Innovation in Latin America and the Caribbean from Advanced Human Capital: Contribution to the Development of Patents in Emerging Countries

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Abstract
This paper uses data collected from the Ibero-American and Inter-American Network of Science and Technology Indicators (RICYT) and the World Intellectual Property Organization (WIPO) and statistically processed using Spearman's bivariate correlation procedure and multiple regression analysis to examine the contribution of a series of variables of the advanced human capital to the innovative performance measured by patenting in Latin American and Caribbean (LAC) economies. These findings establish relationships between patents and R&D expenditure; personnel dedicated to R&D; the number of researchers; and the number of doctoral students, but not higher education expenditure. The combination of advanced human capital factors that optimize the generation of patents in LAC can be identified. Although patenting is an indicator of innovation that has been analyzed, further research supporting it in terms of human capital measured in Latin American and Caribbean countries is needed.

Keywords: Innovation; human capital; patents; Latin America and the Caribbean

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1. Introduction

It is widely acknowledged that innovation generates economic development and growth, improving the competitiveness of firms and nations, and therefore has a prominent place in the strategic agenda of most of them (Fernández et al., 2011; McGuirk et al., 2015; Melendez et al., 2019). On the one hand, competitiveness is manifested in two areas: operational efficiency within the organization, referring to the resources and technological capabilities, productivity, specialization, and knowledge developed therein. On the other hand, the market considers creativity, quality, and other qualities that distinguish it, resulting in new or improved products, services, or processes. Consequently, in any of its dimensions, the prosperity of a company and territory is linked to innovative performance based on the accumulation of knowledge, i.e., the level of human capital it has.

Boschma (2004) adds that it is based on the knowledge that a firm, sector, or territory can generate a competitive advantage that others cannot easily imitate. The "non-visible" elements will be the drivers for creating and maintaining these sustainable advantages over time (Sáenz, 2011). Thus, human capital is a potential source of innovation. According to Bontis et al. (2002), it is the primary input for innovation and strategic renewal, while Sánchez et al. (2007) state that the characteristics and endowment of human capital will determine the latter.

Since the development and innovation levels in Latin America and the Caribbean are not high compared to those of developed countries, the purpose of this research is to approach the understanding of innovative performance, measured from the generation of patents in a group of countries in Latin America and the Caribbean (LAC) from the contribution of advanced human capital, based on a series of observable variables that compose it. This article is a contribution to the study of innovation in countries of the region, considering that although there is interest in studying the phenomenon of innovative activity (Baptista, 2018; Quintero et al., 2021), there is little research that addresses the determinants of patenting in this territory (Garavito & Rueda, 2021; Juliao et al., 2015).

Given the multidimensionality of innovation, the process to which this study refers is not unique. It requires considering the correct assessment of an output indicator or innovation product, in this case, patenting, along with the factors that promote it.

In terms of its structure, the document first presents a theoretical review that supports the model's presentation and hypotheses. Subsequently, the research methodology is described, followed by the presentation of results and discussion. Finally, conclusions and implications are provided.

2. Literature review and hypotheses

2.1 Innovation and human capital

As a key element in the socioeconomic development of a nation, innovation is increasingly less dependent on the accumulation of traditional factors. It is associated with knowledge-based economies (Fernández et al., 2011). The results differences between companies or countries are not only based on the possession and exploitation of their tangible assets. However, they are also subject to the stocks of knowledge and the capacity to use them to generate new knowledge. Thus, knowledge is added to the traditional factors of production, allowing the leverage of innovation and the growth of organizations and territories. Innovation is recognized as a promoter of competitiveness and an essential element of economic growth (Burhan et al., 2017; McGuirk et al., 2015; Melendez et al., 2019).

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For Aguilar-Barceló & Higuera-Cota (2019), it is evident that "innovation is especially relevant for the development and competitiveness of emerging economies" (p.9), the authors add that innovation will be the differentiating factor when address the various challenges that these types of territories present. In Latin American countries, "the successful exploitation of new ideas can lead to various forms of greater organizational or social benefits" (Zapata-Cantu & González, 2021, p.4).

Guarnizo (2018), meanwhile, in a study that analyzes for the years 1980 to 2015, the relationship between economic growth and human capital in a Latin American country such as Colombia, concludes that, mainly in the long term, this variable has a significant degree of incidence on the productive development and economic performance of nations. Sveiby (2000), whose contributions to the measurement of intangible assets are recognized, stresses the need for people and organizations to invest in their talent, in developing their capabilities and skills as necessary conditions for generating changes and adaptations to the volatile environment. The management of the business ecosystem has thus moved from the management of resources to the management of capabilities, where the creation, absorption, exchange, and use of knowledge, and the interrelation with those who also develop it, take precedence (Ibujés-Villacís & Franco-Crespo, 2022).

Consequently, there is a consensus that knowledge management, transferred to the concept of human capital, is the most relevant strategic resource of nations pivotal to business development, efficiency, and innovation (Vedia-Jerez & Chasco, 2016).

Human capital becomes a driver of change in developing countries, since it equips employees with new skills and knowledge essential for business innovation. According to Ibujés-Villacís & Franco-Crespo (2022), business management oriented towards innovation is determined by a series of constructs, which requires the understanding of a systemic vision that essentially includes the management of knowledge and the innovation capabilities derived from it. This resource played a fundamental role in promoting innovation in developed countries and generating competitive advantages for their companies (Torrech et al., 2017).

2.2 Patenting as a measure of innovative performance

Given the difficult task of reaching agreements on measuring innovation, it is essential to highlight that a systemic approach is currently considered, encompassing not only innovation inputs but also concrete results (Baptista, 2018; Juliao et al., 2015). Following this approach, several authors validate the number of patents registered by countries as a measure of innovation (Aguirre et al., 2021; Castillo-Esparza et al., 2022; Parrilli, 2010).

Research by Arredondo-Trapero et al. (2016) and Ochoa et al. (2021), validates the use of patents to characterize the innovation of countries of the Pacific Alliance (PAL) and LAC respectively, based on the Global Competitiveness Index presented by the World Economic Forum, which includes patents as an indicator of innovation. Burhan et al. (2017), who analyzes patents as a measure of innovation in India, also a developing country, proposes that patenting rates and even the propensity to patent are considered acceptable indicators to measure technological innovations. Jensen et al. (2007) suggest that patents measure results though they correspond to an intermediate innovation product. In comparison, García (2017) states that they represent a small part of the multiple events involved in the complex phenomenon of innovation.

It is important to mention that other authors see patenting as an imperfect indicator of innovative activity, considering that not all inventions are patentable and differ in the level of novelty and usefulness and the dispersion in the economic contribution derived from them (Calderón-Martínez, 2014; García, 2017). They add that while in highly developed countries, advanced human capital, mainly associated with the scientific and technological context of universities and research centers linked to them, successfully transfers new knowledge and capabilities to the productive sector, materialized in patents, licensing, or other intellectual property mechanisms, in developing countries, there is a lack of infrastructure and information systems to promote it at all (García, 2017). Nonetheless, the patent quota is perceived as a territory's efforts to improve its innovative performance, which, as pointed out by Juliao et al. (2015), the possibility of patenting depends initially on the generation of innovations that can be legally protected, i.e., recognized as inventions or knowledge generation. The formulation and use of patents are where knowledge creation and transfer and its contributions to technological development can be observed (Castillo-Esparza et al., 2022). Patents guarantee a minimum level of originality, in addition to presenting a high probability of becoming an innovative product (Buesa et al., 2002).

Considering patenting as an indicator of innovation requires reflecting on the context and the political and economic conditions present in the countries of Latin America and the Caribbean, since these become facilitators or obstacles to the innovative dynamism that reaches the territories (Aguilar-Barceló & Higuera-Cota, 2019). Zapata-Cantu & González (2021), citing Schumpeter's contributions, point out that innovation depends on the economic, political and governmental conditions of the environment in which an organization interacts, in addition to the capabilities, resources and internal business configuration it has. According to Loray (2017), "in LAC there is a greater emphasis on science, technology and innovation in terms of intentions than what is represented in the sphere of politics, finances and institutions in each of the countries" (p.73). The author adds that STI policies have had to adjust to the political-economic context of the region characterized by periods of uncertainty and instability presented.

Certainly, LAC countries are not homogeneous, they present differences - in some cases significant - in levels of income and human development (Aguilar-Barceló & Higuera-Cota, 2019). However, they share a series of characteristics. Many researchers who have analyzed the innovative dynamics in different countries from the region, identify a series of common aspects, which explain the lags in the innovation capacity compared to others countries (Quintero et al., 2021). According to the RICYT report (2022), in LAC countries, the efforts

and results in innovation are significantly lower than those recorded in developed countries. Despite this, it is highlighted that the region has great unexplored potential.

In general, there are structural economic limitations, financial barriers and restrictive budgets for science and technology. (Arredondo-Trapero et al., 2016; García, 2017). In some countries, economic volatility and informality have reduced the expected levels of innovation (Heredia et al., 2019). The lack of innovation management in the business ecosystem is acknowledged (Ibujés-Villacís & Franco-Crespo, 2022) and also the weak link between the scientific-technical system and the economic-social system, typical of the historical disconnection between the institutions and companies, created in isolation. According to Jiménez & Geldes (2019), strategies that promote innovation by the public sector have not been efficient, since they do not consider the company as a key element within the innovative process.

In addition to this, there is a dependence on exogenous technological change and innovation supported by the acquisition of technology incorporated into capital goods (Heredia et al., 2019). Inadequate labor and tax regulations, political instability and even corruption are factors that hinder innovation, and authors such as Astudillo & Briozzo (2021) identify in countries just like Argentina and Ecuador. According to Silva et al. (2023), other factors that usually discourage patenting are the legal and bureaucratic obstacles that slow down the processes. The authors also add that the lack of financial incentives become a determining factor in involving more researchers in patenting and licensing activities.

Due to the limited empirical evidence from small Caribbean countries regarding their innovative activity, Mohan et al. (2016) analyze the drivers, benefits and obstacles that this territory presents, and indicate that these are not very different from those observed in Latin America. They establish that investment in innovation translates into similar results to those of Latin American countries and that patent protection seems to be less effective than in this territory.

On the other hand, although research that investigates the issue of innovation in LAC countries is scarce, the burgeoning literature allows us to recognize that despite limitations and unfavorable conditions, several economies in the region have improved their innovative performance. Countries such as Argentina, Brazil, Chile, Costa Rica and Uruguay have implemented a series of strategies to stimulate their innovation, hand in hand with the creation or strengthening of their ministerial institutions or special science and technology agencies in order to guide policies and resources to the creation of innovation environments (Zapata-Cantu & González, 2021). A study by Olavarrieta & Villena (2014) collects the numerous challenges that restrict the innovative potential of LAC, however, it highlights the significant advances obtained, including others by Brazil, Chile, Colombia and Mexico. This was fostered by the strengthening of National Systems of Science, Technology, Knowledge and Innovation and reflected in an increase in patenting. It is recognized that in general, patents are presented by institutions that constitute the National Innovation Systems (Burhan et al., 2017), hence their relevance in promoting them.

According to the Economic Commission for Latin America (ECLAC), the region began implementing S&T development policies some decades ago; however, it is only in recent years that it has been oriented toward innovation (Aguilar-Barceló & Higuera-Cota, 2019). The increase in public support for S&T, hand in hand with initiatives financed by the private sector with a focus on R&D has been a differentiating factor (Ortiz et al., 2023). Heredia et al. (2019) agree that the increase in the public budget for innovation projects has accompanied the progress, such is the case of Chile and Peru.

It is evident, then, that although patenting in emerging countries is much lower than in developed nations, as is the case of LAC countries, it still allows us to reflect the concept of innovative effort or flow of new ideas presented in this territory. A study by Baptista (2018) on the capacity to generate science, technology, and innovation indicators measured in a group of Latin American countries presents patent registration as the highest indicator, with 50% of the countries producing and reporting it constantly. According to WIPO's World Intellectual Property Indicators (2022), LAC, in recent years, has registered a slight increase in patent applications, led by countries such as Brazil and Mexico.

From the above, it is evident that for some years, the Latin American and Caribbean territory has demonstrated a level of competitiveness and growing economic development, and although its innovative activity has also increased, this does not seem to correspond to an optimal link between the variables that must be combined for this (Guarnizo, 2018; Jiménez & Geldes, 2019). In this sense, it becomes interesting to address how those factors linked to human capital impact the innovative activity of companies and territories.

2.3 Advanced human capital

Human capital is understood as the driving force that increases the knowledge absorption capacity of an organization and consequently contributes to the materialization of innovation. This is transformed into value for the organization and although it is intangible, it will be evident as tangible in its results (Moreno & Godoy, 2012). There is no doubt that the scope of human capital is also vast in that its accumulation and development have varied repercussions that transcend productive dynamics, addressing the economic, social, and, for a long time now, innovation and competitiveness factors. Accordingly, as early as 1957, Solow postulated that the growth of an economy was the product of labor and physical capital; however, he considered the contribution of an unknown factor or "residual factor," which was implicitly associated with the education of individuals. The improvements in the quality of the labor force resulting mostly from education would be recognized years later as human capital.

It is evident that in the search for tangible results of innovative performance, several authors measure it in the number of patents obtained by an economy, and this is a reflection of the contribution of the various determinants that converge in advanced human capital (Aguirre et al., 2021; Gama et al., 2019). In this sense, according to Gama et al. (2019), who have studied the impact of human capital as an explanatory variable for patenting for 43 countries in the period

from 2000 to 2012, it is concluded that there is a high significant relationship between both variables in technologically developed economies and less in countries present technological underdevelopment. Castillo-Esparza et al. (2022) also demonstrates this relationship, associated with R&D spending as a determinant. Given the above, it is interesting to investigate the explanatory variables of human capital that could significantly determine patenting.

R&D expenditure

Although the impact of investment in Research and Development (R&D) about product and process innovation has been widely explored in developed markets, there is limited information in emerging countries, mainly due to the scarcity of data (Ortiz et al., 2023). Several authors agree that R&D is the source of knowledge generation and its transformation into results, becoming a fundamental axis to promote the innovative capacity of companies and countries (Parrilli, 2010; Seclen-Luna & Morales, 2022). Conclusions from Ortiz et al. (2023) show a positive relationship between R&D and innovation in Latin American companies.

However, even though the concept of R&D expenditure is usually linked to an economic analysis factor and sometimes separated from human capital, in this research, it is considered as an element that constitutes it, considering that "Research and Development comprises the creative and systematic work carried out by individuals to increase the volume of knowledge and devise new applications of available knowledge" (Frascati Manual, 2015, p.30). The results, while depending on the use of financial, physical, and material resources, are contingent on individuals' training, development, and ability. Analyzing innovation by considering only R&D expenditure underestimates the innovative capacity that a company has. Likewise, excluding it, given the impact it has on the generation of knowledge (Mohan et al., 2016).

Therefore, investment in R&D has a significant impact on innovation capabilities (Heredia et al., 2019) and an economy that will witness an increase in technological innovation derived from investment and the specialized human knowledge. (Vedia-Jerez & Chasco, 2016). Mohan, et al. (2016), based on the limited innovation studies available for the Caribbean, conclude that R&D expenditure drives innovation from the production of knowledge that is achieved in companies. They add, in any case, that this input to innovation is far from becoming a guarantee of this, given that companies from countries in transition usually have significant gaps with the technological frontier and do not present formal policies that encourage innovation. Based on the above, the first hypothesis is proposed:

H_1: R&D expenditure, as a factor of advanced human capital, contributes to the development of patents.

Researchers

It is known that innovation reflects scientific and technological activity. It is considered a specific, isolated area that belongs to groups of highly specialized professionals (Baptista, 2018). Vega et al. (2022) point out that an organization's knowledge base includes, among other factors, the level of education and training of its employees.

A couple of decades ago, Bitrán (2002) indicated that economies that are capable of generating a dynamic of value creation based on more significant human capital will attract higher levels of risk capital available on a global scale and induce the immigration of talent, which in turn reinforces a virtuous circle of higher innovation and growth. Given the above, the number of researchers present in a territory, associated with the stock of knowledge they possess and its distribution in science and technology, is considered as an indicator for measuring advanced human capital (Torrech et al., 2017; Vivarelli, 2012).

This variable is often associated with the contribution to innovation from universities. This is frequently observed in developing countries, the majority of the research that results in patenting belongs to higher education institutions or research centers linked (Burhan et al., 2017; García, 2017). Such is the case of Brazil, where universities are acknowledged as the main generator of patents (Silva et al., 2023). Aspects related to the exchange of knowledge, technical-financial support and the affiliations that exist in this ecosystem encourage its acquisition. It is also known that there is a forced separation of these from the business sector. In Chile, 93% of researchers are employed in higher education institutions or linked to them (84% belong to universities) and only 7% work in the business sector (RICYT, 2022). The arguments described support the following hypothesis:

H_2: The number of researchers, as a factor of advanced human capital, contributes to the development of patents.

R&D personnel

Arredondo-Trapero et al. (2016), define it as those individuals who are part of the creation of new knowledge, products, processes, methods and systems, and are involved in the management of innovative dynamics. Guidelines for its measurement are established in the Frascati Manual (OECD, 2015), which defines the criteria for collecting information on the economic and human resources dedicated to experimental research and development. The Canberra Manual (OECD, 1995) defines standards for measuring advanced human capital associated and the generation, research, application, development and management of knowledge and scientific-technical innovation.

Baptista (2018) adds that countries need to have human resources with training and specialization for research and development activities, as well as in the management and design of science, technology and innovation policies. Those unable to carry out research and development activities will have to settle for adopting incremental innovations of smaller magnitude (Leyva et al., 2020). The knowledge generated in a country is the result of the human resource that is working on it (Zamora & Favila, 2018). This approach allows us to suggest the following hypothesis:

H_3: Personnel dedicated to R&D, as a factor of advanced human capital, contributes to the development of patents.

Higher education expenditure

Within the specific context of education expenditure, Castillo-Esparza et al. (2022) point out that an investment in higher education fosters environments that systemically promote innovation.

A substantial investment in the training of human resources and strengthening the education system is imperative to enhance the development of competencies and skills to innovate (Zapata-Cantu & González, 2021), considering that the higher the educational level achieved by the population , the impact will be greater in the production of innovations (Gama et al., 2019). Findings from McGuirk et al. (2015) agree with the above, and reinforce how the change in the proportion of the labor force with tertiary education have been decisive in the innovation results of European countries. They emphasize the significant increase in the proportion of skilled workers along with the increase in the rate of technological change in this territory. However, the lower rates of individuals with higher education in emerging countries are significant and decisive when developing and sustaining innovations.

A positive association is evident between expenditure and education as an input to innovation, and the results derived from it. Aguilar-Barceló & Higuera-Cota (2019) observed this relationship in countries such as Chile and Costa Rica. However, in the case of Brazil, investment in tertiary education has not necessarily led to a sufficient development of intellectual capital and the generation of intangible assets in other Latin American countries. Based on the above, the following hypothesis is defined:

H_4: Higher education expenditure, as a factor of advanced human capital, contributes to the development of patents.

Doctoral students

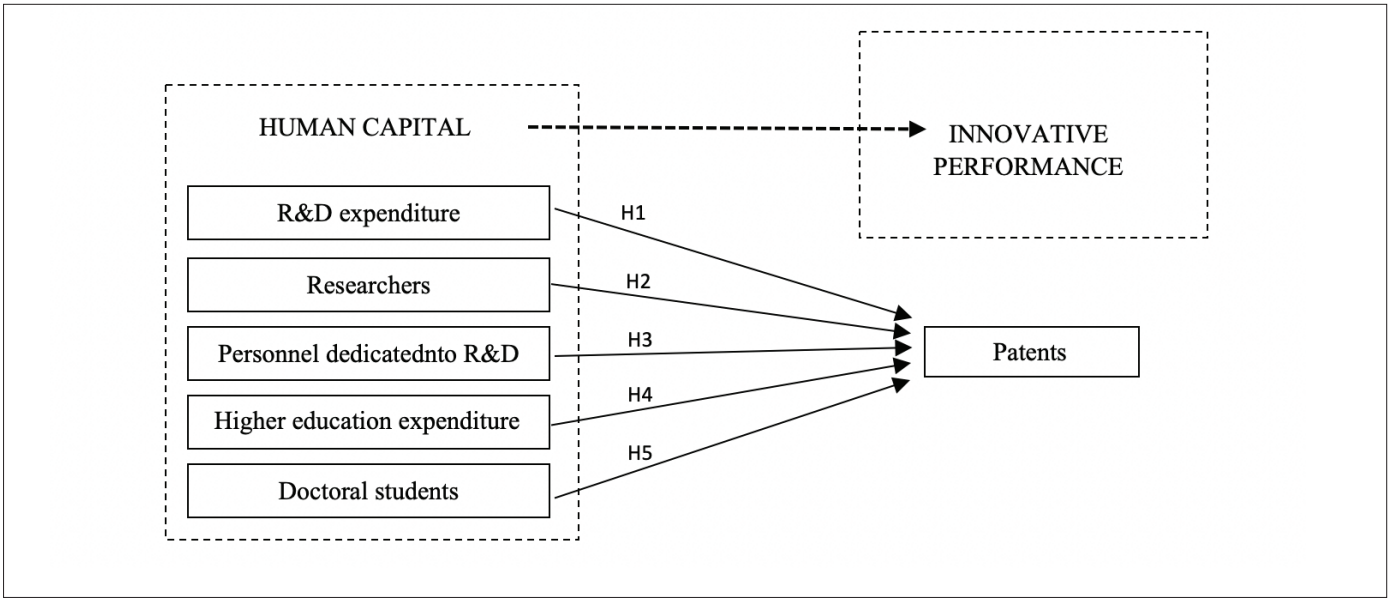
Furthermore, the education level is considered a valid predictor of the knowledge and skills of the population and its extrapolation to the valuation of human capital, considering the impact of training at the highest levels (Dissou et al., 2016; OECD, 2022). Baptista (2018), discussing the training of specialized human resources, states that it is from the 1990s onwards that postgraduate training was consolidated in most Latin American countries, and enhanced interest in developing S&T policies and innovative dynamism. The author declares that education linked to scientific research contributes to new forms of capital, expressed in the increased index of highly educated human capital.

Heredia et al. (2019) observe a significant relationship between the formation of advanced human capital and innovation activities. This association is related to the absorption capacity fostered in postgraduate studies, that allows for the new knowledge to be detected and applied, in order to stimulate innovation. Strategies to promote innovation imply different orientations depending on whether it is a developed or developing country. However, for the latter, the emphasis must be oriented, among other things, to the education of individuals capable of generating and managing knowledge (Aguilar-Barceló & Higuera- Cota, 2019). The previous review allows us to support the fifth and last hypothesis under study:

H_5: The number of doctoral students, as a factor of advanced human capital, contributes to the development of patents.

Based on the above, this research seeks to analyze how advanced human capital (from a set of variables associated with it) favors the innovative performance of an economy measured in the generation of patents. Therefore, the following theoretical model is presented (see Figure 1).

Figure 1. Proposed Model.



Source: Authors' own elaboration

3. Methodology

Methodologically, this is a quantitative, non-experimental research. It has a descriptive and correlational purpose in order to know and inquire about the variables that make up human capital, the relationships between them and patenting. It also considers an explanatory analysis, which addresses how a series of variables contribute to the generation of patents and thus contribute to a better understanding of the phenomenon investigated.

A systematic review of the state of the art was carried out in order to conceptualize and contextualize innovative performance based on the generation of patents in LAC countries, from the contribution of the components of advanced human capital, in order to subsequently develop a series of statistical procedures using SPSS software.

3.1 Sample design and data collection

Data were collected from the report The State of the Science 2022, a report presented every year by the Ibero-American Network of Science and Technology Indicators (RICYT), which, as acknowledged in the Oslo Manual (OECD, 2018) comprises an accepted and internationally comparable source of indicators that follow, in whole or in part, the guidelines of this manual. Meanwhile, the patenting indicator is lifted from the World Intellectual Property Organization (WIPO), a United Nations agency, a global reference source for information on intellectual property. The two records have been validated and used in various research and theoretical-methodological references (Quintero et al., 2021; Seclen-Luna & Morales, 2022; Zamora & Favila, 2018).

The economies listed in Table 1 are considered for optimal comparison, considering the asymmetries in Latin America and the Caribbean due to their political, social, and economic similarities, geographic proximity, and the availability of updated data. Baptista (2018), who analyzes the generation of science, technology and innovation indicators in Latin American countries, reveals the existence of important asymmetries between countries and indicators. She adds that a series of countries do not present information consistently and collected under international guidelines, which makes it impossible to compare them or to include them in a joint analysis. Likewise, the scant empirical evidence available on small island states in the Caribbean is recognized, not only due to the scarcity of studies, but also to the lack of official and updated statistics (Mohan et al., 2016).

Table 1. ALC countries in analysis.

Argentina	Brazil	Chile	Colombia
Costa Rica	Ecuador	Mexico	Panama
Paraguay	Peru	Uruguay	

Source: Authors' own elaboration

3.2 Variables and measures

Based on the literature reviewed, it is possible to consider measuring the innovative performance of a country, based on its level of patenting. Various authors have recently validated its use (Aguirre et al., 2021; Castillo-Esparza et al., 2022; Ochoa et al., 2021). For several decades, human capital has been conceived as a determining factor in innovation. Considering the specific analysis of the variables that compose it and its impact on the innovative dynamics of LAC countries becomes interesting and necessary. Table 2 shows the variables, indicators, and sources of information from which they were extracted.

Table 2. Variables.

Variable	Indicator	Information Source
Innovative performance	Number of patents granted (residents and non-residents) per 1,000 population	World Intellectual Property Organization (WIPO) 2022
R&D expenditure	Percentage of R&D expenditures as a percentage of GDP	Ibero-American and Inter-American Science and Technology Indicators (RICYT) 2022
Researchers	Number of researchers per 1000 population per 1000 EAP	Ibero-American and Inter-American Science and Technology Indicators (RICYT) 2022
Personnel dedicated to R&D	R&D personnel in JCE per 1,000 inhabitants	Ibero-American and Inter-American Science and Technology Indicators (RICYT) 2022
Higher education expenditure	Percentage of education expenditure as a percentage of GDP	Ibero-American and Inter-American Science and Technology Indicators (RICYT) 2022
Doctoral students	PhD students as a percentage of total tertiary education students (ISCED 5,6,7,8)	Ibero-American and Inter-American Science and Technology Indicators (RICYT) 2022

Source: Authors' own elaboration

3.3 Statistical techniques

First, a bivariate analysis uses the correlation test to establish the relationship between the variables. Subsequently, a multiple regression analysis is performed, based on the ordinary least squares method, which allows determining the combination of the factors for measuring advanced human capital, optimizing the estimation of the innovative performance associated with the number of patents granted in Latin American and Caribbean countries.

Multiple linear regression considers the regression equation (1), where yj is the dependent variable, i.e., innovative performance measured by the number of patents granted to each country; β0 corresponds to the constant of the model; x1 is the independent variable called R&D expenditure; β1 weighting factor; x2 independent variable researchers; β2 weighting factor; x3 explanatory variable personnel in R&D; β3 weighting factor; x4 explanatory variable higher education expenditure; β4 weighting factor; x5 as independent variable doctoral students; β5 weighting factor; and εj as residual error of the model. The β parameters allow measuring the average intensity of the effects of the explanatory variables (x1 to x5) on the variable to be explained (yj).

$$yj = \beta 0 + x1\beta 1 + x2\beta 2 + x3\beta 3 + x4\beta 4 + x5\beta 5 + \varepsilon j \qquad (1)$$

4. Results and discussion

Firstly, for the normality analysis, the Shapiro-Wilk test is applied (less than 50 observations), whose p-value must be higher than 0.05, indicating that in this case, the data are not normally distributed (see Table 3), which means that the correlation analysis must be performed using Spearman's test. Table 4 shows the correlations between innovative performance and each independent variable and the bivariate relationship between them.

Table 3. Tests of Normality.

	Shapiro-Wilk		
	Statistic	df	Sig.
Patents granted (total)	,586	11	,000

Table 4. Spearman´s Correlation Matrix.

Spearman´s rho		Patents granted	R&D Expenditure as % GDP	Researchers per 1000 of the EAP	R&D personnel (JCE)	Higher education expenses as GDP %.	PhD students as % of higher education students
Patents granted	Correlation Coefficient	1,000	,445	,582	,691	,059	,693**
	Sig. (2-tailed)		,267	,147	,019	,863	,014
	N	11	11	11	11	11	11
R&D Expenditure as GDP %.	Correlation Coefficient	,445	1,000	,764**	,527	,301	,228
	Sig. (2-tailed)	,267		,011	,096	,369	,501
	N	11	11	11	11	11	11
Researchers per 1,000 EAP members	Correlation Coefficient	,582	,764**	1,000	,645	,405	,465
	Sig. (2-tailed)	,147	,011		,032	,216	,150
	N	11	11	11	11	11	11
R&D personnel (JCE)	Correlation Coefficient	,691	,527	,645*	1,000	,128	,651*
	Sig. (2-tailed)	,019	,096	0,032		,709	,030
	N	11	11	11	11	11	11
Higher education expenditure as GDP %)	Correlation Coefficient	,059	,301	,405	,128	1,000	,062
	Sig. (2-tailed)	,863	,369	,216	,709		,857
	N	11	11	11	11	11	11
PhD students as a % of higher education students	Correlation Coefficient	,693**	,228	,465	,651*	,062	1,000
	Sig. (2-tailed)	,014	,501	,150	,030	,857	
	N	11	11	11	11	11	11

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Consistent with the stated literature (Baptista, 2018; Buesa et al., 2002), it is possible to identify a correlation between the variables associated with advanced human capital and patents granted as a measure of innovative performance. These two variables correlate closely and directly with the percentage of higher education students pursuing a doctorate degree ($r = 0.693$, $p = 0.014$), which coincides with the findings of Heredia et al. (2019), who collects similar references in Chile. The OECD has implied this relationship in its report "Education at a Glance 2022" (OECD, 2022), referring to Brazil with the highest percentage distribution of tertiary education in 2020 and the highest number of patents in the LAC region.

The second highest correlation is identified between patenting and the personnel who carry out R&D tasks ($r = 0.691$, $p = 0.019$).This important finding allows us to strengthen the relevance of this factor in line with what is evident in similar research. An econometric study by Buesa et al. (2002) on the determinants of innovation, which, although carried out in Spain, a country with a different patenting, technological and educational context than Latin America, shows the relationship between the human resources dedicated to S&T and the innovation results obtained. The number of people with doctoral training and dedication to R&D is confirmed as a determinant of patent generation in Mexican universities in the Latin American scenario (Calderón-Martínez, 2014). Results of Ochoa et al. (2021) also confirm a relationship between the capacity to innovate and the availability of scientists and engineers dedicated to research and development in LAC, in a multivariate analysis based on pillar 12th of innovation of the Global Competitiveness Index presented by the Economic Forum World.

These two variables, number of researchers and R&D expenditure have lower correlation with patenting. Otherwise, similar research relates R&D investment and patenting as input and output of innovation with a highly significant correlation (Aguirre et al., 2021). This reflects a positive but moderate relationship. It should be noted that countries with high levels of innovation spend at least 3% on R&D as a percentage of GDP, while in LAC the average is 0.65%, led by Brazil as the only country that exceeds this percentage point (OECD, 2022). In addition, the percentage of researchers (JCE) in LAC represents 4.0% of the world total (RICYT, 2022).

It is interesting to note that the results show a high relationship ($r = 0.764$, $p = 0.011$) between these two variables, R&D spending and the number of researchers within the economically active population, coinciding with Seclen-Luna & Morales (2022), who demonstrate the contribution of investment in R&D to the generation of knowledge thanks to highly specialized human capital in LAC. Despite of this, in a large part of Latin American and Caribbean countries, the gap with the technological frontier that companies present (Mohan et al., 2016) and the distribution of financial and human resources are not necessarily oriented to the development of innovation environments (Zapata-Cantu & González, 2021), this means that the convergence of these two variables does not necessarily trigger innovation, which would explain the moderate relationship that these have with the generation of patents.

On the other hand, doctoral students exhibit a direct connection with the number of people engaged in R&D ($r = 0.651$, $p = 0.030$), coinciding with the relation that research and development have with the postgraduate programs and innovation projects of companies and universities. It is highly common that in developing countries, most of the research that results in patenting belongs to higher education institutions or public and private research centers (Burhan et al., 2017). Doctoral students participate along with the personnel that develop S&T activities aimed at innovation. Heredia et al. (2019) mentionate, it is essentially from doctoral education programs that absorption capacity is developed and important knowledge spillovers are generated that promote innovation.

The exception in the correlations is higher education expenditure (as a percentage of GDP), which has a connection with the number of patents of only 0.059. Although investment in higher education has been identified as a promoter of the creation of environments and the development of innovative capabilities (Castillo-Esparza et al., 2022; Zapata-Cantu & González, 2021), the results of the present study are coinciding with the contributions of Aguilar-Barceló & Higuera-Cota (2019), indicating that in the majority of LAC economies, the increase in budgets aimed at higher education has not managed to generate a significant impact on innovative performance.

In a second statistical analysis, Table 5 presents the results of a multivariate regression; 80% of explained variability is observed ($R=0.897$; $R2=0.805$). The test statistic and the level of significance obtained validate the statistical procedure used ($F= 278.874$; $p<0.00$). Methodologically, the variable expenditure on higher education is not considered in the multiple regression analysis, complying with the basic principle that establishes that there must be some degree of significant correlation between dependent and independent variables. The significance and correlation between the remaining independent variables were analyzed, and it was decided to include them in the model, as no significant multicollinearity problems were perceived.

The innovative performance of a territory, measured in accordance with the number of patents that have been granted, is significantly determined by R&D expenditure, number of researchers, personnel involved in R&D activities and number of doctoral students. These four variables under study are statistically significant and positive ($p<0.05$). Interestingly, as the standardized Beta coefficients show, the four variables that make up human capital have a similar influence on the variable, the number of patents that are intended to be explained as an innovation measure.

Coinciding with the contributions of Castillo-Esparza et al. (2022) and Arredondo-Trapero et al. (2016), the percentage of R&D spending on GDP is highly significant ($p<0.05$), as an essential element for the development of product and/or process innovations that lead to patents. Research in developed nations identifies this as a determinant in the increase in patenting rates. The WIPO indicates that it is imperative that developing countries reduce the low investment in R&D, through investments in key sectors for economic development and policies that foster environments to innovation and proliferation of patents (Aguilar-Barceló & Higuera-Cota, 2019).

Another finding refers to the fact that the number of doctoral students has a significant relationship with the generation of patents and a contribution of 0.463 to the function. This connection is interesting, knowing that the postgraduate training offered in science, technology and innovation within LAC is not high, also recognizing intra-regional heterogeneity in its programs (Baptista, 2018). However, postgraduate training and particularly doctoral training, linked to the innovative efforts of universities, becomes an important source of patent generation in countries in the region (Heredia et al., 2019).

On the other hand, with a contribution of 0.409 to the regression function, the personnel dedicated to R&D is decisive in the results of patenting (p=0.036), recognizing the role this variable has in the ability to innovate a territory (Ochoa et al., 2021). Likewise, there is a significant relationship (p=0.00) and an influence of 0.360 between patenting and the number of researchers that an economy has within its active population. This relationship is also recognized by Baptista (2018), who points out that it was in the early 1980s that research groups connected to the development of scientific and technological capabilities proliferated in countries such as Mexico, Argentina, Chile, Colombia, Uruguay and Brazil, which contributed substantially to the increase in the number of patents that these territories have obtained.

Table 5. Regression model results.

	Patents granted (per 1000 inhabitants)
R	0,897[a]
R Square	0,805
Adjusted R Square	0,801
Std. error of the estimate	0,60280
F	278,874
Sig.	0,000[b]
Constant t-test	2,567
Sig. constant t-test	0,042
Standardized coefficients Beta R&D expenditure (as % GDP)	0,427
t-test R&D expenditure (as % GDP)	3,627
Sig. t-test R&D expenditure (as % GDP)	0,011
Standardized coefficients Beta researchers (per 1000 members of EAP)	0,360
Researchers t-test (per 1000 members of EAP)	6,957
Sig. t-test researchers (per 1000 EAP members)	0,000
Standardized coefficients Beta personnel in R&D (in JCE per 1000 inhabitants)	0,409
Researchers t-test R&D personnel (in CEB per 1000 inhabitants)	2,692
Sig. t-test R&D personnel (in CEB per 1000 inhabitants)	0,036
Standardized coefficients Beta doctoral students (% of students in higher education)	0,463
Doctoral student researchers t-test (as % of students in higher education)	5,426
Sig. t-test doctoral students (as % of higher education students)	0,002

a. Dependent variable: patents granted (per 1000 inhabitants)

b. Predictors: (Constant), R&D Expenditure as % GDP, Researchers (per 1000 EAP), R&D personnel (JCE per 1000 inhabitants), doctoral students (as % of higher education students).

Based on the above and the analysis presented, the correlation between the variables and the multiple regression, we identify which of them optimize the generation of patents, four of the five hypotheses presented are validated. Therefore, the R&D expenditure (hypothesis 1); the number of researchers (hypothesis 2); personnel dedicated to R&D (hypothesis 3) and doctoral students (hypothesis 5) -as factors of advanced human capital - contribute to patenting in Latin American and Caribbean countries. Hypothesis 4 is not supported. Hence, we can propose that the effort associated with expenditure on higher education has not managed to contribute significantly to the innovative performance of these economies, from the perspective of the generation of patents.

5. Conclusions and implications

The current competitive dynamics require organizations and territories to recognize the importance of human capital as an imperative element in their performance and as an enhancer of their capacity for innovation (Leyva et al., 2020), also recognizing it as an element that allows the growth of emerging countries to be accelerated (Arrendon-

do et al., 2016). This research makes a methodological contribution to the understanding of the phenomenon of innovation by developing a correlation and regression analysis allowing the identification of the statistically significant contribution of predictors of advanced human capital on the innovative performance measured in the number of patents presented by certain economies in the Latin American and Caribbean region, a territory in which precisely the exploration of the relationship between human capital and patenting is scarce.

According to the literature review, few articles study a group of countries in this geographical region. Although, innovation involves different processes to be addressed depending on whether it is a developed or developing country, there are no doubts that the management of knowledge and advanced human capital is the strategy to reduce the innovation gap with the developed world. The Organization of Ibero-American States (in Barrere et al., 2012) recognizes developed countries as knowledge economies, and whose empirical evidence reflects that this knowledge is not only the result of the interest of the academic world, but also of government and business. High budgets for R&D and the formation of human capital lead to notable scientific, technological and productive advances. The presence of these variables in a brief and limited form identifies a country as emerging or developing.

The generation of patents is addressed as a valid and interesting indicator to be analyzed, considering that the patent count is not only perceived as an objective indicator, internationally comparable and measuring concrete results but also as a benchmark of progress and technological change at the industrial and national levels (Juliao et al., 2015; Ochoa et al., 2021)

Given the statistical results obtained, this study is consistent and appropriate. The correlational analysis shows that the generation of patents in LAC is mainly intertwined with doctoral training and personnel dedicated to R&D. This is explained, given that both determinants seek to broaden the frontier of knowledge, especially in training associated with the STEM field (Science, Technology, Engineering and Math) where the patenting potential is greater. It is relevant to distinguish the association between the number of researchers and R&D expenditure, a finding that strengthens the recognition that public-private financing is fundamental for research (García, 2017).

Interestingly, higher education expenditure does not show a significant relationship with patenting, which could be determined by the fact that higher education policies in LAC countries are still associated with covering the gaps in the number of students who obtain this level of training and responding to labor market demand and are not necessarily oriented towards the development of science, technology, knowledge, and innovation.

The multiple linear regression analysis allows us to conclude that patenting, as a dependent variable, is determined by the four variables that make up human capital incorporated in this analysis, consistent with studies by Aguirre et al. (2021), Castillo-Esparza et al. (2022) and Silva et al. (2023), also in Caribbean and Latin American countries, in which it is established that the propensity to obtain patents is influenced by some of these factors. We indicate that the standardized beta coefficients of R&D expenditure, the number of researchers, the personnel involved in R&D activities and the number of doctoral students present similar values, which does not allow highlighting which of them could be determining patenting in the region with greater emphasis.

The research has relevant theoretical and practical contributions. From a theoretical standpoint, there is a need to delve into the human capital variables that determine the propensity to develop innovations and obtain patents, all this associated with the study of Latin American and Caribbean countries. It should be noted that according to the availability of data, the study considers a limited sample of LAC countries and characteristics that make them comparable, and although it does not incorporate a detailed analysis of the economic, political or institutional contexts of each of them, it allows a global and analytical view of a complex reality that demands dynamic innovation strategies.

From a practical point of view, the results are a blueprint for designing public policies, business and government strategies aimed at promoting innovation. Although, these must consider the particularities of each country and economic sector, they coincide in that with human capital it is possible to enhance the generation of patents, whenever this is desirable, considering that patenting is warranted by its exploitation, use and social and commercial implications, where in emerging countries there is still a considerable gap in this area.

Efforts to promote innovation at the patenting level involve increasing public-private financing and directing R&D resources to the creation of innovative environments. Strengthening the innovative capacity of companies requires an increase in specialized human resources, capable of getting involved in innovation routines (Bitrán, 2002; Garavito & Rueda, 2021). Although, it is not unknown that these are related to universities or nor to the contribution they make, it is necessary to promote commercial - industrial innovation. In order to achieve this, it is needed an increase in the number of people dedicated to the generation of scientific and technological knowledge, based on their specialization and training in postgraduate programs associated (Calderón-Martínez, 2014; Zapata-Cantu & González, 2021).

Innovative performance is also the result of cultural and geographical synergies that allow, for example, to improve the flow of knowledge among researchers with the limitations of the countries analyzed. As García (2017) points out, innovation requires the formation of techno-scientific conglomerates, which allow the spillover of knowledge and the use of infrastructure for the purpose. It becomes necessary to strengthen the role of multilateral organizations (Loray, 2017) and the articulation of National Innovation Systems, for the design, formation and consolidation of public policies and private strategies of science and technology, in order to promote innovative dynamics of the Latin American and Caribbean territory.

Finally, it is considered advisable to explore other statistical methods provided. For example, the identification of causal relationships among the variables, in order to determine more precisely the contribution of each determinant of patenting, until now somewhat limited by the scarcity of data. Likewise, it opens interest in expanding the comparison with other regions of the world, which allows us to know the dispersions that exist in terms of human capital and generation of patents.

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