INVESTMENT IN SCIENCE, TECHNOLOGY AND INNOVATION AND ITS IMPACT ON INNOVATIVE PERFORMANCE, PRODUCTS, PROCESSES AND THE MARKET

INVERSIÓN EN CIENCIA, TECNOLOGÍA E INNOVACIÓN Y SU IMPACTO EN EL DESEMPEÑO INNOVADOR, LOS PRODUCTOS, LOS PROCESOS Y EL MERCADO

Óscar Hernán López Montoya[1]
Hernando Augusto Triana Gonzalez[2]
Enrique Antonio Ramirez Ramirez[3]
Alain Castro Alfaro[4]

Abstract

This study analyzed the relationships between investment in Science, Technology and Innovation (STI) activities and innovations in performance (IND); product (INP), market (IM) and process (INP). An explanatory methodological design was used with analysis of variables and structural equations, through a survey of a sample of 1,572 organizations in the manufacturing sector in Colombia. The statistical approach used was that of variance, also known as PLS-SEM**.** This activities has a positive impact on innovative performance, the product, the process and the market. Most studies focus on the performance of new products, thus neglecting the importance of performance in the development of the process and its influence on the market.

Keywords: Innovative Performance; process, market; product; manufacturing companies

Resumen

Este estudio analizó las relaciones entre la inversión en actividades de Ciencia, Tecnología e Innovación (CTI) y las innovaciones en desempeño (IND); producto (INP), mercado (IM) y proceso (INP). Se utilizó un diseño metodológico explicativo con análisis de variables y ecuaciones estructurales, a través de una encuesta a una muestra de 1.572 organizaciones del sector manufacturero en Colombia. El enfoque estadístico utilizado fue el de varianza, también conocido como PLS-SEM. Esta actividad tiene un impacto positivo en el desempeño innovador, el producto, el proceso y el mercado. La mayoría de los estudios se centran en el desempeño de los nuevos productos, descuidando así la importancia del desempeño en el desarrollo del proceso y su influencia en el mercado.

Palabras clave: Desempeño innovador; proceso, mercado; producto; empresas manufactureras

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[1] Doctor en Administración de la Universidad de Medellín. Docente de Planta de la Universidad Tolima, adscrito a la Facultad de Ciencias Económicas y Administrativas. Email: ohlopezm@ut.edu.co ORCID: https://orcid.org/0000-0002-7033-3009
[2] Magister en Finanzas. Docente Catedrático Universidad del Tolima – Colombia. Email: hatrianag@ut.edu.co ORCID: https://orcid.org/0000-0003-1037-9299
[3] Magister en Administración. Docente de Planta Universidad del Tolima – Colombia. Email: earamirezr@ut.edu.co ORCID: https://orcid.org/0000-0002-1024-1516
[4] Magister en Gestión de la Alta Dirección. Investigador de la Corporación Universitaria Rafael Núñez y del Centro de Investigaciones y Capacitaciones Interdisciplinares. Email: alain.castro@curnvirtual.edu.co ORCID: https://orcid.org/0000-0003-1727-7770

Introduction

The increasing propensity of consumers to fulfill their needs and expectations within a highly dynamic market landscape necessitates the formulation of novel strategies by companies. However, to meet this objective, companies require the necessary resources to develop new and improved products or services. However, this necessitates that the organization is continuously engaged in aligning its resources and capabilities with consumer needs and market requirements, which are becoming increasingly demanding for disruptive solutions (Hall & Lerner, 2010; Brown *et al.*, 2012; Kaal & Vermeulen, 2017).

In the current academic landscape, the majority of studies emphasize the performance of new products, while overlooking the significance of performance in process development and its ramifications for the market.

The central question of the research was: what is the relationship between investment in Science, Technology and Innovation (STI) activities and innovative performance and its impact on products, processes and markets?

Theoretical Basis

The theoretical basis of the study is based on resource theory, which states that the performance of organizations can be understood by examining their specific resources, which are characterized by being invaluable, heterogeneous, imperfectly imitable, substitutable and mobile (Barney, 1991). This theory provides a perspective on how organizations gain a competitive advantage over their rivals and how resources can create a sustainable advantage (Penrose, 1959; Wernerfelt, 1984; Prahalad & Hamel, 1990; Barney, 1991; Nelson, 1991; Peteraf, 1993; Teece et al., 1997). The theory is fully consistent with the view that the acquisition of resources and capabilities is a long, progressive and cumulative process. Knowledge-based resources underpin innovation processes (Miller et al., 2007), which depend on resources allocated to a set of activities commonly referred to as “science, technology and innovation activities” (STI). These systematic activities are related to the production, promotion, diffusion and application of scientific and technological knowledge (Cheng and Wang, 2019; Parrilli and Elola, 2012; OECD and EUROSTAT, 2005; Hottenrott and Peters, 2012).

Performance Innovation (PI)

For organizations to create value and position themselves in today's complex and competitive environment, they must adopt an innovative approach to their performance and thus facilitate the innovation of products, processes and the market itself. This capability represents a set of capabilities that allow companies to gain a competitive advantage and achieve success in the market (Moura, 2020).

A review of empirical evidence suggests that organizations that engage in innovation processes tend to achieve significant results. Furthermore, IP has been shown to lead to the creation of both new processes and new products. These results are a consequence of the innovation process, as both are closely related and have a bidirectional relationship (product and process). The creation of a new product requires a change in the process used, and vice versa (Askerov et al., 2018; Hernández et al., 2022; Arévalo et al., 2013).

STI and performance innovation (PII)

Investment in STI has a direct impact on innovation (Griliches, 1979; Pakes and Griliches, 1984; Buesa, Heijs and Baumert, 2010; Crépon, Mairesse and Mohnen, 1998; Malaver and Vargas, 2011). This impact is a consequence of the generation of knowledge that allows the development of innovative processes and products. To facilitate the advancement of innovation processes, companies must have access to sufficient economic resources that allow their development and implementation. It is important to note that investments in research and development (R&D) and in internal scientific and technological activities have been shown to significantly increase performance innovation (PII) (Malaver and Vargas, 2011).

Hence the following gupia conjecture or hypothesis is proposed:
H1. There is a direct relationship between the resources allocated to STI activities and innovative performance.

STI and innovation in production

A product can be defined as any item offered on the market that has the potential to satisfy a consumer need or desire. Furthermore, the product must be interchangeable or usable and can take the form of tangible or intangible goods (Association, 2017). Investments in product-related STI activities lead to improvements in the overall production of the product and its derivatives (Malaver & Vargas, 2011).
H2. There is a positive relationship between investment in STI activities and the impact on product innovation.

Impact of product development on market development

Mankiw (2012) defines the market as a system comprising demanders and suppliers of a specific good or service. Similarly, Bonta and Farber (2002) define the market as the point of convergence between supply and demand. The market encompasses not only those who currently own a good or service, but also those who are willing to buy it and have the necessary means of payment.

The market and the products available within it have been crucial to the growth of companies over time. In terms of market development, as Monferrer (2013) notes, a growth strategy involves decisive actions aimed at new markets (geographic expansion), new customer segments or alternative distribution channels, attracting new customers, and offering new or existing products. It is reasonable to conclude that market and product development are inextricably linked. The market is the primary driver of product development, dictating the need for products that meet consumer needs. In contrast, product development is a key factor in market expansion, as it enables companies to penetrate new segments and territories. Both processes reinforce each other and the success of one depends on the other. This enables companies to grow, innovate and adapt to a changing environment.

H3. The impact of product development or improvement is positively correlated with market development.

The goal of market and process development is to create and implement strategies that facilitate the growth and expansion of a company or organization. The processes addressed in this study are related to productivity and cost reduction. As Medina (2010) notes, the concept of productivity can be understood as the relationship between total output and the resources used to reach that level. In other words, it is how factors of production are used to meet societal needs through the creation of goods and services. For organizations, this is a critical consideration because goods and services that are not produced with high levels of productivity will not be competitive.

From this line of reasoning, it can be inferred that by improving productivity, organizations can achieve more output with fewer resources (including time). As stated by Samuelson & Nordhaus (2000), increasing productivity is crucial for organizational expansion and cost minimization. This is corroborated by Solow (1988) growth model in which he posits that productivity improvements, driven by technological progress, are the primary driver of economic growth and cost reduction. At the same time, Drucker (1999) asserts that productivity is the key determinant of organizational effectiveness. Organizations can reduce costs and improve overall performance by optimizing the management of resources and processes.

Market development is directly related to productivity and cost reduction. Market expansion creates the need to develop products that meet consumer expectations. This, in turn, serves to increase productivity by requiring efficiency in production. Higher productivity enables companies to produce more with fewer resources, which in turn reduces costs and increases competitiveness in the marketplace.

H4. Market development is positively correlated with increased productivity and reduced costs.

Finally, and to answer the research question, the above variables are integrated to determine their relationship with each other in manufacturing SMEs (Figure 1).

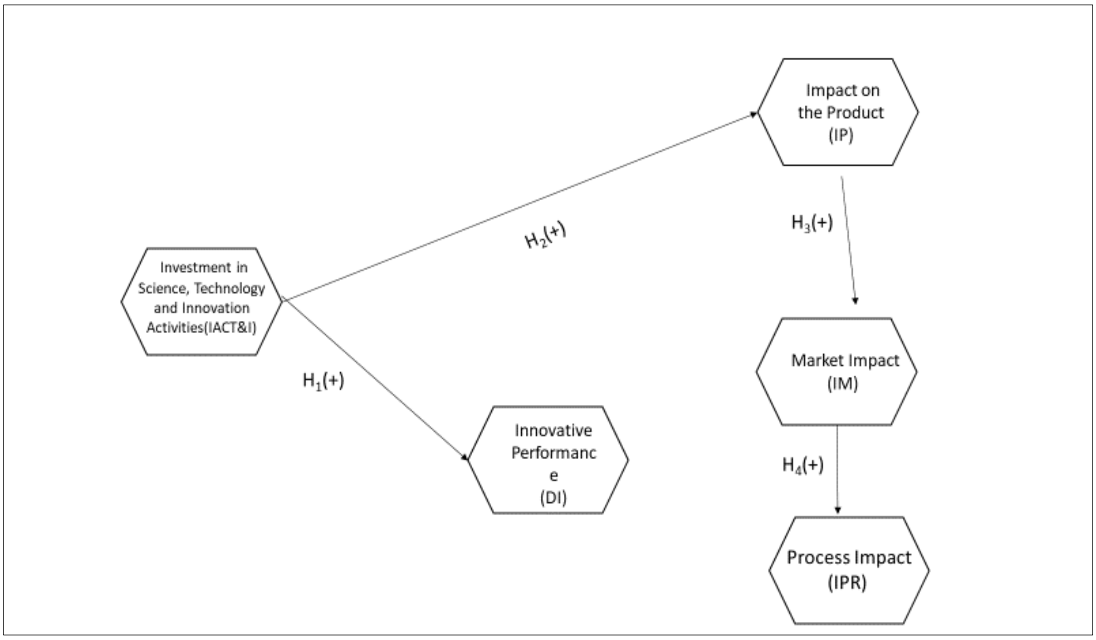

Figure 1. Proposed structural model to analyze the relationship of the proposed constructs

Methodology

Design

According to the classification system of research designs proposed by Ato *et al.*, (2013), the present study can be classified as empirical. This is because it sought to provide an answer to a research problem through the implementation of a concrete strategy based on the formulated research purpose. The study was explanatory to elucidate the influence of STIA and its impact on PI, IP, MI, and IPR. The explanatory design was based on latent variables (LVD).

Participants

The methodology proposed by National Department of Statistics (DANE, 2019), which regularly presents its innovation survey in the manufacturing sector, has been adopted. This methodology establishes a baseline for the innovation climate in this sector. For this purpose, the study considers Colombian industrial manufacturing companies with a minimum of 10 employees. A questionnaire entitled Survey to Measure Technological Development and Innovation in Manufacturing Companies (DANE, 2019) was administered to the aforementioned companies.

Sample

The present study adopted the proposal put forth by Kock and Hadaya (2018). With an assumed power of 80% and a significance level of 1%, the minimum sample size will be calculated using the following equation:

ηmin > 3.168| Pmin|2 Replacing for Pmin= 0.1

The minimum value of the parameter is given by ηmin = 1004. In light of the aforementioned considerations and the size of the sample, the decision was taken to retain 1.572 companies**.**

$$\eta_{min} > \left(\frac{3.168}{|\,P_{min}|}\right)^2$$

Instruments

The EDIT IX survey on Technological Development and Innovation of manufacturing companies (DANE, 2019) was employed. Table 1 presents the selected indicators for measuring the variables under investigation.

Table 1. EDIT IX questionnaire indicators

Identifier	Indicator
Investment in Scientific and Technological Activities	
STIA01, STIA02	The objective of the work conducted within the organization is to augment the corpus of knowledge and thereby cultivate the capacity for the development of novel or enhanced products or services for the years 2017 and 2018, respectively.
STIA03, STIA04	The acquisition of plant and equipment for the creation of new or improved products or services for the years 2017 and 2018, respectively.
Impact on the product	
IP01, IP02	Advancement and expansion in the quality of new or improved goods or services
Impact on the process	
IPR01, IPR02, IPR03	Increase in productivity, reduction of labor costs, and reduction in the use of raw materials or inputs, respectively.
Impact on the Market	
IM01, IM02	The company maintains its geographic market share and enters entirely new markets.
Performance innovation	
PI01, PI02	Number of innovations in new and improved goods or services

Statistical analysis

The equation technique was used to test the hypotheses. The procedure proposed by Hair *et al.*, (2022) suggests the analysis of two models, the measurement model and the structural model (Fornell and Larcker, 1981).

Results

Evaluation of the measurement model

The dimensions of relationships with CNS&T were considered constructs with reflective measures. Table 2 presents the external burdens associated with each indicator. As can be seen in Table 2, all the indicators associated with each of the proposed constructs were found to be significant. Subsequently, the methodology proposed by Hair *et al.*, (2022) was used to evaluate the measurement model.

Table 2. Measurement model with significant indicators

Variable	External Loads	t-value
STIA		
stia01	0.856	11.324
stia02	0.669	6.766
stia03	0.689	9.288
stia04	0.741	10.020
Performance Innovation		
pi	0.787	11.019
pi	0.822	11.275
Impact on the product		
ip01	0.856	59.770
ip02	0.868	87.064
Impact on the market		
im01	0.885	105.74
im02	0.821	66.408
Impact on the process		
ipr01	0.836	46.930
ipr02	0.777	40.023
ip03	0.739	31.490

Cronbach's alpha and composite reliability

Most constructs have a value greater than 0.600. Despite the low alpha coefficient observed for the Performance Innovation construct, the indicators that comprise it are maintained due to the excellent alternative measures that have been identified to validate reliability. A complementary measure is the composite reliability, which is interpreted in a similar way to Cronbach's alpha. As illustrated in Table 3, the indicators have values between 0.786 and 0.843 (Hayduk & Littvay, 2012).

Convergent validity

It refers to the degree to which a test is positively related to alternative measures of the same construct. Consequently, high external loadings for a construct indicate that the associated indicators have a substantial degree of similarity, which is reflected in the construct. The AVE (average variance extracted) is used to assess this validity. The proposed constructs show values greater than 55.1%. This indicates that each latent variable explains a significant proportion of the variance associated with the indicator (see Table 3).

Discriminant validity

It is defined as the degree to which a construct is distinguishable from other constructs. The HTMT ratio of correlations was used as an assessment criterion for discriminant validity, as it is the most appropriate measure in PLS-SEM (Henseler et al., 2015). As an alternative approach to improve the reliability of the statistic, the bootstrap procedure was used, which yielded the distribution of the HTMT statistic. From this procedure, a confidence interval (with a confidence level of 95%) was obtained within which the true value of HTMT can be expected to fall. Therefore, the interval does not have a value of 1, which allows to conclude that discriminant validity exists and that the proposed constructs are adequate (Hair et al., 2022).

Table 3. Measurement model evaluation

	Alpha	CR	AVE	PI	IM	IP
Investment in STI&AI	0.729	0,829	0.551			
IP	0.612	0.837	0.837			
IM	0.631	0.828	0.729			
IPR	0.698	0.828	0.616			
HTMT (Heterotrait-monotrait Ratio)						
Investment in STI&AI				*[0.142; 0351]		*[0.048;0.162]
IP					*[0.459;0.561]	

*Alpha: alpha coefficient; CR, composite reliability; AVE, average variance extracted; STI&IA: Science, Technology and Innovation Activities; PI: Performance Innovation; IP: Impact on Product; IPR: Impact on Process; IM: Impact on Market; *: 95% Confidence Intervals.*

Evaluation of the structural model

To evaluate the structural model, the proposal made by (Hair *et al.*, 2022) was used. The collinearity of the structural model is evaluated, and then the significance and relevance of the model's relationships are assessed. Repeatedly, the R2 is evaluated, as well as its predictive significance and the effect of f2 size.

Evaluation of structural model collinearity

The Variance Inflation Factor (VIF) was used, where multicollinearity occurs when there is a correlation between multiple independent variables of a model. The consequence of this correlation is that it can negatively affect the results of the regression. Therefore, the VIF can estimate the degree to which the variance of a regression coefficient is inflated due to multicollinearity.

Relevance of model relationships

This measure shows the strength of the relationships between STIA, IP, and the impact on PI, MI, and IPR. These standardized values range between -1 and +1. As can be seen, the weights of the relationships are significant, indicating the validity of the model proposed (See table 4).

To evaluate whether these standardized coefficients are significant, a procedure called Bootstrapping is used. It selects a large number of subsamples with replacements randomly drawn (at least 5,000) from the original sample. Another indicator is the confidence intervals constructed using the bootstrapping procedure. Using a 95% confidence interval, the central idea is that this interval does not contain zero, as can be seen in Table 4.

The coefficient of determination and effect size (f²)

The model exhibits an R^2 of 0.260. As indicated by Hair et al., (2022), this level of explanatory power is considered satisfactory and is used to determine whether an omitted construct can exert an influence on the endogenous constructs. To do this, one can look at the influence of product development on improving the quality of goods or services and expanding the range of goods or services, which in turn affects the market, in terms of maintaining market share and the potential for entry into a new geographic market (see Table 4).

The final indicator for evaluating the structural model is Predictive Relevance (Q2)

This indicator represents the final stage of the evaluation process for the structural model. The same approach was proposed by Geiser (1974) and Stone (1974) to measure such relevance. This value is calculated via a procedure referred to as "blindfolding" that employs cross-validity redundancy. This indicates that the impacts generated by the investment in science, technology, and innovation predict the results on IP, and a similar relationship can be observed with the PI. Similarly, product management is also able to predict the behavior of the market. Consequently, the impact on output predicts the effects of increased productivity, reduced labor costs, and the use of raw materials or inputs. This is the case because the value in question is greater than zero. Please refer to Table 4 for further details.

Table 4. Analysis of structural model indicators

	PI	**IP**	**IM**	**IPR**	**Predictive Relevance Q2**
Performance Innovation					0.026
Impact on product			*0.510 **25.337 ***[0.461;0.554] ****0.352		0.006
Impact on process			****0.110		0.057
Impact on the Market				*0.315 **13.355 ***[0.253;0 369]	0.187
Investment in STI&AI	*0,216 **5.615 ***[0.123; 0.304] ****0.049 ****0.010	*0.102 **4.705 ***[0.028; 0.148]			

*PI: Performance Innovation; IP: Impact on Product; IPR: Impact on Process; IM: Impact on Market; *: Model loadings; *:t-value*: ***: 95% Confidence Intervals. ****: Effect size f2*

Discussion

The hypotheses were tested and proved correct, while the results support the existing theoretical framework on the relationship between these constructs, aligning with the empirical evidence observed in the Colombian manufacturing companies analyzed. The contribution to the knowledge base on the variables under study in the Latin American context, particularly on open innovation, is notable. The research underlines the central role of STIA in open innovation (PI) processes, both in terms of inputs and outputs, and its impact on PI, IM and DPI. This ultimately demonstrates that such investment catalyzes the improvement of manufacturing companies' performance.

The results indicate that investment in activities to increase the volume of knowledge) and the acquisition of assets associated with innovation processes allow the generation of new capabilities that result in the generation of new products, processes and services for customers (Cheng & Wang, 2019; Parrilli & Elola, 2012; Hottenrott & Peters, 2012). This is because the generation of new knowledge (a key element in open innovation) is vital to achieving better PI (Griliches, 1979; Pakes & Griliches, 1984; Buesa, Heijs, & Baumert, 2010; Crépon, Mairesse & Mohnen, 1998 and Malaver & Vargas, 2011).

Secondly, it can be posited that such investment in STIA has a positive impact on the quality of new goods or services and the expansion of the supply of new or improved goods or services. While there are instances of open innovation where resources (of all types) to advance innovation processes can be sourced from external sources, it is also evident that when internal innovation processes are undertaken in the manufacturing companies that are the focus of this study, investment represents the primary source that provides the necessary resources to advance such processes (Acemoglu, 2008; Edquist, 2017). It is precisely for this reason that manufacturing companies allocate the majority of their resources to the improvement of existing products and services, given the considerable resources required to generate entirely new products (Maldonado & Portilla, 2020).

Third, the generation of new or improved products and services has a significant impact on the market (Arévalo *et al.*, 2013). This impact can be observed in the ability of manufacturing companies to maintain their participation in existing markets or to enter new ones. In light of the economic contraction in developing countries, it is of paramount importance for these companies to achieve the requisite growth. It is noteworthy that some firms can maintain their market position despite the challenging conditions of intense competition and uncertainty.

The final element associated with the results obtained is that, due to the continuous contact that manufacturing companies have with their customers, it is to be expected that they will respond to the demands of their consumers. As a result of process improvement, costs are reduced (Samuelson & Nordhaus, 2000). Among the factors identified as influencing the processes is an increase in productivity, a reduction in labor costs, and a decrease in the utilization of raw materials or inputs (Samuelson & Nordhaus, 2000; Tello, 2017; Crespi & Zuniga, 2011; Askerov *et al.*, 2018; Hernández *et al.*, 2021; Arévalo *et al.*, 2013).

A comprehensive review of the literature reveals a significant gap in the assessment of the impact of innovative performance, as the majority of studies do not address this crucial aspect. The majority of studies focus on the performance of new products, neglecting the significance of performance in process development and its influence on the market (Kusunoki *et al.*, 1998; De Brentani and Kleinschmidt, 2004; Frishammar and Hörte, 2005; Chen *et al.*, 2006; Kleinschmidt *et al.*, 2007; Urgal *et al.*, 2011). In these studies, the relationship between STIA investments is considered not only in terms of their impact on products but also in terms of their impact on processes and the market.

Conclusions

From a managerial perspective, the findings have practical implications for the various agents involved in the management of manufacturing companies. First and foremost, exemplary innovative performance, particularly through this mode of open innovation, offers the potential for revenue generation that can then be reinvested in resources for a range of projects. Secondly, the government must receive the backing of manufacturing companies to meet the demands of the public. Current policies are unable to achieve this. It is therefore evident that the scientific, technological, and innovative development of companies is of vital importance to improve the quality of life of the general public.

The hypotheses were not falsified and, on the contrary, the necessary and imperative need to achieve a relationship between investment in science and technology activities, innovative performance and its impact on product, process and market innovation.

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