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Innovation and Intellectual Capital: Factors for Business Survival

Youseline Garavito-Hernández[1], *Javier Francisco Rueda-Galvis*[1], *Albeiro Beltrán-Díaz*[1], *Lina Rosenda Bonilla Rueda*[1]

Abstract

The objective of this research is to analyze whether intellectual capital and product innovation are significant factors in the survival of Colombian manufacturing companies. So, the research question to answer is: How do intellectual capital and innovation contribute to business survival in Colombian manufacturing? This study employed a quantitative, correlational, and causal approach. It analyzed 7,529 Colombian manufacturing companies that participated in the Technological Development and Innovation Survey, conducted by the National Administrative Department of Statistics. The findings indicate that employees with higher educational levels are more likely to foster product innovation and intellectual property, thereby strengthening the company's innovative capacity and survival over the analyzed periods. Additionally, structural capital, particularly in marketing and design processes, shows a negative relationship with intellectual property registrations, and excessive focus on creativity without strategic integration also can negatively affect business sustainability. Contrary to the Resource-Based View, the mediation effect of innovation on the relationship between intellectual capital and business survival was not statistically significant. This result may be explained by weaknesses in innovation management and organizational culture, as well as limitations in implementing innovations. The conclusions highlight the importance of developing training programs to generate new organizational knowledge. The findings also contribute to the formulation of new public policies that, through tax incentives, subsidies, and access to credit, promote Research and Development and boost the registration of patents and intellectual property. This study is limited by its focus on a two-period window, which prevents an analysis of more dynamic long-term.

Keywords: Innovation; Intellectual property; Intellectual capital; business survival; human resources

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1. Introduction

The disciplinary literature has identified over the years different factors as determining elements of business survival, among which intellectual capital (IC) and innovation stand out as essential components in this process. It has been shown that organizations that invest in IC as a strategic element have a higher likelihood of growing in a sustained way. Others postulate that innovation processes in small and medium enterprises (SMEs) increase the ability to survive economic crises (Cortés-Palacios et al., 2025).

The theory of Intellectual Capital is currently an essential management concept for companies, as it enables the creation of new knowledge that promotes better performance of assets such as brand, innovation, human talent, and customer relationships (Kianto, 2007). As Karagiorgos et al. (2024) argue, knowing how to manage IC radically improves the competitiveness of any organization, as its knowledge and thus the value of intangible resources increase. A fact demonstrated in their study is that companies investing in IC have higher profitability, while those that do not lose adaptive capacity in the market.

Similarly, Audretsch et al. (2024) state that combining R&D and IC processes is a highly beneficial financial strategy that increases business profitability and generates competitive advantages. So, it is undeniable that companies with an innovation culture have more capacity to endure over time, as the IC drives innovation processes at about 20% and allows better adaptation to technological and market changes. Also, AlGhamdi and Durugbo (2021) validate this by stating that organizations with patent registrations reduce the risk of bankruptcy, as they prioritize innovative culture and knowledge management. That is why, to survive in the current global scenario, linking IC strategies and innovation is the pillar for developing competitiveness both locally and internationally (Fan et al., 2026).

In the Colombian context, the manufacturing sector stands out for being dynamic and relevant to the national economy; data confirm this affirmation, demonstrating that its production grew 1.9% and companies increased their sales by 1.8% in 2025 (DANE, 2025). Although, Domínguez (2023) in his study confirms that the 5-year survival rate of companies in the manufacturing sector is only 33.5%. The most relevant factors are a lack of liquidity, inability to access international markets, and difficulty in attracting investment capital, which are closely related to intellectual capital and business innovation.

It means, then, that studying the survival of enterprises in the manufacturing sector must be an important approach in the disciplinary field of organizational management, especially when it has already

[1]University of Research and Development, Bucaramanga, Colombia.
*Corresponding author: ygaravito2@udi.edu.co

been shown that IC and R&D are factors that improve both financial performance and resilience in times of crisis or disruptive situations (Lakhdari & Grine, 2026). Despite this, in Latin America and, particularly, in the Colombian context, this theme has been little studied in depth. Nevertheless, previous studies have used the Colombian Survey of Technological Development and Innovation (EDIT) to study innovation, internationalization, and intellectual capital in Colombian manufacturing companies; however, they did not analyze business survival and tested the mediating role of innovation (Carvache-Franco et al., 2022; Pulido-López and López-Salazar, 2025).

Therefore, this research aims to contribute to reducing this gap through empirical evidence, the formulation of administrative strategies, and the development of public policies to promote R&D and IC as strategic axes for business success. Therefore, this study aims to answer the research question: How do intellectual capital and innovation contribute to business survival in Colombia?

2. Literature Review

In the current global landscape, IC is essential for generating added value and improving productivity, profitability, and business competitiveness, compelling organizations to adopt a dual approach of implementing IQ-related strategies and innovation to promote long-term survival (Abdallah et al., 2025). Thus, The theory of Intellectual Capital (IC) which is an applied derivation of the Resources and Capabilities Theory (RBV) formulated by Penrose (1959), among others, focuses on the efficient management of three key resources which are: the Human Capital (HC), Structural Capital (SC), and Relational Capital (RC); which are assets generating competitive advantages, value creation, and business survival, concept associated with the ability to adapt and overcome the challenges imposed by the market (Kianto, 2007).

In this order of ideas, IC is an intangible asset that supports knowledge generation, which is decisive in creating sustainable competitive advantages. When properly managed, this promotes organizational innovation in all its dimensions (Nguyen et al., 2021). Through the IC, the organization gains access to new knowledge and resources that activate R&D processes and reduce the risks associated with adapting to market changes and new technologies, thereby maintaining continuous evolution (Karagiorgos et al., 2024).

2.1. Intellectual capital in Colombia and business survival

Despite the research gap in Colombia on this subject, there is no doubt that IC is a key factor in innovation and business competitiveness. For example, Rondón-Castillo et al. (2026) describe how IC is a binding factor of technological innovation in Colombian manufacturing companies, and especially show that HC was the most important contributor to innovation in the sector. Zuluaga et al. (2023) note that in Colombia, IC has a significant impact on product innovation in the manufacturing sector, achieved through the intensive use of new technologies, which directly influences process improvement and business model optimization.

Colombian companies investing in IC and R&D are more likely to survive in highly competitive markets, especially by developing advanced technological solutions, which results in SMEs having greater capacity for adaptation and growth when the IC develops collaborative networks with customers, suppliers, and universities (Gómez Rodríguez et al., 2020). Also, Colombian manufacturing companies that have implemented strategies to promote IC have managed to increase their innovative capacities and sustainability, while those that do not face major barriers to competing at a regional level (Hernández Restrepo et al., 2024).

Rosero et al. (2022) conclude that, given the sector's shortcomings in corporate strategies for R&D development, it is essential to structure processes to adopt knowledge management and business innovation as an organizational policy. Finally, Torres et al. (2024) establish that the current competitive capacity of the sector presents great difficulties in generating IC, especially in an environment that demands innovation with new products, processes, and business models, making it necessary to redesign knowledge management strategies that effectively generate an innovative business culture with appropriate technologies and leadership.

Regarding these antecedents, the evidence persists of a gap in studies that directly relate IC to business survival (Ahmad, 2025). The present study aims to help reduce this research gap at the national level by formulating the following hypothesis:

Hypothesis 1: Intellectual capital generates a positive and significant effect on the business survival of manufacturing companies in Colombia.

2.2. Intellectual capital, innovation, and business survival

Martins and Lopes (2024) recognize IC as the strategic asset that most contributes to driving innovation and professional development of employees, because it allows the organization to generate new knowledge to improve production processes and develop products or services that are adaptable to market conditions, reducing financial risks and increasing its competitiveness. It means that IC is a key driver for value creation, insofar as it allows knowledge to create innovative capabilities and adopt new technologies, which make the competitive and financial situation of the company less vulnerable (Ahmed et al., 2024).

About the relevance of each of the components of IC, it is undoubtedly the most relevant HC recognized by the disciplinary literature, particularly in the economics of human capital theory up to the knowledge management theory, which coincide in pointing out its decisive role in competitiveness and long-term business survival (Truong et al., 2024). Malerba and McKelvey (2020) note in their research that organizations that had developed high-level knowledge management processes were able to reduce adaptation times to the COVID-19 pandemic by 40%.

So, the positive influence of competencies and skills developed by HC on organizational performance creates a positive relationship with survival as agents that promote innovation (Beltramino et al., 2022). It is emphasized that companies that know how to manage

the selection, training, and motivation of human talent have a greater opportunity to generate, exchange, and apply knowledge acquired, especially for product innovation (Danial et al., 2026). Although Beltrán-Díaz et al. (2022) warn that traditional management, focused solely on efficiency, can limit innovative capacity, the focus should therefore be on promoting creativity and knowledge generation for business survival.

With SC, its importance lies in the contribution it makes to the improvement of operational and administrative processes, thereby increasing the productivity of human resources and indirectly enhancing income growth (Nguyen et al., 2021). This is how the CH and SC integrate to generate a driving duo that creates new ideas that strengthen the organization's ability to adapt to changing environments and have greater resilience to crises (Xu & Wang, 2018); for example, patent registries protect inventions and facilitate the dissemination of knowledge to create sustainable competitive advantages (Mention, 2012).

Based on RC, previous studies indicate that the construction of solid relationships with Stakeholders generates alliances that allow for better facing the difficulties that arise in the company environment, a condition ratified by Ozgun et al. (2022), by demonstrating that SMEs participating in alliances and collaborative networks manage to reduce the probability of bankruptcy by 35%. It is also evident that the RC builds cooperative scenarios that drive beneficial alliances for organizational performance (van Burg et al., 2022), while increasing levels of customer retention and loyalty in highly competitive scenarios by developing products tailored to customer needs (Mubarik et al., 2022).

This is how the IC integrates with innovation to be the engine that drives organizational adaptability, evolution, and survival by creating mechanisms through which new processes/products/services are developed that are articulated to market needs, and by making companies such as those in the pharmaceutical sector achieve through innovations, increase 22% of the value of their shares on the stock exchange during the period of Covid-19 (Khurana et al., 2022). This is why we implement open innovation through partnerships with stakeholders, universities, associations and research centers using the 3 knowledge flow models that can be Inbound (from outside to inside), Outbound (from inside to outside) and Combined (entry and exit), highlight the importance of structuring networks (internal/external) that allow new knowledge to be created and accessed (Tjahjadi et al., 2024). Therefore, the research hypothesis is:

Hypothesis 2: Intellectual Capital generates a positive and significant effect on product innovation in companies within the Colombian manufacturing sector.

Hypothesis 3: Intellectual Capital generates a positive and significant effect on the intellectual property registers of companies in the Colombian manufacturing sector.

While much of the academic literature focuses on how IC drives organizations' competitive performance, it is essential to recognize its role in establishing conditions for long-term business survival through innovation (Beltramino et al., 2022; Amna Manzoor, 2026). About it, the literature highlight the importance of IC as an agent for survival through open innovation practices focused on creating new knowledge to improve competitiveness and indicators of resistance to changes in a globalized market, which are ratified by Rideg et al. (2023) noting that companies with the highest investment in knowledge management have a 27% higher probability of surviving crises, while Rangel et al. (2020) show that IC-generated knowledge and innovations reduce the risk of bankruptcy by 19%. In this context, the following scenarios are proposed:

Hypothesis 4: Intellectual capital has an indirect effect on the business survival of Colombian manufacturing companies through innovation.

3. Methodology

The type of research is correlational-causal, which analyzes the relationships between variables. To test the hypotheses, the Colombian Survey of Technological Development and Innovation (EDIT), compiled by the National Administrative Department of Statistics, served as the primary source of information. Data from the last two available periods through 2025 were considered (2019-2020 -EDIT X and 2017-2018- EDIT IX). The final sample included 7529 companies, representing the total number of organizations that participated in the questionnaire in EDIT IX.

Then, for the dependent variable, business survival is defined as the ability of companies to remain active and competitive over time, despite the various changes in the market and technological advances. This implies the ability to effectively adapt to the transformations occurring in their environment (Zuluaga et al., 2023). In this study, business survival (ACTIVE) was measured by a dichotomous variable that takes the value of 1 if the company was active in the previous period and continues to operate in the subsequent period; otherwise, the variable will retain its current value of 0. The independent and mediating variables were measured based on the previous period, this was done to allow a reasonable period to evaluate the effect of IC and innovation (independent variables) on business survival (dependent variable).

Mediators as intervening variables account for the relationship between the independent and the dependent variable (Baron & Kenny, 1986); that is, the mediating function of the innovation variable and intellectual property records represents the generative mechanism through which the independent variables, human capital, structural capital, and relational capital can influence the dependent variable, business survival. Table 1 presents the variable descriptions and codes related to the mediating function. It was measured through the total number of innovations of new goods or services and the total intellectual property registrations.

Table 1. Mediating Variable Innovation

Mediating variable	Code
Innovations in goods or services	I1R4C2N
Intellectual property registrations	VI1R8C2

Regarding IC variables, Table 2 lists the dimensions associated with HC, along with their respective descriptions and codes. In this case, if it has the word 'ACTI,' it means that they are employees who have undergone a certain level of training and are dedicated to science, technology, and innovation activities (ACTI). It was measured through the total number of employers with education.

Table 2. Dimensions of the Human Capital variable

Mediating variables	Code
PhD	IV1R1C2
Doctorate ACTI	IV1R1C4
Master's Degree	IV1R2C2
ACTI Master's Degree	IV1R2C4
Specialization	IV1R3C2
ACTI Specialization	IV1R3C4
University	IV1R4C2
ACTI University	III1R4C2
Technologist	IV1R5C2
ACTI Technologist	IV1R5C4
Professional technician	IV1R6C2
ACTI professional technician	IV1R6C4
Secondary education (Complete)	IV1R7C2
Secondary education (Complete) ACTI	IV1R7C4
Integral Vocational Training - SENA	IV1R9C2
Integral Professional Training - SENA ACTI	IV1R9C4
Education and training.	II1R9C2

Table 3 lists the dimensions associated with SC, with their respective descriptions and codes. They are dichotomous variables.

Table 3. Dimensions of the Structural Capital variable

Variables	Code
Infrastructure	II1R3C2
Marketing processes	II1R5C2
Processes related to the acquisition or use of intellectual property	II1R6C2
Engineering processes, design, and other creative work activities	II1R8C2

Table 4 lists the dimensions associated with RC with their respective descriptions and codes. They are dichotomous variables.

Table 4. Dimensions of the Relational Capital variable

Variables	Code
Cooperation with other companies of the same group (conglomerate)	IV3R1C1
Cooperation with suppliers	V3R2C1
Cooperation with customers	V3R3C1
Cooperation with Competitors	V3R4C1
Cooperation with consultants	V3R5C1
Cooperation with universities	V3R6C1
Cooperation with Technology Development Centers	V3R7C1
Cooperation with autonomous research centers	V3R8C1
Cooperation with Technology Parks	V3R9C1
Cooperation with Regional Productivity Centers	V3R10C1
Cooperation with non-governmental organizations	V3R11C1
Cooperation with the Government	V3R12C1

Finally, considering the number of variables and the possible presence of collinearity, a principal component analysis was applied; authors such as Greenacre et al. (2022) maintain that this procedure is appropriate when using multiple independent variables. Given the nature of the dependent variable (based on the hypotheses to be addressed), probit regression and multiple linear regression models were applied, as this variable is dichotomous (Williams & Jorgensen, 2023).

4. Results

First, the results showed that most of the variables have significant correlations, with coefficients ranging from moderate to strong values (values close to 1), which suggests multicollinearity, limiting the possibility of analyzing effects among them (Pearson correlation analysis). Therefore, it was decided to perform a principal component analysis (PCA) to reduce dimensionality and group the independent variables into orthogonal components that reflect the greater variability of the data, thereby eliminating multicollinearity.

For PCA, the eigenvalues were used to determine the number of relevant components following the Kaiser principle. This criterion establishes that only components with eigenvalues greater than 1 should be considered, since they represent an explained variance greater than that of a standard variable. According to this, the first eight components were selected, which together explain 63% of the total variation in the independent variables (see Table 5).

Table 5. Principal components and explained variance.

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	9.356700	653.986	0.2835	0.2835
Comp2	2.816840	0.297581	0.0854	0.3689
Comp3	2.519260	101.047	0.0763	0.4452
Comp4	1.508790	0.194916	0.0457	0.4910
Comp5	1.313870	0.146314	0.0398	0.5308
Comp6	1.167560	0.111751	0.0354	0.5662
Comp7	1.055810	0.0331093	0.0320	0.5981
Comp8	1.022700	0.0982344	0.0310	0.6291

Table 6 shows the variables that make up each principal component. A variable is assigned to a component when it has the highest absolute value in that component.

Table 6. Variables by component.

Components	Variables Intellectual Capital
PC1	Master's Degree (IV1R2C2); Specialization (IV1R3C2); University (IV1R4C2); Technologist (IV1R5C2); Professional technician (IV1R6C2).
PC2	Infrastructure (II1R3C2); Training and education (II1R9C2); PhD (IV1R1C2); Doctorate ACTI (IV1R1C4); ACTI Master's Degree (IV1R2C4); Cooperation with consultants (V3R5C1); Cooperation with universities (V3R6C1).
PC3	Secondary education (Complete) (IV1R7C2).
PC4	ACTI Specialization (IV1R3C4); ACTI Technologist (IV1R5C4); ACTI professional technician (IV1R6C4); Secondary education (Complete) ACTI (IV1R7C4); Integral Professional Training - SENA ACTI (IV1R9C4).
PC5	Marketing processes (II1R5C2); Engineering processes, design, and other creative work activities (II1R8C2); Integral Vocational Training – SENA (IV1R9C2).
PC6	Cooperation with customers (V3R3C1); Cooperation with Competitors (V3R4C1); Cooperation with Technology Development Centers (V3R7C1); Cooperation with autonomous research centers (V3R8C1); Cooperation with Technology Parks (V3R9C1); Cooperation with Regional Productivity Centers (V3R10C1).
PC7	Processes related to the acquisition or use of intellectual property (II1R6C2); Cooperation with other companies of the same group (conglomerate) (IV3R1C1); Cooperation with suppliers (V3R2C1); Cooperation with non-governmental organizations (V3R11C); Cooperation with Government (V3R12C1).
PC8	ACTI University (III1R4C2).

Table 7 presents a correlation model between the selected components and the dependent variable (ACTIVA).). In this case, Pearson correlation is used solely to demonstrate the absence of a relationship between the principal components—rather than their relationships with the dependent variable—given that the latter will be addressed in the regression models. The results indicate the absence of collinearity between the independent variables, allowing the regression model to be adequately developed.

Table 7. Correlations between principal components and the dependent variable (ACTIVA).

	ACTIVA	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
ACTIVA	1,00								
PC1	0,09*	1,00							
PC2	0,03*	0.00	1.00						
PC3	-0.04*	0.00	0.00	1.00					
PC4	0.00	0.00	0.00	0.00	1.00				
PC5	-0.04*	0.00	0.00	0.00	0.00	1.00			
PC6	-0.01	0.00	0.00	0.00	0.00	0.00	1.00		
PC7	-0.04*	0.00	0.00	0.00	0.00	0.00	0.00	1.00	
PC8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

To test Hypothesis 1, the probit regression results showed a positive and significant effect for the principal component PC1 (see Table 8); that is, an increase in the number of employees performing activities other than Science, Technology, and Innovation (STIA) with a master's degree, specialization, university, technologist, and professional technician training increases the cumulative probability that the company will last over time.

On the other hand, negative and significant coefficients are evident for PC3 and PC5, i.e., an increase in employees with completed secondary education and an increase in structural capital related to marketing processes, engineering processes, design, and other creative activities decrease the cumulative probability that the company will last over time.

Table 8. Probit regression testing H1.

ACTIVA	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% Conf.**	**Interval]**
PC1	0.4068317	0.048084	8.46	0.000	0.312588	0.501075
PC2	0.106742	0.065378	1.63	0.103	-0.021396	0.234881
PC3	-0.297034	0.052199	-5.69	0.000	-0.399342	-0.194726
PC4	-0.040337	0.064522	-0.63	0.532	-0.166799	0.086123
PC5	-0.206106	0.074502	-2.77	0.006	-0.352128	-0.060085
PC6	0.058826	0.061947	0.95	0.342	-0.062589	0.180241
PC7	-0.119967	0.068381	-1.75	0.079	-0.253993	0.014058
PC8	0.089142	0.132243	0.67	0.500	-0.170049	0.348333
Innovation of goods and services	0.010038	0.064809	0.15	0.877	-0.116985	0.137061
Intellectual property registrations	-0.000297	0.003519	-0.08	0.933	-0.007194	0.006600
_cons	1.581.142	0.042136	37.52	0.000	1.498.556	1.663.727
Number of obs	7529					
LR $Chi^2(10)$	323.51					
Prob > Chi^2	0.0000					
Pseudo R2	0.0646					
Log likelihood	-23.404.852					

Note: 0 failures and 152 successes are completely determined.

To test hypothesis 2, an optimal negative binomial regression model for count variables was performed (Table 9). The results show that the principal components PC1, PC2, PC3, PC4, and PC6 are significantly related to the innovation in goods and services variables, with p-values less than 0.05. Specifically, the results provide evidence that PC1 and PC4 have the highest coefficients (.3089489 and .4127544, respectively), indicating a greater influence on the innovation in goods and services. In this case, PC1 is related to employees who perform activities other than Science, Technology, and Innovation (STI) and who possess training levels such as a master's degree, specialization, university degree, technologist, or professional technician. On the other hand, PC4 includes personnel involved in STI activities and those who possess training levels such as a specialization, technologist, qualified technician, completed secondary education, and SENA professional training.

Table 9. Negative Binomial regression testing H2 with the goods and services innovation variable

I1R4C2N	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
PC1	.3089489	.0278257	11.10	0.000	.2544116	.3634862
PC2	.1370696	.0578379	2.37	0.018	.0237094	.2504298
PC3	.0937679	.0445499	2.10	0.035	.0064518	.181084
PC4	.4127544	.0593521	6.95	0.000	.2964264	.5290824
PC5	-.0541672	.0550802	-0.98	0.325	-.1621225	.053788
PC6	-.1108188	.0431285	-2.57	0.010	-.1953491	-.0262885
PC7	-.0895373	.0663237	-1.35	0.177	-.2195295	.0404548
PC8	.1288771	.0957808	1.35	0.178	-.0588498	.316604
_cons	-2.75542	.060032	-45.90	0.000	-2.873081	-2.63776
/lnalpha	2.207772	.0854228			2.040346	2.375198
alpha	9.095429	.7769574			7.693273	10.75314
Number of obs	=	7529				
LR chi2(8)	=	466.31				
Prob > chi2	=	0.0000				
Log likelihood	=	-2012.1811				
Pseudo R2	=	0.1038				
Model	**Obs**	**ll(null)**	**ll(model)**	**df**	**AIC**	**BIC**
	7529	-2245.334	-2012.181	10	4044.362	4113.627

Note: The results of the Akaike Information Criterion (AIC) and Bayesian Information

Criterion tests (BIC) showed fundamentally lower values for the negative binomial regression model than for the Poisson regression model, demonstrating that the negative binomial regression model fits the data better compared to the Poisson regression model, so this paper presents only the results corresponding to the negative binomial regression model.

Concerning testing hypothesis 3, the results show that there is a significant effect of intellectual capital on the variable for the principal components PC1, PC3, PC4, PC5, and PC7, as they exhibit statistically significant relationships with this variable, with p-values less than 0.05 (Table 10). PC1, in particular, shows the highest coefficient (.44892), indicating a greater and more significant positive influence on the intellectual property registration variable. In this case, PC1 is related to employees who perform activities other than Science, Technology, and Innovation (STI) and who possess educational levels such as master's degrees, specializations, university degrees, technologists, or professional technicians.

Likewise, negative coefficients are observed for PC3, PC4, PC5, and PC7; that is, when the independent variables increase, the dependent variable decreases. In this case, PC4 and PC5 present the highest coefficients (-.1518059 and -.1464883, respectively). PC4 refers to personnel dedicated to science, technology, and innovation activities with training in Specialization, Technology, Professional Technician, Secondary Education (Complete), and Integral Professional Training – SENA. In the case of PC5, this component groups the variables of Marketing processes, Engineering processes, design, and other creative work activities, and Integral Vocational Training – SENA.

Table 10. Negative Binomial regression testing H3 with the variable Intellectual Property Registrations.

VI1R8C2	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95%Conf.**	**Interval]**
PC1	.44892	.0197271	22.76	0.000	.4102556	.4875843
PC2	.0409355	.0394703	1.04	0.300	-.0364248	.1182957
PC3	-.1264816	.0309512	-4.09	0.000	-.1871448	-.0658184
PC4	-.1518059	.0299669	-5.07	0.000	-.2105399	-.0930718
PC5	-.1464883	.0412017	-3.56	0.000	-.2272421	-.0657344
PC6	-.0133385	.0406949	-0.33	0.743	-.0930991	.066422
PC7	-.1067719	.0419455	-2.55	0.011	-.1889836	-.0245602
PC8	.0196554	.035939	0.55	0.584	-.0507838	.0900945
_cons	.5039783	.0270841	18.61	0.000	.4508944	.5570621
Number of obs	=	7529				
LR chi2(8)	=	2112.91				
Prob > chi2	=	0.0000				
Log likelihood	=	-11412.582				
Pseudo R2	=	0.0847				
Model	**Obs**	**ll(null)**	**ll(model)**	**df**	**AIC**	**BIC**
.	7529	-12469.04	-11412.58	10	22845.16	22914.43

Note: The results of the Akaike Information Criterion (AIC) and Bayesian Information

Criterion tests (BIC) showed fundamentally lower values for the negative binomial regression model than for the Poisson regression model, demonstrating that the negative binomial regression model fits the data better compared to the Poisson regression model, so this paper presents only the results corresponding to the negative binomial regression model.

Finally, for hypothesis 4, the Karlson-Holm-Breen (KHB) method was applied, designed to measure mediating effects with a dichotomous dependent variable (Breen et al., 2021). The results presented in Table 11 support the conclusion that there is no evidence of a mediating effect, as none of the p-values presented in the row are significant. Therefore, Table 11 shows that changes in the innovation variable do not mediate the effect between intellectual capital and business survival in Colombian manufacturing over the analyzed periods.

Table 11. Calculation of the mediating effect using the KHB method.

	ACTIVA	Coef.	Robust Std. Err.	z	P>z	[95% Conf.	Interval]
	Reduced	0.4062099	0.0708463	5.73	0.000	0.2673538	0.545066
PC1	Full	0.4068317	0.0727987	5.59	0.000	0.2641489	0.5495145
	Diff	-0.0006218	0.0189743	-0.03	0.974	-0.0378108	0.0365671
	Reduced	0.1072708	0.0673925	1.59	0.111	-0.0248161	0.2393576
PC2	Full	0.1067424	0.0679404	1.57	0.116	-0.0264184	0.2399032
	Diff	0.0005284	0.0073871	0.07	0.943	-0.0139501	0.0150069
	Reduced	-0.2963603	0.0701325	-4.23	0.000	-0.4338175	-0.1589031
PC3	Full	-0.2970347	0.0701756	-4.23	0.000	-0.4345764	-0.1594929
	Diff	0.0006744	0.0048283	0.14	0.889	-0.0087889	0.0101376
	Reduced	-0.0389005	0.0853685	-0.46	0.649	-0.2062197	0.1284186
PC4	Full	-0.0403377	0.0857321	-0.47	0.638	-0.2083695	0.1276941
	Diff	0.0014371	0.0094657	0.15	0.879	-0.0171153	0.0199895
	Reduced	-0.2063087	0.0580982	-3.55	0.000	-0.3201791	-0.0924382
PC5	Full	-0.2061069	0.0580751	-3.55	0.000	-0.319932	-0.0922819
	Diff	-0.0002017	0.0056503	-0.04	0.972	-0.0112761	0.0108726
	Reduced	0.059724	0.0486612	1.23	0.220	-0.0356502	0.1550983
PC6	Full	0.058826	0.0457548	1.29	0.199	-0.0308518	0.1485038
	Diff	0.0008981	0.0091691	0.1	0.922	-0.0170731	0.0188692
	Reduced	-0.1199634	0.0672339	-1.78	0.074	-0.2517395	0.0118127
PC7	Full	-0.1199678	0.0672727	-1.78	0.075	-0.2518199	0.0118842
	Diff	4.42E-06	0.0012031	0	0.997	-0.0023536	0.0023625
	Reduced	0.0897974	0.1222448	0.73	0.463	-0.1497979	0.3293928
PC8	Full	0.0891422	0.1228535	0.73	0.468	-0.1516463	0.3299307
	Diff	0.0006552	0.0084596	0.08	0.938	-0.0159254	0.0172358

Finally, based on the results, the answer to the research question, "How does intellectual capital and innovation contribute to business survival in Colombia?", can be stated as follows: intellectual capital contributes to the business survival of these companies when they have highly trained employees who perform activities other than science, technology, and innovation (STI). On the other hand, innovation does not contribute to business survival, which can be explained by the low levels of innovation and the lack of intellectual property registration among these companies.

5. Discussion

This research provides evidence that employees with educational levels, especially those with master's degrees, specialization, university degrees, technologists, and professional technicians, have a significant influence on the innovation of goods and services and intellectual property registrations for Colombian manufacturing companies. Results are supported by the Human Capital Theory, which emphasizes the importance of qualified personnel as a promoter of innovation (Segantini, 2024).

This is mainly because the skills and knowledge of employees enable the organization to generate disruptive ideas and apply know-how in creative and design processes (Delgado-Verde et al., 2016). In addition, the results provide evidence of the need to allocate human and financial resources to R&D activities to strengthen organizational innovation, since STI personnel are responsible for generating technical and scientific knowledge to create novel solutions in the development of new products or improvements in production processes (Faraji et al., 2022).

Likewise, results reinforce the contribution of the theories of human capital, organizational knowledge resources, and capabilities by proposing that trained and educated employees are not only relevant for innovation but also for organizational sustainability (Alvino et al., 2020). This is possible by enabling the companies under study to adapt to the current dynamic environment in the post-pandemic context and to make more informed strategic decisions according to the needs and expectations of external customers (Wang et al., 2020). Moreover, the results are consistent with previous literature, which suggests that less educated employees often lack the key skills necessary to address complex challenges, thereby limiting the firm's ability to adapt, compete, and survive (Ahmed et al., 2024).

Concerning structural capital, it is evident for Colombian manufacturing companies that an excessive focus on creative and design activities without integration with strategic processes can negatively affect business sustainability; these results are supported by the organizational contingency theory (Arcidiacono & Schupp, 2024). Therefore, these organizations need to balance their structural capital between creativity (innovation and design) and strategic functionality from the perspectives of operational, financial, and market management to avoid an imbalance in resource utilization, which can negatively affect business sustainability.

Finally, the lack of a significant mediating effect of innovation was evidenced, results that contradict the position of the resources and capabilities theory that proposes innovation as the main bridge between intellectual capital and business sustainability (Beltramino et al., 2022; Díaz-Vega and Gutierrez-Rincon, 2024). There are several reasons why there is evidence of a lack of mediation, one of them could be related to deficiencies in the internal management of innovation capabilities, lack of leadership, and organizational culture focused on value creation (Li et al., 2018); equally it can be explained by the fact that in these companies there are limitations or difficulties at the time of implementation of these innovations (Beltramino et al., 2022); finally, it may also be related to the little innovation carried out by these organizations (Table 12) (Geldes and Castillo-Vergara, 2025), a challenge that may have been exacerbated by the disruptive context of the COVID-19 pandemic, which affect the 2019-2020 period analyzed in this study (Martínez Guerra and Romo Melo, 2024). As a future line of research, it is proposed to investigate how leadership, openness to change, and learning orientation moderate or mediate these relationships, since leaders are the ones who foster collaboration, innovation, and empowerment in employees, factors that can maximize the impact of intellectual capital on business survival and transform knowledge into sustainable competitive advantages over time.

6. Conclusions

The results confirmed that HC with higher education levels and structural capital related to creative and design processes are key determinants. These findings show that focusing on knowledge management and continuous training helps foster organizational innovation. Likewise, it has been indicated that the importance of these organizations lies in having employees with both technical and managerial skills that enable companies to adapt to current challenges.

On the other hand, although innovation did not mediate the relationship between IC and business survival, this result raises questions about other internal or external factors that could influence this relationship, such as organizational culture, leadership, or market conditions. Additionally, these results may be related to the lack of innovation within these organizations.

This research concludes that companies in the manufacturing sector should design continuous training programs to enhance the technical and innovation competencies of their personnel, particularly at the technical, technological, and university levels. Regarding marketing, design, and engineering activities, companies in the manufacturing sector must first ensure that these processes are aligned with their long-term objectives. Likewise, it is essential to promote continuous improvement in knowledge management systems, as these tools facilitate the capture, storage, and utilization of employees' knowledge, particularly for those involved in R&D activities.

Finally, the Colombian government should strengthen fiscal incentive policies, especially those focused on reducing the costs associated with investment in research, development, and innovation, to encourage these companies to develop more R&D activities that are fundamental for innovation. Additionally, create alliances between universities and companies to develop technical and technological training programs tailored to the needs of the manufacturing sector and simplify intellectual property registration processes. This study is limited by its focus on a two-period window, which prevents an analysis of more dynamic long-term.

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