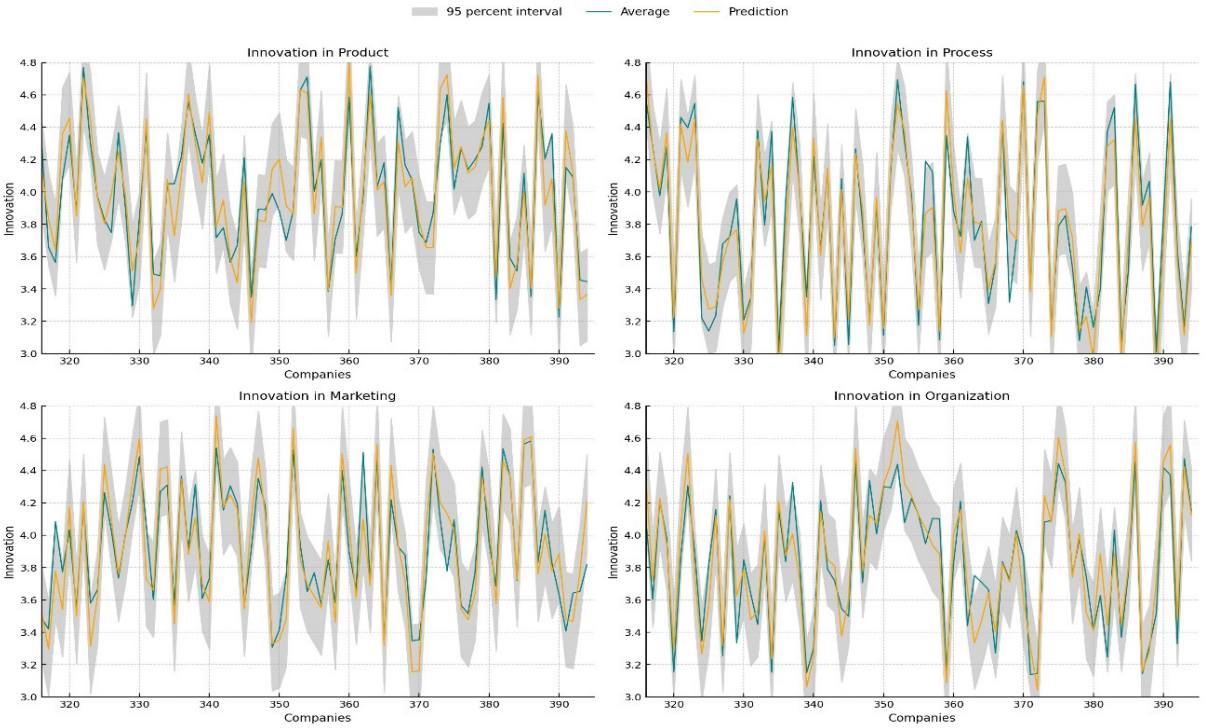
To validate the predictive capacity of the model, a holdout segmentation approach was applied, using 80% of the data for model training. This stage assesses whether the structural relationships remain stable in an independent subsample. The procedure was carried out using the partial least squares technique (PLS-SEM), retaining the same measurement and structural model specification.

Table 6. Structural coefficients of the training model

Relationship	β Coefficient	R^2	Adjusted R^2
HCE → IP	0.590		
HCE → IP	0.311	0.469	0.464
HCE → IP	0.229		
HCE → IPr	0.460		
SCE → IPr	0.473	0.522	0.517
RCE → IPr	0.329		
HCE → IM	0.295		
SCE → IM	0.586	0.496	0.491
RCE → IM	0.280		
HCE → IO	0.199		
SCE → IO	0.294	0.443	0.437
RCE → IO	0.551		

Note: Estimate using 80% of the data (n = 316). HCE = Human Capital Efficiency; SCE = Structural Capital Efficiency; RCE = Relational Capital Efficiency; IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

The structural coefficients estimated in the training model in Table 6 show high agreement with those of the complete model. The direction and



Note: The prediction is based on 20% of the sample (79 small and medium-sized enterprises), corresponding to cases numbered 316 to 395.

Figure 1. Actual and predicted values of innovation constructs using the prediction model

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magnitude of the coefficients remain comparable across estimations, indicating stability of the structural relationships.

The predictive capability of the model is evaluated using the remaining 20% of the sample (n = 79). The predicted values for each dimension of innovation were compared with the observed values. The comparison includes 95% confidence intervals. Figure 1 shows the degree of agreement between actual values and predicted values for the four dimensions of business innovation. This visual correspondence validates the predictive accuracy of the model, reinforced by the 95% confidence intervals. Overall, the results show that the dimensions of intellectual capital are robust predictors of innovative performance in small and medium-sized enterprises.

Table 7. Predicting business innovation

Company	IP	IPr	IM	IO	Company	IP	IPr	IM	IO
316	4.1	3.7	4.2	4.7	356	4.4	4.0	4.1	4.0
317	4.0	4.1	3.8	4.1	357	4.2	3.7	4.1	4.5
318	4.3	3.8	4.3	4.3	358	4.0	4.1	4.0	4.2
319	4.7	4.2	4.0	4.2	359	4.1	4.2	3.6	3.8
320	4.0	4.3	4.2	5.0	360	3.5	4.4	4.2	4.1
321	3.9	3.8	4.1	4.5	361	3.9	4.5	4.5	4.3
322	4.5	4.4	3.7	4.1	362	4.2	3.5	4.0	3.7
323	4.4	4.0	4.7	3.9	363	4.3	3.9	4.0	4.4
324	4.0	4.2	3.8	3.9	364	4.1	4.0	4.2	3.9
325	4.2	4.5	3.6	4.3	365	3.6	4.1	3.8	4.4
326	4.0	3.9	4.5	3.9	366	4.1	4.2	4.2	4.1
327	4.0	4.0	4.2	3.8	367	3.8	5.0	4.1	3.6
328	4.3	3.8	4.2	3.9	368	3.9	4.1	4.0	3.8
329	3.5	3.6	4.3	3.6	369	4.2	4.3	3.8	4.1
330	3.5	4.1	4.1	4.6	370	4.5	4.2	4.0	4.1
331	3.9	4.3	3.9	4.2	371	4.3	4.1	4.2	3.7
332	3.6	4.2	4.0	4.1	372	4.0	4.0	4.6	4.5
333	4.2	4.1	3.7	4.6	373	3.9	4.3	4.2	3.7
334	3.9	4.0	4.5	4.3	374	4.2	3.7	4.7	4.1
335	3.7	4.6	4.0	3.9	375	4.5	4.0	3.8	3.8
336	4.5	3.8	3.7	4.6	376	3.8	3.9	4.2	3.8
337	3.9	4.9	4.1	4.4	377	4.1	4.1	4.1	4.4
338	4.1	4.3	4.2	3.6	378	3.9	4.8	4.6	3.9
339	3.6	3.7	4.0	4.1	379	3.6	3.4	3.8	4.0
340	3.9	3.7	3.8	4.0	380	4.4	4.1	3.7	4.5
341	4.1	3.8	4.3	3.6	381	4.5	3.6	4.1	4.0
342	3.8	3.8	4.3	4.5	382	4.2	3.9	3.4	4.4
343	4.4	4.2	3.9	4.8	383	4.3	4.3	3.8	3.7
344	3.9	4.0	4.0	3.7	384	4.1	4.0	3.8	4.4
345	4.0	4.1	4.2	4.4	385	4.0	3.8	4.1	4.8
346	3.9	3.6	3.8	4.2	386	4.2	3.7	4.1	3.5
347	4.5	3.5	3.5	4.0	387	4.6	4.3	4.7	4.1
348	4.1	3.9	3.9	4.0	388	4.1	3.8	4.4	4.3
349	3.8	4.4	4.1	3.8	389	4.5	4.0	3.8	4.0
350	4.6	3.9	4.0	4.1	390	3.3	4.1	3.7	4.2
351	3.7	3.7	4.4	4.0	391	4.4	3.9	4.2	4.0
352	4.2	4.1	4.1	4.1	392	4.1	4.7	3.4	4.3
353	3.5	4.0	4.0	4.1	393	4.2	4.3	4.4	3.9
354	3.6	3.8	4.1	4.0	394	4.2	3.4	4.5	4.7
355	4.3	4.1	3.9	3.9					

Note: The values correspond to predictions generated by the PLS-SEM model trained with 80/20 of the sample. IP = Product Innovation; IPr = Process Innovation; IM = Marketing Innovation; IO = Organizational Innovation.

To evaluate the accuracy of the model in the validation set (20% of the sample, $n = 79$), error metrics were estimated for the four dependent constructs. For product innovation (PI), the mean absolute error (MAE) was 0.16 and the root mean square error (RMSE) was 0.20. Process innovation (PPr) showed MAE = 0.18 and RMSE = 0.22. For marketing innovation (MI), MAE = 0.17 and RMSE = 0.21 were obtained, while organizational innovation (IO) yielded MAE = 0.18 and RMSE = 0.23. All metrics were calculated using standardized Likert-scale values.

4. DISCUSSION

The general hypothesis of this study proposed that robust intellectual capital (articulated through knowledge management practices and continuous improvement processes) significantly enhances the innovative capacity of SMEs. The empirical results support this proposition, showing that human, structural, and relational capital exert positive and statistically significant effects on the four dimensions of business innovation. This overall finding is consistent with T. Do and N. Do (2024), who conceptualize intellectual capital as a catalyst for organizational innovation, particularly in emerging economies where intangible resources compensate for structural constraints.

Among the relationships analyzed, the strongest effect corresponds to structural capital and marketing innovation (SCE → MI). This result suggests that formal organizational structures, information systems, and standardized procedures constitute critical enablers for the development of innovative marketing strategies. Similar evidence has been reported by Chu et al. (2006), who argue that codified and formalized knowledge allows innovation processes to be systematized. Likewise, Bangun et al. (2024) and Rodrigues et al. (2022) emphasize that solid organizational infrastructures increase firms' ability to adapt marketing practices to customer demands and environmental conditions. These findings reinforce the view that structural capital, due to its institutionalized nature, represents a stable and replicable source of competitive advantage (Al-Dhobee et al., 2025; Sakuma & Furutani, 2024).

Human capital also exhibits a strong influence on product and service innovation, indicating that technical skills, accumulated experience, and creative capabilities of employees are decisive for the generation of new offerings. This relationship has been widely documented in previous research. Ekayani et al. (2023) and Wang et al. (2014) demonstrate that staff training, motivation, and learning capacity directly foster technological and product innovation. In the Ecuadorian SME context, this result suggests that investment in human capital becomes a critical pathway for improving product competitiveness in markets characterized by limited resources and high uncertainty (Gutiérrez Ponce et al., 2024).

Relational capital shows its strongest impact on organizational innovation, highlighting the relevance of external networks, strategic alliances, and institutional relationships in driving internal organizational change. Han and Li (2015) argue that external ties not only provide legitimacy but also function as channels for knowledge transfer and co-creation. In Ecuador, where SMEs often face financial and institutional constraints, collaboration with suppliers, customers, and public entities becomes essential for accessing complementary resources and facilitating organizational transformation (Rustiarini et al., 2023; Saltos et al., 2017).

From a theoretical standpoint, these findings align with the Resource-Based and Capabilities Theory (Barney et al., 2001) and the Knowledge-Based View (Grant, 2001), which posit that intangible resources generate sustainable advantages when they are valuable, scarce, and difficult to imitate. Agostini and Nosella (2017) and Mousavi Shiri and Salehi (2025) further demonstrate that it is the synergistic interaction of human, structural, and relational capital that enables SMEs to achieve superior innovative performance.

The results also indicate that both structural and human capital significantly influence process innovation, supporting the idea that formal organizational arrangements and technical competencies facilitate the adoption of new production methods and operational schemes. This interpretation is consistent with Edeh et al. (2025) who views organizations as information-processing

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systems whose effectiveness depends on their cognitive infrastructure. Similarly, Chen and Huang (2009) and Sung and Choi (2018) highlight the role of knowledge management and organizational learning in fostering incremental innovation, particularly in resource-constrained environments.

In the Ecuadorian context (where semi-manual production systems prevail, and R&D investment remains limited (Cobos-Salvador & Armijos-Yambay, 2020)), the structuring role of organizational capital becomes particularly relevant. Rodrigues et al. (2022) and Sucena et al. (2024) show that formalized procedures, functional databases, and a culture of continuous improvement enhance firms' readiness to adopt technological practices. This, in turn, allows manufacturing SMEs to improve productivity and adaptability in volatile environments (Le et al., 2025).

The influence of human capital on process innovation further corroborates the findings of Ekayani et al. (2023), who identify skilled and adaptable employees as key agents of operational transformation. Abredu et al. (2023) add that human capital does not always translate directly into economic outcomes but becomes effective through the activation of technological and innovative capabilities. Consequently, coordination between people and processes emerges as a critical mechanism for overcoming technical barriers and enhancing efficiency.

Moderate but significant effects were also observed for the relationships between structural capital and product innovation, as well as between human capital and marketing innovation. These results support the notion that internal structures and individual competencies generate complementary effects across different innovation dimensions. Ting et al. (2020) and Yitmen (2011) emphasize that structured information flows and documented processes facilitate product development, while Achmad and Wiratmadja (2025) highlight the role of organizational foundations in scaling product-oriented innovation.

The effect of human capital on marketing innovation aligns with Becker's (1964) human capital theory and the dynamic capabilities perspective, suggesting that individual competencies enable firms to adjust marketing strategies to environmental demands. Appiah et al. (2025) and Zhao et al. (2025) argue that innovative marketing requires not only access to market information but also personnel with analytical, communicative, and creative skills.

Relational capital also contributes positively to process and marketing innovation, underscoring the importance of inter-organizational cooperation. Chowdhury et al. (2019) and Han and Li (2015) note that relationships with suppliers, customers, and institutional actors facilitate access to external knowledge, accelerate decision-making, and support strategic adaptation.

Overall, the combination of these effects suggests that innovation in SMEs does not depend on a single form of capital but rather on the continuous interaction among its components. As emphasized by Agostini and Nosella (2017), innovative performance is enhanced when intellectual capital dimensions operate in an integrated manner, particularly when efficient internal structures are combined with strategic external linkages.

These findings are consistent with Oliveira et al. (2020), who demonstrate that intellectual capital influences innovation directly and indirectly through absorptive capacity, as well as with Khalique et al. (2018), who identify human and structural capital as key predictors of innovative performance. Handzic et al. (2016) further highlight that relational and structural capital facilitate knowledge circulation and cross-functional collaboration, strengthening firms' dynamic capabilities. Similarly, McDowell et al. (2018) emphasizes the role of organizational learning and trust in knowledge management in fostering radical innovation, particularly in manufacturing contexts.

Finally, Javed et al. (2023) reinforce the importance of a comprehensive knowledge management approach, showing that the combination of strong external networks and efficient internal structures is essential for translating intangible assets into sustainable innovative outcomes. This evidence supports and enriches the results of the present study, contributing to a robust conceptual framework for understanding the link between intellectual capital and innovation in Latin American SMEs.

CONCLUSION

The purpose of this study was to evaluate the predictive effect of human, structural, and relational capital on different dimensions of business innovation in Ecuadorian small and medium-sized enterprises, using a structural equation modeling approach. The analysis focused on identifying how intangible organizational resources contribute to innovation outcomes in a context characterized by resource constraints and structural limitations.

The results show that all three dimensions of intellectual capital exert positive and statistically significant effects on product, process, marketing, and organizational innovation. Structural and relational capital exhibit stronger effects on organizational and marketing innovation, while human capital shows a greater influence on product and process innovation. These findings indicate that innovation in Ecuadorian SMEs is driven by the complementary interaction between internal organizational structures, human capabilities, and external relational networks.

Based on these results, effective management of intellectual capital constitutes a key mechanism for strengthening innovative performance and adaptive capacity in SMEs. The evidence supports the idea that intangible assets function as strategic resources that enable firms to respond to competitive pressures and market dynamics, particularly in emerging economies where access to tangible resources is limited.

Despite the contributions of this study, certain limitations must be acknowledged. The use of cross-sectional data restricts causal inference, and the focus on specific sectors and regions may limit the generalizability of the findings. Future research should adopt longitudinal designs, expand the geographical and sectoral scope, and incorporate mediating or moderating variables to further explore the mechanisms through which intellectual capital influences innovation. Replicating the model in other Latin American contexts or in sectors with different levels of technological intensity would also strengthen its external validity.

AUTHOR CONTRIBUTIONS

Conceptualization: Myriam Naranjo-Vaca, Esteban David López-Manobanda.
Data curation: Myriam Naranjo-Vaca, Esteban David López-Manobanda.
Formal analysis: Myriam Naranjo-Vaca, Esteban David López-Manobanda.
Funding acquisition: Myriam Naranjo-Vaca, Esteban David López-Manobanda.
Investigation: Miriam Salas-Salazar.
Methodology: Miriam Salas-Salazar.
Project administration: Miriam Salas-Salazar.
Resources: Miriam Salas-Salazar.
Software: Marco Gavilanes-Sagñay.
Supervision: Marco Gavilanes-Sagñay.
Validation: Marco Gavilanes-Sagñay.
Visualization: Marco Gavilanes-Sagñay.
Writing – original draft: Myriam Naranjo-Vaca, Miriam Salas-Salazar, Marco Gavilanes-Sagñay, Esteban David López-Manobanda.
Writing – review & editing: Myriam Naranjo-Vaca, Miriam Salas-Salazar, Marco Gavilanes-Sagñay, Esteban David López-Manobanda.

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