SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 7542-7560
Open Access. Online & Print

DOI: 10.5281/zenodo.122126582

DETERMINANTS OF PRODUCT INNOVATION IN COLOMBIAN INDUSTRIAL COMPANIES

Albeiro Beltrán-Díaz[1]*, Isabel Cristina Rincón Rodríguez[2], Silvia Paola Gallardo-Figueroa[3], Javier Francisco Rueda-Galvis[4], Youseline Garavito-Hernández[5], Jorge E. Chaparro Medina[6]

[1,2,3,4,5] University of Research and Development UDI, Colombia.
[6] Unified National Corporation of Higher Education CUN, Colombia.

Received: 01/12/2025
Accepted: 02/01/2026

Corresponding author: Albeiro Beltrán-Díaz (abeltran2@udi.edu.co)

ABSTRACT

The present research analyses the determinants of product innovation in Colombian industrial firms, integrating a variety of theories and approaches on innovation to identify how internal and external factors affect their innovation capacity. A systemic approach is employed, combining Resource-Based View (RBV), Institutional Perspective, Resource Dependency Theory, Open Innovation, Innovation Systems, and Knowledge-Based Economy. Findings reveal that investment in R&D, favourable institutional conditions, and collaboration with external factors such as universities and research centers are crucial for fostering innovation. Additionally, it is highlighted that adopting open innovation practices accelerates the development of new products, although an excessive reliance on technological development centers may limit idea diversity. Continuous staff training and a favourable regulatory environment are also essential for maintaining a competitive advantage. The research, based on data from the Colombian Survey of Technological Development and Innovation (EDIT) and employing advanced statistical techniques, provides a solid foundation for understanding innovation dynamics in the Colombian context. The originality and value of this study lie in its integrative approach and analysis of a specific context that has been underexplored in existing literature.

KEYWORDS: Bussiness Administration, Latin America, Management of technological Innovation and R&D, Open Innovation

1. INTRODUCTION

Colombia, with its diverse business fabric, stands as a country capable of developing a wide range of industries, reflecting its varied geographical and social context. The Colombian economy is distinguished by key sectors such as agriculture, mining, manufacturing, and services, with notable expansion in technology and innovation in recent years (Zuñiga-Collazos, 2025). In particular, the manufacturing industry has been a fundamental pillar, encompassing textiles and apparel, as well as food, chemical, and pharmaceutical products. This diversified industrial environment has allowed the country not only to meet domestic demands but also to increase its presence in international markets through exports (Pulido-López & López-Salazar, 2025). Among the most prominent industries are coffee, flowers, coal, and oil production, which stand out for their significant contribution to the national GDP and their international recognition. The coffee industry, in particular, is globally renowned, positioning the country as one of the leading producers and exporters of this commodity (Quintero & Zúñiga, 2025). Additionally, the technology and information sector has experienced remarkable growth, driven by the adoption of new technologies, contributing to economic development and the strengthening of the Colombian business sector (Pineda & Urrego, 2025).

However, the Colombian industry faces multiple challenges that hinder its full development and competitiveness in the global arena (Melo et al., 2024). Issues such as insufficient infrastructure, limited access to financing, political and social instability, and gaps in education and technical training constrain growth opportunities and operational efficiency. The reliance on traditional sectors and vulnerability to fluctuations in international commodity prices also pose significant risks to the country's economic stability (Fajardo et al., 2024). Thus, key determinants of innovation in Colombia, such as strengthening the educational system—particularly in science, technology, engineering, and mathematics (STEM)—promoting investment in research and development (R&D) from both the public and private sectors, and implementing government policies that support innovation and entrepreneurship, have become topics of general interest. Additionally, collaboration between universities, research centres, and industry is crucial to fostering knowledge transfer and the commercialisation of innovations. The adoption of a favourable regulatory framework and the encouragement of foreign direct investment can facilitate access to new technologies and global best practices, thereby enhancing industrial development and innovation in Colombia.

In the academic sphere, the determinants of innovation in firms have been extensively studied under various theoretical frameworks, with the Resource-Based View (RBV) standing out as a prominent perspective (Quintero- Sepúlveda et al., 2024). This perspective posits that a firm's innovative capability is grounded in the possession of unique and valuable resources, as well as its ability to effectively orchestrate these resources. Studies adopting this approach have concluded that innovation results from the dynamic interaction between specific internal capabilities, such as research and development (R&D) capacity, technological competencies, and organisational culture, alongside external factors such as regulations, markets, and collaboration with academic institutions and other firms (Quintero & Zúñiga, 2025). Beyond the Resource-Based View (RBV), academic literature has explored the determinants of innovation from various perspectives, such as the institutional perspective, which considers the impact of the regulatory environment and policies on business innovation. Similarly, the Resource Dependency Theory emphasises the importance of access to critical external resources. Open Innovation suggests leveraging both internal and external knowledge flows to drive innovation. The Innovation Systems Theory advocates for the interaction among various actors within the system to foster innovation (Melo et al., 2024). Lastly, the Knowledge-Based Economy highlights knowledge, information, and continuous learning as pillars of innovation (Pulido-López & López-Salazar, 2025). These perspectives provide a diversified outlook on how firms can enhance their capacity to innovate in a complex and ever-changing business environment.

The perspectives described above are integrated synergistically under the systemic approach, which advocates for a holistic understanding of the determinants of innovation in firms (Pertuz & Ojeda, 2023). This approach recognises that innovation is not the result of isolated factors but rather the dynamic interaction between internal resources, institutional factors, shared knowledge, and strategic collaborations. It is precisely the objective of this research to analyse, from a systemic perspective, the key historical determinants of product innovation in Colombian industrial firms for organisational decision-making. This analysis allows for the identification of how the interaction between different elements and actors within the innovation system influences the development of new products, thereby facilitating more effective and adaptive

strategies. Furthermore, it enriches the understanding of innovation mechanisms at the national level and provides valuable insights into how firms can navigate and leverage their innovation ecosystem to achieve excellence in new product development. This document is structured into five main sections: first, the theoretical foundations are presented; second, the methodology employed is outlined; third, the research findings are discussed; fourth, the implications and discussions are addressed; and finally, the main conclusions of the study are presented.

2 THEORETICAL BACKGROUND

2.1. Innovation from the Resource-Based View (RBV)

Studies based on the Resource-Based View (RBV) have explored how firms can develop, maintain, and apply their unique resources and capabilities to achieve sustainable competitive advantage (Quintero & Zúñiga, 2025). It has been acknowledged that, in a globalised and rapidly changing environment, the RBV alone cannot explain why firms with similar resources achieve different outcomes (Quintero- Sepúlveda et al., 2024). This has led to the integration of dynamic capabilities theory as an extension of the RBV, emphasising the importance of renewing competencies to adapt to changing environments.

This theoretical approach suggests that dynamic capabilities, which include the ability to explore, exploit, and maintain or reconfigure resources, are crucial for organisations to achieve superior long-term performance (Pineda & Urrego, 2025; Garzón, 2015). It highlights the need to develop skills to perceive and shape opportunities and threats, seize these opportunities, and maintain competitiveness through constant innovation (Quintero- Sepúlveda et al., 2024).

The determinants of innovation within the RBV framework, adapted to the Colombian industrial context, include the effective management of internal resources and capabilities, organisational adaptability and flexibility, and the ability of firms to integrate new knowledge and technologies. The continuous renewal of competencies and investment in dynamic capabilities emerge as key strategies for maintaining competitive advantage in volatile and globalised markets (Fajardo et al., 2024).

Given the above, it can be argued that the determinants of innovation in the Colombian manufacturing industrial sector are significantly influenced by firms' ability to manage internal resources and capabilities, operate within a favourable institutional framework, access critical external resources through collaborative networks, and adopt open innovation practices. These interactions are modulated by the specific context of Colombia's knowledge-based economy. Based on this understanding, it is proposed that:

H1: Industrial firms in Colombia achieve product innovations depending on their internal resources and capabilities.

This proposition allows for the examination of the direct relationship between an organisation's internal assets and its success in developing new product offerings, in line with the Resource-Based View (RBV). The RBV posits that a firm's competitive advantages and innovation depend on how it manages its unique resources and capabilities.

2.2. Impact of the Environment on Business Innovation

The influence of the institutional environment on business innovation is manifested through the regulatory framework established by norms, policies, and legal systems, which define the conditions under which firms can carry out innovative activities (Zuñiga-Collazos et al., 2023; Acemoglu & Robinson, 2012; Streeck, 2014). This framework outlines the opportunities and constraints for investment in new developments, underscoring the importance of a regulatory system that is clear, efficient, and conducive to innovation (Zuñiga-Collazos, 2025). Intellectual property protection, market regulations that promote competition, and government support for research and development are key examples of policies that can stimulate innovative activity within the business sector (Pertuz & Ojeda, 2023; Acemoglu & Robinson, 2012; Streeck, 2014). These elements are fundamental to fostering an environment that incentivises the creation and adoption of innovations.

In the Colombian context, firms' ability to adapt to the institutional environment is crucial. Participation in the development of public policies and the formulation of innovation strategies that consider the specific institutional context enables firms to navigate the regulatory landscape and seize the opportunities it offers. Adaptability and the ability to forge alliances with research institutions and other strategic partners are important factors that can facilitate innovation within a challenging institutional framework (Costamagna et al., 2022).

The political situation and regulatory changes in Colombia present both challenges and opportunities for business innovation. Recent progress towards creating a more innovation-friendly environment must balance the challenges associated with political uncertainty, inadequate infrastructure, and limited investment in R&D (Pertuz & Ojeda, 2023). However, opportunities arising from a growing domestic market, an expanding middle class, and a strategic

position in Latin America offer significant potential for the development of innovations that address local and regional needs. This underscores the importance of a coordinated approach to improving the institutional and regulatory environment in favour of innovation (Costamagna et al., 2022).

Thus, the second hypothesis of this research proposes that the ability of industrial firms in Colombia to achieve product innovations depends significantly on their institutional conditions, including the regulatory framework, innovation support policies, and the quality of the institutions with which they interact (Cuevas-Vargas et al., 2022). This approach highlights the importance of the institutional environment in fostering or limiting business innovation.

H2: Industrial firms in Colombia achieve product innovations depending on their institutional conditions.

2.3. Resource Dependency Theory

Another approach to studying innovation in industrial firms is provided by the Resource Dependency Theory, which is crucial for understanding the dynamics of innovation in the Colombian context, particularly in how industrial firms access and manage critical external resources. In Colombia, critical resources for firms may include advanced technology, financial capital, specialised human talent, and technical knowledge. Key relationships for accessing these resources are often established with universities, research institutions, investors, and through business networks and industrial clusters (Zuñiga-Collazos et al., 2023). Authors have suggested that firms strengthen these relationships through strategic collaborations, participation in joint research projects, and leveraging government incentives for innovation and technological development (Cuevas-Vargas et al., 2022; Agarwal et al., 2019; Dagnino et al., 2015). These strategies can facilitate access to the resources needed to drive innovation and enhance competitiveness in the global market (Cerquera-Losada & Rojas-Velásquez, 2020; Gracia & Misas, 2021; Tarapuez et al., 2016).

The third hypothesis of this research suggests that the ability of industrial firms in Colombia to generate product innovations is influenced by their access to and use of external resources, such as collaborations with other firms, universities, and research centres. This reflects the importance of collaborative networks and knowledge exchange beyond organisational boundaries to enrich the innovation process.

H3: Industrial firms in Colombia achieve product innovations depending on their external resources.

2.4. Open Innovation

The theory of open innovation posits that firms should leverage both internal and external knowledge to drive innovation (Melo et al., 2024). In this sense, it is crucial for a wide range of information to flow within the firm, including market data, technological trends, customer feedback, and scientific knowledge (Fajardo et al., 2024; Von, 2010). Industrial firms, in turn, must integrate these knowledge flows with their R&D capabilities to generate innovative products and processes (Leenders & Dolfsma, 2016). Collaboration with universities, research centres, other firms, and startups is key to accessing new knowledge and accelerating innovation (Vélez-Rolón et al., 2020).

To expand open innovation in Colombia, barriers such as a lack of trust and understanding between the public and private sectors, an inadequate regulatory framework, and the absence of incentives must be overcome (Arango-Alzate et al., 2015). These challenges, along with limited funding, restricted access to venture capital, a lack of specialised financial instruments for innovation, and a risk-averse culture, hinder the adoption of innovative practices (Arango-Alzate et al., 2015; Restrepo-Morales et al., 2019). These factors impede effective collaboration and investment in innovative projects, favouring continued investment in traditional sectors. However, the adoption of open innovation practices in technological and agro-industrial sectors in Colombia highlights the potential to overcome these obstacles and foster economic growth (Omonijo & Zhang, 2025).

To achieve success in open innovation, it is crucial to strengthen intersectoral cooperation through the creation of collaborative platforms, the development of joint programmes that foster synergy among diverse actors, and the implementation of appropriate public policies to improve this cooperation framework (Fuenmayor & Polo, 2015). Additionally, expanding access to financing is essential, which can be achieved through the creation of specialised investment funds, the development of innovative financial instruments such as crowdfunding, and the provision of tax incentives for firms investing in innovation. These measures can significantly catalyse the innovation process, creating a more dynamic and productive ecosystem (Fajardo et al., 2024).

Considering the above, the fourth hypothesis of this research states that the ability of industrial firms in Colombia to achieve product innovations is influenced by their open innovation dynamics. This implies that success in innovation depends not only on internal resources and capabilities but also on how

firms interact and cooperate with external agents, integrating external knowledge and sharing resources in the innovation process.

H4: Industrial firms in Colombia achieve product innovations depending on their open innovation dynamics.

2.5. Innovation Systems

To analyse industrial firms from the perspective of innovation systems theory, it is crucial to understand how the interaction between different actors (firms, universities, government) drives innovation. Previous studies highlight the importance of collaboration networks, knowledge transfer, and innovation support policies (Pineda & Urrego, 2025; Edquist, 2011; Lundvall, 2016). In Colombia, several important collaboration networks can be cited within the context of innovation systems theory. These include government-led initiatives such as Minciencias programmes, which promote research and development; university-industry-government networks that facilitate knowledge and technology transfer; and industrial clusters in key sectors such as coffee, flowers, and technology, which foster cooperation between small and large firms to drive innovation. These networks are crucial for the innovation ecosystem in Colombia (Garavito et al., 2018; González, 2018; Mauricio, 2019; Parra et al., 2016; Saltos et al., 2018).

To effectively integrate into innovation systems, Colombian firms can focus on developing strategic alliances with universities and research centres (Chesbrough et al., 2006; Dagnino et al., 2015). For example, in Colombia, they can participate in co-financing programmes for R&D projects offered by Minciencias and engage in specific industrial clusters. These actions facilitate access to new knowledge and technologies, expand networks, and enhance innovative capabilities through collaboration and the exchange of experiences (Villa & Melo, 2015). In Colombia, it is also important to consider local particularities, such as the economic structure and the country's specific challenges, to design effective innovation systems for the industrial sector (Lora, 2019).

Colombia's economic structure is characterised by diversification across sectors such as agriculture, manufacturing, and services, with a growing emphasis on technology and innovation. In the context of innovation systems, this structure implies the need to design strategies that align with the strengths and opportunities of each sector, promoting specialisation and technological development (Saltos et al., 2018; Villa & Melo, 2015). Specific challenges include overcoming gaps in education and talent development, providing adequate infrastructure for innovation, and establishing a regulatory framework that supports investment in R&D (Omonijo & Zhang, 2025).

Thus, it is proposed that industrial firms in Colombia achieve product innovations based on the effectiveness of their innovation systems, which encompass the coordinated interaction between firms, universities, government, and other key actors. This approach highlights how the structure and dynamics of the innovation system, including support policies and collaboration networks, facilitate or limit the innovative capacity of firms within a specific environment.

H5: Industrial firms in Colombia achieve product innovations depending on their innovation systems.

2.6. The Knowledge-Based Economy

From the perspective of the knowledge-based economy, the central tenets emphasise that knowledge and learning are crucial resources that drive innovation and competitiveness in firms (Fajardo et al., 2024). To delve deeper into the knowledge-based economy and its impact on Colombian industrial firms, it is essential to understand that this approach positions knowledge as the primary driver of economic growth, innovation, and competitiveness. Firms that invest in the creation, acquisition, and application of knowledge through continuous training, research and development, and technological innovation tend to be more competitive and adaptable to market changes.

In Colombia, organisational learning and the development of employee capabilities are key aspects that require attention to strengthen the industrial fabric (Chaparro-Banegas et al., 2023; Valencia-Rodríguez, 2015). This involves not only investments in education and technical training but also the creation of ecosystems that foster collaboration between universities, the private sector, and the government (Barrios-Hernández & Olivero-Vega, 2020). The adaptation of these practices can overcome barriers such as limited knowledge transfers and skill gaps, thereby driving innovation and industrial development (Marulanda et al., 2019).

Finally, a sixth hypothesis is proposed in this research, suggesting that industrial firms in Colombia achieve product innovations depending on their focus on knowledge, information, and continuous learning. This implies that success in innovation is strongly influenced by organisations' ability to acquire, integrate, and apply new knowledge effectively, highlighting the importance of a culture of constant learning and adaptability to change.

H6: Industrial firms in Colombia achieve product innovations depending on their knowledge, information, and continuous learning.

Table 1 presents the main postulates of the various theories analysed regarding the determinants of innovation in firms.

Table 1: Main determinants of innovation in firms from various management theories.

Theory	Key Postulates	**Autores**
Resource-Based View (RBV)	Posits that a firm's innovative capability is grounded in the possession of unique and valuable resources and its ability to effectively orchestrate them.	(Dnaz-Delgado et al., 2018; Pradana et al., 2020)
Institutional Perspective	Examines how the institutional and regulatory environment affects firms' innovation capacity, focusing on norms, policies, and legal systems.	(Cheah & Ho, 2020; Fuentelsaz et al., 2018; Mukherjee et al., 2017; Sampedro-Hernández & Ojeda, 2018; Sharma et al., 2022)
Resource Dependency Theory	Focuses on how firms access critical external resources through their environment and relationships with other actors.	(Drees & Heugens, 2013; Klein & Pereira, 2016; Sánchez & Rotundo, 2018; Wang & Liu, 2021)
Open Innovation	Proposes that firms can and should leverage both external and internal knowledge flows to accelerate innovation.	(Omonijo & Zhang, 2025; Cheah & Ho, 2020; Fuenmayor & Polo, 2015)
Innovation Systems Theory	Emphasises the importance of interaction among various actors in the system (firms, universities, government) for the innovation process.	(Castellacci & Natera, 2013; Radosevic & Yoruk, 2013)
Knowledge-Based Economy	Highlights the role of knowledge, information, and continuous learning as key determinants of innovation in the modern era.	(Veselá & Klimová, 2014)

Source: Project Authors

2.7. Innovation from a Systemic Perspective

Integrating the aforementioned theories through a systemic approach involves viewing innovation as a complex process involving multiple factors and actors. This approach considers internal resources and capabilities (RBV), institutional conditions, dependency on external resources, open innovation dynamics, innovation systems, and knowledge as interdependent. In practice, this means that firms must manage these elements holistically, fostering collaboration among all actors in the innovation ecosystem, adapting to regulatory frameworks, and leveraging both internal and external resources to drive innovation, as shown in Figure 1.

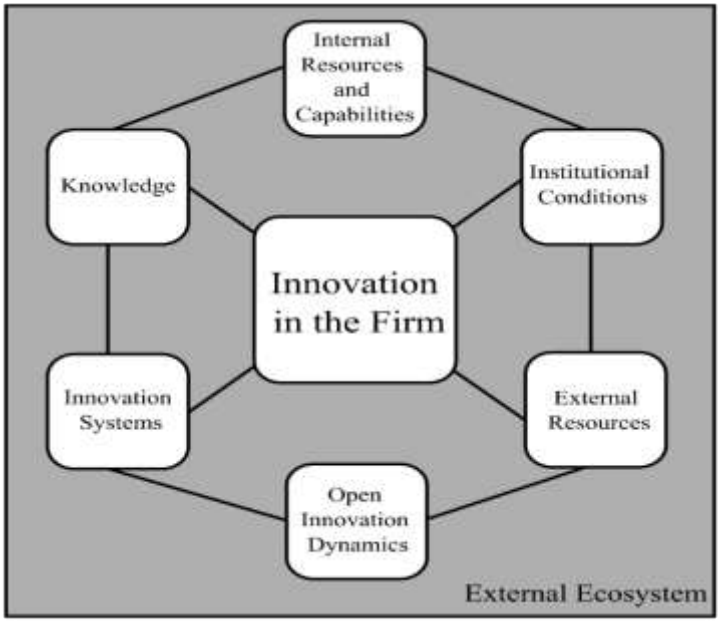

Figure 1: Innovation ecosystem in firms from a systemic perspective.
Source: Project Authors

Integrating all these theories through a systemic approach involves recognising how each contributes to understanding different aspects of innovation and business competitiveness. This approach views firms as open systems that dynamically interact with their environment, leveraging internal and external resources, adapting to regulations, and fostering collaboration among various actors. Thus, it emphasises the importance of knowledge management, adaptability, and collaboration as key drivers of innovation and sustainable development. To address this task, a quantitative study on innovation in the Colombian industrial sector will be conducted, characterising the firms included in the

EDIT industrial survey. This involves analysing specific variables that describe their profiles, capabilities, and operational environments. Subsequently, the main historical determinants of innovation in the manufacturing industry will be identified using inferential statistical models. This approach allows for the examination of relationships between various variables and their impact on innovative capacity, providing valuable insights for developing strategies focused on enhancing innovation, particularly in product innovation.

3. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

3.1. Data Source

This research is based on data obtained from the Survey of Technological Development and Innovation (EDIT) for the Colombian industrial sector for the period 2019-2020. This survey is administered by the National Administrative Department of Statistics (DANE) and is conducted biennially, collecting information on 729 variables from industrial firms located across the country. For this study, N=1978 manufacturing firms were selected, following a non-probabilistic convenience sampling method due to data availability in the survey (Hernández et al., 2014).

3.2. Study Variables

Proxy variables included in the survey were used to represent the constructs of interest, as detailed in Annex 1. The dimensions analysed include product innovation, resources and capabilities, and control variables related to investment in scientific, technological, and innovation activities (ACTI).

3.3. Analysis Techniques

To analyse the data, several advanced statistical techniques were employed: (1) Correlational Analysis: Spearman's correlation was used due to the non-linear nature of the data, allowing for the identification of significant relationships between independent and dependent variables. (2) Principal Component Analysis (PCA) to reduce the dimensionality of the independent variables and avoid multicollinearity issues. Principal components were selected based on eigenvalues greater than 1 and explained variance, following the criteria of Chen et al. (2025). (3) Random Effects Logit Regression Models for each hypothesis, given that the dependent variable is binary. These models were estimated using the statistical software Stata. Specific commands were included for stepwise variable selection with defined significance levels (pr(0.1) and pe(0.05)). (4) Model Validation was conducted using a confusion matrix to calculate the percentage of correct predictions, evaluating sensitivity, specificity, and correct classification rates. Additionally, the area under the ROC curve was calculated for each model, ensuring an acceptable level of data discrimination (Vizcaíno-Salazar, 2017).

3.4. Procedure

The analysis began with the characterisation of the firms included in the survey, describing their profiles, capabilities, and operational environments. Subsequently, the main historical determinants of innovation in the manufacturing industry were identified using inferential statistical models. This approach allowed for the examination of relationships between various variables and their impact on innovative capacity, providing valuable insights for developing strategies focused on enhancing innovation, particularly in products. The use of a combination of correlational analysis, PCA, and Logit regression models is justified by their ability to handle large datasets with multiple variables and to identify significant patterns and relationships that can inform firms' innovative capacity. Furthermore, these methods allow for the control of confounding variables and provide robust and reliable estimates.

4 RESULTS AND DISCUSSION

4.1. Correlational Analysis

Spearman's correlation analysis was conducted to evaluate the relationships between the independent variables and the dependent variable (Innovbys) due to the non-linear nature of the data. The results, grouped by hypothesis, are presented in the following paragraphs, highlighting significant correlations and their interpretation. For detailed calculations of this section, please refer to Annex 2.

Hypothesis 1: Internal Resources and Capabilities. The correlational analysis revealed that variables related to internal resources and capabilities showed positive and significant correlations with product innovation. Specifically, internal R&D activities (Invactid), the acquisition of machinery and equipment (Invadqmye), and investments in marketing (Invmerca) presented the highest correlations. These associations indicate that firms with greater investments in these areas tend to achieve higher levels of innovation. However, variables such as the scarcity of internal resources (Bajorecur) and the lack of qualified personnel (Falperscalif) did not show significant correlations, suggesting that other factors may play a more prominent role in the innovation process.

Hypothesis 2: Institutional Conditions. These variables showed significant negative correlations with innovation. This suggests that innovation tends to decrease when firms face greater regulatory difficulties and less effective public support instruments. Specifically, the difficulty in complying with regulations (Reguregla) and the limited capacity of the

intellectual property system (Caprointel) were particularly notable. In contrast, the variable related to compliance with technical regulations (Cumpreglam) was the only one that showed a positive correlation, indicating that firms that comply with these regulations tend to be more innovative. Given the high level of multicollinearity among the variables in this hypothesis, a principal component analysis was conducted, grouping the variables into five components. The first component has a variance of 2.59, explaining 23.5% of the total variance, and the sum of the five components explains 72.64% of the information. The components were selected based on two criteria mentioned in McCrea et al., (2024): 1) eigenvalues equal to or greater than 1, and 2) explained variance of 70% for firm-level data. For the inclusion of variables in each component, the highest positive factor loading value was considered, indicating a stronger presence of the variable in the component.

Hypothesis 3: External Resources. The analysis showed that, in general, these variables have little correlation with product innovation. However, significant positive correlations were observed with investment in public resources (Invrecpubl), private resources (Invrecprivn), and the hiring of consultants (Colsultant and Nconsext). On the other hand, the lack of information about the market (Infmercad) and technology (Inftecnol) showed significant negative correlations, indicating that the lack of information can be a significant obstacle to innovation.

Hypothesis 4: Open Innovation. Positive and significant correlations were found with product innovation, highlighting the importance of intersectoral collaboration and the integration of external knowledge. Variables such as cooperation with other firms (BYScompany), internal R&D departments (Fdepintid), and collaboration with universities (Funiversity) showed particularly high correlations, underscoring the relevance of strategic alliances and collaboration in fostering innovation.

Hypothesis 5: Innovation Systems. There is a positive and significant association between innovation systems and product innovation. The results indicate that cooperation with other firms, suppliers, customers, universities, technological development centres, technology parks, government, and non-governmental entities is crucial for generating innovations. To reduce multicollinearity among the independent variables, a principal component analysis was conducted, grouping the variables into three components that explain 47.9% of the variance.

Hypothesis 6: Knowledge, Information, and Continuous Learning. These variables showed a positive and significant association with product innovation. Most variables indicated that greater staff training and development are positively correlated with innovation. However, staff with primary education (Primaria) did not show a significant correlation, which could be explained by their limited contribution to innovative development. In contrast, those with primary education engaged in science, technology, and innovation activities (Primariacti) did show a positive and significant correlation. Similarly, staff training leading to a doctoral degree (Formdocacti) did not show a significant association, possibly because it represents a very small fraction of the staff in firms.

Through Spearman's correlational analysis, a comprehensive view was obtained of how various dimensions, from internal resources to institutional conditions and open innovation dynamics, influence the innovative capacity of Colombian industrial firms. These results highlight the importance of investment in R&D, strategic collaboration, and the regulatory environment in fostering product innovation.

4.2. Analysis of Regression Models

To validate the hypotheses proposed in this study, random effects Logit regression models were employed, given the binary nature of the dependent variable (Innovbys). The regression models included variables that showed a significant correlation with the dependent variable. Additionally, the Stata command for stepwise estimation was used, which allows for backward elimination (pr(#)) and forward inclusion (pe(#)) of variables in the model with a defined significance level, adjusting the regression model to all explanatory variables (Hidayat & Pok, 2025). For this study, a significance level of pr(.1) and pe(.05) was defined, meaning that variables with a significance level equal to or greater than 10% were eliminated, while those with a significance level of 5% were eligible for the model. Six regression models were calculated to explain the proposed hypotheses. For each model, coefficients were calculated, identifying the positive or negative significance between the variables; Odds Ratios were calculated to determine the relative probability of the event occurring; and marginal effects were calculated, representing the percentage probability of the event occurring (Ballesteros, 2018; Salmerón, 2019).

The Logit model used is presented in Equation 1, where ln represents the natural logarithm, Pi the probability of occurrence, 1-Pi the complement of the probability, βo the constant coefficient, β the regression coefficient associated with the covariate, and X the covariates (Sagaró & Zamora, 2019).

$$Li = \ln\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 X_I + \beta_2 X_2 + \ldots \beta_i X_i \quad (1)$$

The evaluation of the models was conducted using the confusion matrix to calculate the percentage of correct predictions (indicators of sensitivity, specificity, and correct classification rate). It was found that in all six models, the prediction accuracy exceeds 60%, meaning that more than half of the

manufacturing firms included in the study were correctly classified. Additionally, the area under the ROC curve was calculated, with an indicator greater than 0.60 in all models, indicating an acceptable distance between the curve and the slope (Vizcaíno-Salazar, 2017). Therefore, all models possess an acceptable level of data discrimination. The results, based on goodness-of-fit measures (Pseudo R2), indicate that the predictive capacity of the models is acceptable, as the values are close to zero (Babrer, 2013; Lee, 2013); the chi-square statistic (LR chi2) is greater than 10(+) in all six regressions (Fuente-Alba & Molina, 2016), and the associated p-value (Prob > chi2) is less than 0.05, allowing the rejection of the null hypothesis that the estimated parameters are zero.

Below, the results for each hypothesis are presented, highlighting the coefficients, standard errors, and significance of the predictor variables.

Hypothesis 1: Internal Resources and Capabilities. The results of the Logit model presented in Table 2 allow for the acceptance of Hypothesis 1, which states that industrial firms achieve product innovations depending on their internal resources and capabilities. It can be observed that, for this particular model, it is crucial for the development of innovations that firms invest resources in internal product development. The findings suggest that investment in the acquisition of machinery and equipment, as well as technical assistance, decreases the probability of the firm generating innovations. This result is not aligned with findings from other authors who highlight the importance of these resources for achieving product innovations. However, it is noted that the impact on innovation is relatively low in percentage terms. In this model, the total staff dedicated to scientific, technological, and research activities is an important control variable, as it increases the probability of obtaining innovations by 1%, making it the variable with the highest impact.

Table 2: Logit regression for H1

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
Invintbys	2.71e-07** (9.54e-08)	1** (9.54e-08)	6.31e-08** (2.21e-08)
Invadquid	5.45e-06* (2.91e-06)	1.000005* (2.91e-06)	1.27e-06* (6.76e-07)
Invadqmye	-4.05e-07** (1.16e-07)	.9999996** (1.16e-07)	-9.45e-08** (2.68e-08)
Invtic	-2.98e-07* (1.77e-07)	.9999997* (1.77e-07)	-6.95e-08* (4.12e-08)
Invprointel	-4.85e-06* (2.75e-06)	.9999951* (2.75e-06)	-1.13e-06* (6.39e-07)
Invasistec	-9.59e-07** (4.53e-07)	.999999** (4.53e-07)	-2.23e-07** (1.05e-07)
Tperacti	.0431926** (.006763)	1.044139** (.0070616)	.010064** (.0015152)
_cons	-.4502521** (.0568677)	.6374674** (.0362513)	-
Number of obs	1978	1978	1978
LR chi2(7)	141.64	141.64	-
Prob>chi2	0.0000	0.0000	-
Log likelihood	-1296.0807	-1296.0807	-
Pseudo R2	0.0518	0.0518	-
Sensitivity Pr (+|D)	28.97%		
Specificity Pr (-|~D)	87.75%		
Correct Classification Rate	60.26%		
Area Under the Curve ROC	0.6852		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

Hypothesis 2: Institutional Conditions. The Logit model allows for the acceptance of Hypothesis 2, as it revealed that most variables related to regulatory difficulties have negative and significant coefficients. Considering the principal components PC1H2, PC2H2, and PC3H2, it was found that tax benefits, such as deductions or exemptions on income for investments (PC1H2), increase the probability of achieving innovations (2%).

On the other hand, negative marginal effects were observed. These indicate in PC2H2 that difficulties in complying with regulations and technical standards, limited information about public instruments, and insufficient capacity of the intellectual property system reduce the probability of the firm innovating. Meanwhile, PC3H2 suggests that if the importance of improving compliance with regulations, norms, and technical standards, reducing tax payments, or obtaining tax benefits for investments is low, there is a negative effect on innovation, indicating a 5% probability of reducing it. In this model, the control variable related to the total staff dedicated to

scientific, technological, and research activities reinforces its importance for the firm, as under institutional conditions, it can increase innovation by 0.7% (see Table 3).

Table 3: Logit regression for H2

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
PC1H2 (Dedubentribu, Exenbentribu, Deducley)	.0984402** (.0295977)	1.103448** (.0326595)	.0226297** (.0067307)
PC2H2 (Reguregla, Instpublic, Caprointel)	-.1269566** (.0347187)	.8807719** (.0305792)	-.0291851** (.0078773)
PC3H2 (Normreg, Taxes, Bentribut)	-.232175** (.0410177)	.7928074** (.0325191)	-.053373** (.0091291)
TPERACTI	.0337445** (.0048964)	1.03432** (.0050645)	.0077573** (.0010775)
_cons	-.3811895** (.0572407)	.6830484** (.0390982)	-
Number of obs	1978	1978	-
LR chi2(7)	161.48	161.48	-
Prob>chi2	0.0000	0.0000	-
Log likelihood	-1286.1608	-1286.1608	-
Pseudo R2	0.0591	0.0591	-
Sensitivity Pr (+|D)	44.00%		
Specificity Pr (-|~D)	79.01%		
Correct Classification Rate	62.64%		
Area Under the Curve ROC	0.6693		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

Hypothesis 3: External Resources. The results allow for the acceptance of the third research hypothesis, which states that industrial firms achieve product innovations depending on their external resources. The model shows that hiring external consulting agents increases the probability of generating innovations by 13%. The difficulty in accessing external financing does not appear to be negative, as even when it exists, the firm is likely to innovate (3%). Access to public resources to finance investments in scientific activities is a relevant variable that increases the development of innovations by 12%, while the lack of information about markets decreases the probability of firms achieving innovations by 7%. In this model, the total investment in scientific, technological, and research activities is an important control variable, as it increases the probability of obtaining innovations, although this effect is very small (see Table 4).

Table 4: Logit regression for H3

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
Infmercad	-.3193179** (.0758354)	.7266445** (.0551053)	-.0764034** (.0178257)
Consultant	.5716953** (.1598308)	1.771267** (.283103)	.1367899** (.0377618)
Difinancia	.1344099** (.0636446)	1.143862** (.0728006)	.0321604** (.0151617)
Nconsext	-.0904127* (.0469161)	.9135541* (.0428604)	-.0216331* (.0111874)
Finacti	.5305416** (.1597909)	1.699853** (.271621)	.126943** (.0378191)
Tinvacti	1.23e-07** (2.59e-08)	1** (2.59e-08)	2.94e-08** (6.08e-09)
_cons	.1245036 (.1958476)	1.132586 (.2218143)	-
Number of obs	1978	1978	-
LR chi2(7)	80.17	80.17	-
Prob>chi2	0.0000	0.0000	-
Log likelihood	-1326.816	-1326.816	-
Pseudo R2	0.0293	0.0293	-
Sensitivity Pr (+|D)	35.68%		
Specificity Pr (-|~D)	79.30%		
Correct Classification Rate	58.90%		
Area Under the Curve ROC	0.6055		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

Hypothesis 4: Open Innovation. Regarding the Logit model presented in Table 5, the results allow for

the acceptance of the fourth research hypothesis, which states that industrial firms achieve product innovations depending on their dynamic capabilities in open innovation. The findings reveal that the probability of generating innovations increases by 3% when the firm uses information sources such as other firms in the sector, universities, consultants, patents, technical standards and regulations, and public institutions, as well as when it engages with entities such as Minciencias, public universities, trade associations, chambers of commerce, innovation consultants, and Innpulsa. Additionally, the probability of innovation increases by 5% if the firm has contracts with public sector entities, develops products in collaboration with other firms, or uses information sources from other departments within the firm, interdisciplinary groups, other firms, and the R&D department of another firm. Furthermore, the probability of innovation increases by 10% when the firm uses internal R&D departments, production departments, sales departments, or company executives as information sources.

On the other hand, the results suggest that the probability of the industry generating innovations decreases by 4% if the firm establishes relationships with entities such as MINCIT or Colombia Productiva. It also decreases by 2% if the firm uses scientific and technological databases (Fbdct), regional productivity centres (Relcrp), other ministries (Relminister), or autonomous research centres (Relcia) as information sources. Additionally, the probability of innovation decreases by 3% if the firm uses the parent company as an information source. Finally, the results highlight the relevance of staff dedicated to scientific, technological, and innovation activities (ACTI) in the model, underscoring the importance of having a specialised team to foster innovation within industrial firms.

Table 5: Regresión logit para H4

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
PC1H4 (Fempsect, Fagremiaci, Funiversity, F Consultant, Fpatent, Fstandard, Findtpub, Relmincienc, Relunivpub, Relagreycc, Relconsult, Relinnpulsa)	.1990824** (.0194274)	1.220283** (.0237069)	.0397139** (.0034983)
PC2H4 (Relmincit, Relcolprod)	-.2218059** (.0338514)	.8010708** (.0271174)	-.0442469** (.0064697)
PC7H4 (Conpubnal, Bycompany, Fotrodep, Fgrupinter, Fotremp, Fdepidotremp)	.253408** (.0492516)	1.288409** (.0634562)	.0505511** (.009591)
PC8H4 (Fbdct, Relcrp)	-.1076055** (.0490141)	.8979818** (.0440138)	-.0214657** (.0097338)
PC9H4 (Fdepintid, Fdepproduc, Fdepventa, Fdirectivos)	.5226611** (.0525006)	1.68651** (.0885427)	.104263** (.0095109)
PC11H4 (Fcasamatriz)	-.1596285** (.053888)	.8524604** (.0459374)	-.0318435** (.0106727)
PC12H4 (Fcompetid, Fclientes, Relsena, Relicontec, Relsic)	.0882296* (.0523457)	1.092239* (.0571741)	.0176005* (.0104157)
PC14H4 (Relminister, Relcia)	-.1110332** (.0557833)	.8949091** (.049921)	-.0221494** (.0110924)
Tperacti	.0124061** (.0048038)	1.012483** (.0048638)	.0024748** (.000953)
_cons	-.1903906 (.0623119)	.8266362** (.0515093)	-
Number of obs	1978	1978	
LR chi2(7)	429.19	429.19	
Prob>chi2	0.0000	0.0000	
Log likelihood	-1152.304	-1152.304	
Pseudo R2	0.1570	0.1570	
Sensitivity Pr (+|D)	58.59%		
Specificity Pr (-|~D)	77.59%		
Correct Classification Rate	68.71%		
Area Under the Curve ROC	0.7600		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

Hypothesis 5: Innovation Systems. Regarding the Logit model presented in Table 6, the results allow for the acceptance of the fifth research hypothesis, which states that industrial firms in Colombia achieve product innovations depending on their innovation systems, that is, the interaction among various actors in the system, such as firms, universities, and the government. The findings suggest that cooperation with other firms, suppliers, customers, innovation consultants, universities, autonomous research centres, non-governmental organisations, or the government increases the probability of a firm generating product innovation by 5%. However, the probability may decrease by 2% if the cooperation is with technological development centres, technology parks, or regional productivity centres. Finally, the model highlights the relevance of the control variable related to staff dedicated to scientific, technological,

and research activities (ACTI), which shows a positive influence on firms' ability to innovate in products.

Table 6: Logit regression for H5

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
PC1H5 (Coopempre, Coopprove, Coopclient, Coopconsul, Coopunive, Coopcia, Coopnogub, Coopgobier)	.2374842** (.0342074)	1.268055** (.0433768)	.0544442** (.0074927)
PC2H5 (Coopcdt, Coopparktec, Coopcrp)	-.1258954** (.0529626)	.8817071 ** (.0466975)	-.028862** (.0120753)
TPERACTI	.0279961** (.0048985)	1.028392** (.0050376)	.0064182** (.0010896)
_cons	-.3168325** (.0584455)	.7284527** (.0425748)	-
Number of obs	1978	1978	-
LR chi2(7)	169.41	169.41	-
Prob>chi2	0.0000	0.0000	-
Log likelihood	-1282.1969	-1282.1969	-
Pseudo R2	0.0620	0.0620	-
Sensitivity Pr (+|D)	37.08%		
Specificity Pr (-|~D)	85.47%		
Correct Classification Rate	62.84%		
Area Under the Curve ROC	0.7033		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

Hypothesis 6: Knowledge, Information, and Continuous Learning. Finally, the model presented in Table 7 accounts for the relationship between the dependent variable and the independent variables, allowing for the acceptance of the sixth hypothesis, which states that industrial firms in Colombia achieve product innovations depending on their knowledge, information, and continuous learning, measured through proxy variables related to the academic and professional training of employees. The results show that the probability of innovating increases when firms have employees with secondary education, specialisation, master's, and doctoral degrees dedicated to scientific, technological, and research activities. This suggests that higher academic and professional training of staff is positively correlated with the firm's ability to generate product innovations, highlighting the importance of knowledge and continuous learning as determining factors in the innovation process.

Table 7: logit Regresión for H6

	INNOVBYS		
	Coef.	**Odds ratio**	**Efect Margins**
Secundacti	.0672052** .0215347	1.069515** .0230317	.0157082** .0049864
Doctoracti	.5633435** .2447336	1.756536** .4298833	.1316731** .0569422
Primaria	-.0040014* .0020538	.9960065* .0020456	-.0009353* (.0004784)
Masteracti	.1306921** .0638185	1.139617** .0727286	.0305473** .0148602
Espcialista	-.0176396** .0053851	.9825151** .005291	-.004123** .0012462
Espcialacti	.1040392** .0361888	1.109644** .0401566	.0243176** (.008393)
Secundar	.000826** .0003448	1.000826** .0003451	.0001931** .0000801
Profesacti	.0463396** .0154747	1.04743** .0162087	.0108312** .0035878
Primariacti	.3000206* .167658	1.349887* .2263193	.0701253* .0390759
_cons	-.4412178** .0580464	.6432526** .0373385	-
Number of obs	1978	1978	-
LR chi2(7)	131.66	131.66	-
Prob>chi2	0.0000	0.0000	-
Log likelihood	-1301.0726	-1301.0726	-
Pseudo R2	0.0482	0.0482	-
Sensitivity Pr (+|D)	31.03%		
Specificity Pr (-|~D)	86.23%		
Correct Classification Rate	60.41%		
Area Under the Curve ROC	0.6695		

Note: Standard error in parentheses. P<0.1*, p<0.05**.

5. DISCUSSION

The results obtained for the first hypothesis are consistent with the findings of Dnaz-Delgado et al. (2018), who highlight that economic and technological resources are important means for generating innovations. However, the finding in this research related to investment in the acquisition of machinery and equipment, which decreases the probability of innovating, may paradoxically be due to the fact that many industrial firms' investments in technology are often aimed at improving operational efficiency, which may divert resources and attention from more creative and innovative research and development (R&D) activities. Additionally, technological dependence on suppliers of these assets may limit flexibility to experiment with new technologies. Furthermore, financial resources allocated to machinery acquisition may reduce funds available for hiring specialised personnel. Moreover, the acquired technology may quickly become obsolete, and if firms cannot update their equipment, they may fall behind in terms of innovative capacity (Cuevas-Vargas et al., 2022; López & Robledo, 2014). Finally, the focus on maintaining and operating these assets may divert attention from seeking new opportunities and developing innovative products. These reasons suggest that, although fundamental for modernisation, machinery acquisition must be balanced with investments in R&D and an organisational culture that promotes creativity and experimentation. However, this result is consistent with the fact that the Colombian manufacturing industry is still a low-innovation sector, with limited resources for updating efficient machinery, and those that do acquire machinery focus on maintaining operations. Of the 1978 firms in the sample, only 859 invested in machinery and equipment, with amounts ranging from $196 to $12,781,333 (thousands of pesos), and of these, only 108 reported at least one developed innovation. This could be understood, as suggest Huy & Phuc (2025), that the best survival prospects are independent of the technological intensity of the industry, as other factors have a more direct influence, such as R&D.

On the other hand, the results of the second hypothesis are consistent with the findings of other authors. Tax benefits, such as deductions and exemptions on income for investments, increase the probability of achieving innovations by reducing the fiscal burden and financial risk, freeing up capital for strategic reinvestments in research and development (R&D) (Cheah & Ho, 2020). These incentives allow firms to allocate more resources to innovation projects, facilitating long-term planning and the execution of high-risk initiatives. Additionally, they foster a competitive and innovation-friendly environment, attracting skilled talent and stimulating collaboration between firms, universities, and research centres. Meanwhile, Mukherjee et al. (2017) indicate that taxes negatively impact the introduction of new products by reducing firms' resources to invest in patents and R&D. Furthermore, Sampedro-Hernández and Ojeda (2018) mention that the adoption and appropriation of institutional rules and procedures play a fundamental role in shaping innovation models, which aligns with the findings of this study that identify non-compliance with regulations and technical standards as reducing the probability of firms innovating. This is due to several reasons: legal and financial penalties from non-compliance imply additional costs and resource diversion, reducing funds available for R&D activities. Additionally, the loss of credibility and reputation among customers, investors, and business partners hinders collaboration and the ability to secure funding for innovative projects (Brown et al., 2021). Moreover, the need to divert resources to address compliance issues reduces the capacity for investment in innovation, and finally, an environment of insecurity and instability within organisations affects employee morale and motivation, which is not conducive to creativity (Aliane, 2023). Non-compliance with regulations can also impede the commercialisation of new products, directly affecting the firm's ability to innovate and compete. Finally, managing compliance issues can distract senior management from a strategic focus on innovation, forcing them to concentrate on resolving these issues rather than driving and fostering innovation.

Regarding the third hypothesis, several studies in the literature support the obtained results. Klein & Pereira (2016) and Sánchez and Rotundo (2018), who affirm, in line with the postulates of Resource Dependency Theory, that firms require support from their environment and other firms, especially when they are not self-sufficient to generate all the necessary resources. According to this theory, organisations operate in an interdependent environment and, to survive and thrive, must acquire critical resources from their surroundings (Quintero□Sepúlveda et al., 2024). This implies that firms must engage in transactions and exchanges with other organisations to access essential and financial resources. Access to financial resources is crucial for firms to invest in research and development (R&D) activities, which is vital for innovation. The lack of adequate financing can limit a

firm's ability to explore new ideas, develop prototypes, and bring innovative products to market (Zuñiga-Collazos et al., 2025). Additionally, access to knowledge resources, such as collaboration with universities, research centres, and other firms, is equally essential. These collaborations allow firms to access specialised knowledge, advanced technologies, and innovative practices that would otherwise not be available internally. The theory suggests that firms must create and maintain strategic relationships with other organisations to mitigate environmental uncertainty and ensure a steady flow of critical resources (Pulido-López & López-Salazar, 2025). This is particularly relevant in sectors where technology and knowledge advance rapidly, as firms need to continuously adapt to new developments and opportunities. Interorganisational collaboration and the establishment of strong networks can provide firms with access to privileged information, best practices, and funding opportunities that are vital for the development of innovations (Pineda & Urrego, 2025). The lack of external resources not only decreases the probability of firms achieving innovations but can also affect their long-term competitiveness. Without access to financial and knowledge resources, firms may fall behind their competitors who do have access to these resources (Quintero & Zúñiga, 2025). Additionally, excessive reliance on internal resources may limit the diversity of ideas and approaches, which is crucial for disruptive innovation (Melo et al., 2024).

Regarding the results of the fourth hypothesis, the findings are supported by the very concept of open innovation, which can act as a catalyst in generating product innovations due to its ability to integrate knowledge, resources, and technologies from diverse external sources, significantly expanding the creative horizon and the knowledge base available to firms (Fajardo et al., 2024). In this study, it is identified that the probability of generating innovations increases when the firm uses as information sources other firms in the sector, universities, consultants, patents, technical standards and regulations, public institutions, other departments within the firm, interdisciplinary groups, other firms, and the R&D department of another firm, as well as the production department, sales department, or company executives; when it engages with Minciencias, public universities, trade associations or chambers of commerce, innovation consultants, and Innpulsa; and when it develops products in collaboration with other firms. It is clarified that not all information sources are relevant or contribute to the development of innovations, as this may vary across industries and even among firms within the same industry. In this sense, external sources of knowledge enable the development of innovation and the improvement of business models (Quintero□Sepúlveda et al., 2024), and relationships with external agents have substantial benefits for firms and national development. As mentioned by Zuñiga-Collazos et al. (2023), Open Innovation proposes an emerging model of innovation where firms rely on R&D that may even be outside their boundaries; this is a key strategy to improve the innovative performance of organisations (Fuenmayor & Polo, 2015). For example, the study by Almirall et al. (2014), although focused on six cities that opened their data for innovation, highlights the importance of open innovation as a strategy that uses knowledge flows to accelerate internal innovation and expand its use in the external market. This collaborative approach allows organisations to access ideas and solutions that would otherwise be unavailable, promoting greater diversity and depth in the development of new products. Additionally, open innovation facilitates the rapid adoption and adaptation of emerging technologies, reducing development times and associated costs. By incorporating the capabilities and perspectives of external partners, including universities, research centres, and other firms, the ability to respond to market demands is enhanced, and the innovation cycle is accelerated, contributing significantly to the dynamism and competitiveness of firms in a globalised environment.

The results of the fifth hypothesis, regarding innovation systems, are supported by studies such as that of Stojčić et al. (2025), who indicates that interaction with actors, networks, and institutions positively affects innovation; highlighting that universities and public research centres, as well as governmental and non-governmental organisations, private firms, venture capitalists, and associations are sources of innovation (Morales et al., 2012). Cooperation with other firms, suppliers, customers, innovation consultants, universities, autonomous research centres, non-governmental organisations, or government entities increases the probability of a firm generating product innovation by facilitating the exchange of knowledge, resources, and technologies (Sime & Tadesse, 2025). This collaborative approach allows firms to access a diversity of perspectives and expertise, enhancing their ability to identify and exploit new market opportunities. Additionally, interdisciplinary and multisectoral collaboration reduces the risks and costs associated with innovation, accelerates development processes, and fosters the adoption of emerging technologies

(Walpole et al., 2025), significantly contributing to the creation of innovative and competitive products. Regarding the findings related to cooperation with technological centres, it is likely that product innovations decrease in industrial firms if cooperation is limited exclusively to technological development centres, technology parks, or regional productivity centres due to the potential lack of diversity in perspectives and approaches that these specialised environments may offer (Pertuz & Ojeda, 2023). While these institutions provide valuable technical knowledge and resources, their predominantly technical and regional focus may restrict firms' ability to incorporate broader and multidisciplinary insights from other key actors, such as customers, suppliers, and international market experts. This limitation can lead to reduced adaptability and creativity in product development, resulting in less competitive innovations aligned with global market dynamics (Costamagna et al., 2022).

Finally, the results of the sixth hypothesis, which identify the important role of firm employees in generating innovations, particularly those with secondary education, specialisation, master's, and doctoral degrees, dedicated to scientific, technological, and research activities. The diversity and depth of knowledge that each educational level contributes is evident, for example, in employees with secondary education who can contribute essential practical and operational skills, while those with specialisation and master's degrees can provide advanced technical knowledge and management capabilities. Employees with doctoral degrees, on the other hand, enrich the innovation process with cutting-edge research and highly developed critical thinking. This combination of skills and knowledge enables synergy that enhances creativity, problem-solving efficiency, and the ability to implement emerging technologies, thus favouring the development of innovative and competitive products. These findings align with those mentioned by Pradana et al. (2020), who find in their study that human capital, along with absorptive capacity, allows firms to capture and leverage the benefits of innovation. Akadiri et al. (2025) indicate in their study that human capital refers to knowledge and skills and comprises the know-how of a firm, making it a key source for innovation; in their study, they propose that investment in human capital training for work is a driver of organizational productivity and competitiveness, which are achieved through innovative behaviors.

Other studies supporting these results include: Malik (2023), who shows with econometric analyses that institutional quality, education, and trade openness are related to the achievement of innovations, and finds a negative impact from foreign direct investment on the level of innovation. Roelandt & Andries (2025) studies various determinants of innovation, including human resources and investment in their scientific and technological training, as this leads to better utilisation of their potential to produce innovations

6.CONCLUSION

This research highlights that the determinants of product innovation are a complex set of elements related to both internal and external factors within organisations. The study of these determinants is intricate due to the dynamic interaction among various actors and conditions, and this research seeks to integrate multiple perspectives to identify how these factors affect the innovation capacity of Colombian industrial firms. The contribution of this study to the existing literature on the determinants of product innovation includes several key aspects: First, it offers a comprehensive integration of various theories and approaches to innovation, such as the Resource-Based View (RBV), the Institutional Perspective, Resource Dependency Theory, Open Innovation, Innovation Systems, and the Knowledge-Based Economy. This integration provides a holistic and systemic view of how multiple factors interact and affect firms' innovation capacity.

Second, the study focuses on the specific context of Colombian industrial firms, providing a detailed analysis of how these determinants operate in an emerging economy. This fills a gap in the literature, which often focuses on developed economies, and offers new perspectives on innovation dynamics in countries with distinct characteristics and challenges. Additionally, the research employs a robust quantitative approach, using data from the Survey of Technological Development and Innovation (EDIT) for the Colombian industrial sector and applying advanced statistical techniques such as correlational analysis, principal component analysis, and Logit regression models. This rigorous methodology ensures the validity and reliability of the findings, providing strong empirical evidence on the factors influencing product innovation.

Finally, the article highlights the importance of specific factors such as favourable institutional conditions, intersectoral collaboration, and continuous staff training, emphasising their impact on firms' innovation capacity. In doing so, it offers practical recommendations for public policies and business strategies that can enhance innovation in the

industrial sector.

Concretely, the research has demonstrated that firms' capacity to innovate is influenced by the effective management of internal resources and capabilities, such as investment in research and development (R&D) activities. The ability to efficiently manage and orchestrate these resources is crucial for the creation of innovative products. Additionally, institutional conditions and the regulatory environment play a significant role. Tax benefits, such as deductions and exemptions on income for investments, reduce the fiscal burden and financial risk, freeing up capital for strategic reinvestments in R&D, which fosters an innovation-friendly environment.

Access to external resources and strategic collaborations are also key determinants. Firms that collaborate with universities, research centres, and other organisations can access specialised knowledge and advanced technologies that drive their innovation capacity. This collaborative approach helps overcome internal resource limitations and enhances creativity and efficiency in developing new products.

Moreover, the adoption of open innovation practices, which integrate knowledge and technologies from external sources, has been shown in this study to be fundamental for accelerating the innovation process. Collaboration with various actors in the innovation ecosystem, such as universities and research centres, facilitates the rapid adoption of emerging technologies and reduces the costs associated with developing innovative products. This study found that innovation systems, defined by the coordinated interaction among firms, universities, government, and other key actors, are essential for fostering an innovative environment. However, the findings highlight that excessive reliance on development centres and technology parks may limit the diversity of perspectives needed for disruptive innovation. On the other hand, continuous knowledge and academic training of staff are essential for maintaining a competitive edge in generating innovative outcomes. Employees with diverse educational levels bring a combination of practical skills and advanced knowledge that are crucial for implementing emerging technologies.

This research focused on Colombian industrial firms, which may represent a limitation when attempting to scale the results to other countries or types of firms. However, the sample size used and the methodology employed provide a solid and reliable foundation for the results achieved. Thus, this study offers valuable insights into innovation dynamics and the factors influencing the development of innovations in the Colombian context. For future research, it would be beneficial to explore how these findings apply to other industrial sectors and different geographical contexts. Additionally, longitudinal studies analysing the impact of changes in institutional and economic policies on innovation could provide a deeper understanding of the mechanisms driving innovation. It would also be interesting to investigate how emerging technologies, such as artificial intelligence and the Internet of Things (IoT), can be integrated into these innovation frameworks to further enhance firms' capacity to develop innovative products.

REFERENCES

Acemoglu, D., & Robinson, J. A. (2012). Why nations fail: The origins of power, prosperity, and poverty. Crown Business.

Agarwal, S., Dagnino, G. B., Gulati, R., Ranganathan, R., & Rothaermel, F. T. (2019). Coopetition and Innovation in the Digital Age. Academy of Management Proceedings, 2019(1), 10503. https://doi.org/10.5465/AMBPP.2019.10503symposium

Akadiri, S. Saint, Ozkan, O., & Kirikkaleli, D. (2025). Synergistic impact of renewable energy technology, governance, digitalisation, and human capital on sustainable development and load capacity factor in Germany's energy landscape. Technology in Society, 83, 103002. https://doi.org/10.1016/j.techsoc.2025.103002

Aliane, N., Al-Romeedy, B. S., Agina, M. F., Salah, P. A. M., Abdallah, R. M., Fatah, M. A. H. A., ... & Khairy, H. A. (2023). How Job Insecurity Affects Innovative Work Behavior in the Hospitality and Tourism Industry? The Roles of Knowledge Hiding Behavior and Team Anti-Citizenship Behavior. Sustainability, 15(18), 13956. https://doi.org/10.3390/su151813956

Arango-Alzate, B., Zartha-Sossa, J. W., Medina-Henao, J. G., Avalos-Patiño, A. F., & Velez-Salazar, F. M. (2015). Barriers for innovation detected in 400 colombian businesses, based on the innovation "U" coefficient methodology. Revista Facultad de Ingeniería Universidad de Antioquia, 77. https://doi.org/10.17533/udea.redin.n77a02

Babrer, X. (2013). Vender o no vender ese es el problema (I). Regresión Logística (pp. 1–48). Centro de

Investigación Operativa. Universidad Miguel Hernández de Elche. http://umh1480.edu.umh.es/wp-content/uploads/sites/44/2013/02/tema_5_1.pdf

Ballesteros, M. (2018). Promedio de los efectos marginales e interacciones en las regresiones logísticas binarias (Issue 3). INCASI international Network for comparative Analysis of Social Inequalities. https://ddd.uab.cat/record/189811

Barrios-Hernández, K. del C., & Olivero-Vega, E. (2020). Relación universidad-empresa-estado. Un análisis desde las instituciones de educación superior de Barranquilla-Colombia, para el desarrollo de su capacidad de innovación. Formación Universitaria, 13(2), 21–28. https://doi.org/10.4067/S0718-50062020000200021

Brown, P., Von Daniels, C., Bocken, N. M., & Balkenende, A. R. (2021). A process model for collaboration in circular oriented innovation. Journal of Cleaner Production, 286, 125499.

Castellacci, F., & Natera, J. M. (2013). The dynamics of national innovation systems: a panel cointegration analysis of the coevolution between innovative capability and absorptive capacity. Research Policy, 42(3), 579–594.

Cerquera-Losada, Ó. H., & Rojas-Velásquez, L. (2020). Inversión extranjera directa y crecimiento económico en Colombia. Revista Facultad de Ciencias Económicas, 28(2), 9–26. https://doi.org/10.18359/rfce.4202

Chaparro-Banegas, N., Ibañez Escribano, A. M., Mas-Tur, A., & Roig-Tierno, N. (2023). Innovation facilitators and sustainable development: a country comparative approach. Environment, Development and Sustainability, 1–29.

Kashwani R, Kumari A. Healthcare Startup Incubators in India: Successes, Shortcomings, and Systemic Gaps. Bull. Health Sphere 2026;1(1):11-18. doi: https://doi.org/10.63150/bhs.2026.02

Chen, M., Tan, X., Zhu, J., & Dong, R. K. (2025). Can supply chain digital innovation policy improve the sustainable development performance of manufacturing companies? Humanities and Social Sciences Communications, 12(1), 307. https://doi.org/10.1057/s41599-025-04601-9

Costamagna, R., Idrovo-Carlier, S., Mendi, P., & Rodriguez, A. (2022). Human resource management practices and innovation in Colombian firms. Academia Revista Latinoamericana de Administración, 35(4), 458-481. https://doi.org/10.22201/10.1108/ARLA-06-2021-0112

Cuevas-Vargas, H., Velázquez-Espinoza, N., & Colín-Salgado, M. (2022). Technological Innovation in Colombian Small Firms: A Gender Multi-Group Analysis. Business Systems Research: International journal of the Society for Advancing Innovation and Research in Economy, 13(1), 46-65. https://doi.org/10.22201/10.2478/bsrj-2022-0004

Dagnino, G. B., Levanti, G., Minà, A., & Picone, P. M. (2015). Interorganizational network and innovation: a bibliometric study and proposed research agenda. Journal of Business & Industrial Marketing, 30(3/4), 354–377. https://doi.org/10.1108/JBIM-02-2013-0032

Dnaz-Delgado, M. F., Gil-Gómez, H., Vargas, L. F., & Martínez, H. E. (2018). Practices for the Construction of Innovation Capacity Base on the Structural Organization Capital. 2018 congreso Internacional de Innovación y Tendencias En Ingeniería (CONIITI), 1–6. https://doi.org/10.1109/CONIITI.2018.8587108

Drees, J. M., & Heugens, P. P. M. A. R. (2013). Synthesizing and Extending Resource Dependence Theory. Journal of Management, 39(6), 1666–1698. https://doi.org/10.1177/0149206312471391

Edquist, C. (2011). Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures). Industrial and Corporate Change, 20(6), 1725–1753. https://doi.org/10.1093/icc/dtr060

Fajardo, E. J., Riaño, D. A., Romero, H., y Ruiz, F. (2024). Género e innovación empresarial en Colombia. Revista Venezolana De Gerencia, 29 (Especial 11), 37-52. https://doi.org/10.52080/rvgluz.29a.107.2

Fraunhofer Institute. (2012). Innovation system revisited. experiences from 40 years of fraunhofer isi research. Fraunhofer Verlag.

Fuenmayor Vergara, L. F., & Polo Otero, J. (2015). The impacts of open innovation strategies on innovative performance: The case of Colombian food and beverage firms. DIEM: Dubrovnik International Economic Meeting, 2(1), 259–275.

Fuente-Alba, C. S., & Molina, M. (2016). Likelihood ratio (razón de verosimilitud): definición y aplicación en Radiología. Revista Argentina de Radiología, 81(3), 204–208. https://doi.org/10.1016/j.rard.2016.11.002

Fuentelsaz, L., Maicas, J. P., & Montero, J. (2018). Entrepreneurs and innovation: The contingent role of institutional factors. International Small Business Journal: Researching Entrepreneurship, 36(6), 686–

711. https://doi.org/10.1177/0266242618766235
Garavito, J. C., Pérez Peña, N. L. & Munive Herrera, B. M. (2018). Iniciativas Clúster en Colombia: Instrumentos de desarrollo económico y competitividad. ISBN: 978-958-56681-1-9
Garzón, M. A. (2015). Modelo de capacidades dinámicas. Dimensión Empresarial, 13(1), 111-131. https://doi.org/http://dx.doi.org/10.15665/rde.v13i1.341
González, X. (2018). El país cuenta actualmente con 87 iniciativas clúster en diferentes Cámaras. La República.
Gracia Cabrera, D. A., & Misas Arango, M. (2021). Relación entre el desarrollo financiero y el crecimiento económico en Colombia en el periodo 1994-2018. Cuadernos de Economía, 40(83), 361–382. https://doi.org/10.15446/cuad.econ.v40n83.79314
Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, M. del P. (2014). Metodología de la Investigación (6a). McGraw-Hill / Interamericana Editores.
Hidayat, A. S., & Pok, W. C. (2025). Empowering SMEs innovation through intangible factors. Journal of Innovation and Entrepreneurship, 14(1), 1. https://doi.org/10.1186/s13731-024-00437-w
Huy, P. Q., & Phuc, V. K. (2025). Does effectiveness of digital accounting system intensify sustainable business model innovation with mediating role of digital business ecosystem? Journal of Innovation and Entrepreneurship, 14(1), 3. https://doi.org/10.1186/s13731-024-00444-x
Klein, L. L., & Pereira, B. A. (2016). The survival of interorganizational networks: a proposal based on resource dependence theory. RAM. Revista de Administração Mackenzie, 17(4), 153–175. https://doi.org/10.1590/1678-69712016/administracao.v17n4p153-175
Lee, D. (2013). A Comparison of Choice-based Landscape Preference Models between British and Korean Visitors to National Parks. Life Science Journal, 10(2), 2028–2036. http://umh1480.edu.umh.es/wp-content/uploads/sites/44/2013/02/tema_5_1.pdf
Leenders, R. T. A. J., & Dolfsma, W. A. (2016). Social Networks for Innovation and New Product Development. Journal of Product Innovation Management, 33(2), 123–131. https://doi.org/10.1111/jpim.12292
López, C., y Robledo J. (2014). Una aproximación a la gestión de capacidades de innovación en la pyme colombiana. Gestión y Sociedad, 7(2), 11-30.
Lora, E. (2019). Economía esencial de Colombia. (1er ed.). Penguin Random House Grupo Editorial.
Lundvall, B. Å. (2016). The learning economy and the economics of hope. Anthem Press. http://library.oapen.org/handle/20.500.12657/31613
Marulanda, C. E., Valencia, F. J., & Marín, P. F. (2019). Principales Obstáculos para la Transferencia de Conocimiento en los Centros e Institutos de Investigación del Triángulo del Café en Colombia. Información Tecnológica, 30(3), 39–46. https://doi.org/10.4067/S0718-07642019000300039
Mauricio Carbó, E. A. (2019). Software y TI. Cámara de Comercio de Bogotá.
McCrea, R., Coates, R., Hobman, E. V., Bentley, S., & Lacey, J. (2024). Responsible innovation for disruptive science and technology: The role of public trust and social expectations. Technology in Society, 79, 102709. https://doi.org/10.1016/j.techsoc.2024.102709
Melo, M. M., Jurado, J. M., y Melo, L. I. (2024). Innovación en la agroindustria de la guayaba en la Hoya del Río Suárez-Colombia. Revista Venezolana De Gerencia, 29 (Especial 11), 69-86. https://doi.org/10.52080/rvgluz.29.e11.4
Mukherjee, A., Singh, M., & Žaldokas, A. (2017). Do corporate taxes hinder innovation? Journal of Financial Economics, 124(1), 195–221. https://doi.org/10.1016/j.jfineco.2017.01.004
Omonijo, O. N., & Zhang, Y. (2025). Examining the relationship between technological innovation, environmental social governance and corporate sustainability: the moderating role of green operational innovation. Humanities and Social Sciences Communications, 12(1), 107. https://doi.org/10.1057/s41599-025-04389-8
Parra Gaviño, G., Gómez Ortiz, R., & Pastor Román, I., (2016). El apoyo del gobierno como determinante de la colaboración exitosa entre la universidad y la empresa. Universidad & Empresa, 17(29), 213–238. https://doi.org/10.12804/rev.univ.empresa.29.2015.09
Pertuz, V., & Ojeda, M. M. (2023). Importance of knowledge sources for innovation: An analysis of service companies in Colombia. Contaduría y Administración, 68(3), 292-316. https://doi.org/10.22201/fca.24488410e.2023.3495
Pineda, V. G., & Urrego, J. A. M. (2025). Identifying The Innovation Capabilities of Information and Communication Technologies Companies in the Context of an Emerging Country. Sociología y tecnociencia, 15(1), 16-38.

Pradana, M., Pérez-Luño, A., & Fuentes-Blasco, M. (2020). Innovation as the key to gain performance from absorptive capacity and human capital. Technology Analysis & Strategic Management, 32(7), 822–834. https://doi.org/10.1080/09537325.2020.1714578

Pulido-López, A., & López-Salazar, A. (2025). Business internationalization and intellectual capital components: the case of the Colombian manufacturing sector exports. Journal of Intellectual Capital, 26(1), 130-151.

Quintero Sepúlveda, I. C., & Zúñiga Collazos, A. (2025). Innovation capabilities, innovation strategies and performance: An empirical analysis in SMEs. Technology Analysis & Strategic Management, 37(1), 19-34.

Quintero□Sepúlveda, I. C., Gallón□Londoño, L., & Collazos, A. Z. (2024). Systemic relation between innovation capabilities, innovation strategy, and financial performance of small and medium enterprises: Impact of technology trajectory, management obstacles, and investment. Systems Research and Behavioral Science. https://doi.org/10.1002/sres.3027

Radosevic, S., & Yoruk, E. (2013). Entrepreneurial propensity of innovation systems: Theory, methodology and evidence. Research Policy, 42(5), 1015–1038. https://doi.org/10.1016/j.respol.2013.01.011

Restrepo-Morales, J. A., Loaiza, O. L., & Vanegas, J. G. (2019). Determinants of innovation A multivariate analysis in Colombian micro, small and medium-sized enterprises. Journal of Economics, Finance and Administrative Science, 24(47), 97–112.

Roelandt, J., & Andries, P. (2025). From intrapreneurship to entrepreneurship: the role of displacing events. International Entrepreneurship and Management Journal, 21(1), 76. https://doi.org/10.1007/s11365-025-01090-9

Sagaró, N. M., & Zamora, L. (2019). Análisis estadístico implicativo versus Regresión logística binaria para el estudio de la causalidad en salud. Multimed, 23(6), 1416–1440.

Salmerón, R. (2019). Entorno de programación RStudio: regresión con variable discreta. http://www.ugr.es/~romansg/material/WebEco/04-Eco2/Ordenador/R/02_LogitProbit.html

Saltos Briones, G., Odriozola Guitart, S., & Ortiz Torres, M. (2018). La vinculación universidad-empresa-gobierno: una visión histórica y conceptual. ECA Sinergia, 9(2), 121. https://doi.org/10.33936/eca_sinergia.v9i2.1466

Sampedro-Hernández, J. L., & Ojeda, A. N. (2018). Determinantes institucionales para la innovación y desarrollo inclusivo. Propuesta para un análisis de la microempresa en contextos de informalidad institucional. In Economía informal y otras formas de producción y trabajo atípico Estudios para el caso de México (pp. 203–222). Universidad Autónoma Metropolitana.

Sánchez, M. R., & Rotundo, G. Z. (2018). Teoría de dependencia de recursos: premisas y aplicaciones. Ciencia y Sociedad, 43(1), 75–92.

Sharma, A., Sousa, C., & Woodward, R. (2022). Determinants of innovation outcomes: The role of institutional quality. Technovation, 118, 102562. https://doi.org/10.1016/j.technovation.2022.102562

Sime, Z., & Tadesse, G. (2025). The impact of firm-level innovation on labor productivity and employment in selected African countries. Journal of Innovation and Entrepreneurship, 14(1), 9. https://doi.org/10.1186/s13731-024-00450-z

Stojčić, N., Vujanović, N., & Baum, C. F. (2025). Breaking or making futures: How laws and regulations shape innovation in emerging innovation systems. Review of Managerial Science, 19(6), 1743–1782. https://doi.org/10.1007/s11846-024-00806-5

Streeck, W. (2014). How will capitalism end? Essays on a dying system. Verso Books.

Tarapuez, E., Guzmán, B. E., & Parra Hernández, R. (2016). Estrategia e innovaciÃ3n en las Mipymes colombianas ganadoras del premio Innova 2010-2013. Estudios Gerenciales, 170–180. https://doi.org/10.1016/j.estger.2016.01.002

Valencia-Rodríguez, M. (2015). Capacidades dinámicas, innovación de producto y aprendizaje organizacional en pymes del sector cárnico. Ingeniería Industrial, 36(3).

Vélez-Rolón, A. M., Méndez-Pinzón, M., & Acevedo, O. L. (2020). Open Innovation Community for University–Industry Knowledge Transfer: A Colombian Case. Journal of Open Innovation: Technology, Market, and Complexity, 6(4), 181. https://doi.org/10.3390/joitmc6040181

Veselá, D., & Klimová, K. (2014). Knowledge-based Economy vs. Creative Economy. Procedia - Social and Behavioral Sciences, 141, 413–417. https://doi.org/10.1016/j.sbspro.2014.05.072

Villa, L., & Melo, J. (2015). Panorama actual de la innovación social en Colombia. In Banco Interamericano de Desarrollo (pp. 1–84).

Vizcaíno-Salazar, G. (2017). Importancia del cálculo de la sensibilidad, especificidad y otros parámetros estadísticos en el uso de las pruebas de diagnóstico clínico y laboratorio. Medicina y Laboratorio, 23(7–8), 365–386. http://docs.bvsalud.org/biblioref/2018/05/883697/importancia-calculo-sensibilidad-y-especifidad.pdf

Walpole, G., Liu, Z., Clifton, N., & Li, S. (2025). Developing innovation capabilities through Programme Communities of Practice: Evidence from Wales. The International Journal of Management Education, 23(3), 101215. https://doi.org/10.1016/j.ijme.2025.101215

Wang, Y., & Liu, B. (2021). The effect of supplier globalization on firm innovation: a resource dependence theory perspective. Industrial Management & Data Systems, 121(12), 2450–2466. https://doi.org/10.1108/IMDS-01-2021-0070

Zuñiga-Collazos, A., Galvez-Albarracin, E. J., Vera-Jaramillo, F., & Patiño-Giraldo, L. V. (2025). Digitalization, innovation, sustainability and performance: A causal analysis applied to tourism MSMEs. International Journal of Innovation Studies, 9(1), 46-59.

Zuñiga-Collazos, A., Gómez-López, J. M., Ríos-Obando, J. F., & Vargas-García, L. M. (2023). Innovation and public policies as factors to promote the development of tourism organizations in Colombia. RETOS. Revista de Ciencias de la Administración y Economía, 13(26), 341-355. https://doi.org/10.17163/ret.n26.2023.10