

# The Development of Scientific Growth in Latin America and the Caribbean. An Economic and Social Approach

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**Abstract** In Latin American and Caribbean countries, research and developmental processes have been the determinant factors in productivity, innovation, and economic growth since they have contributed to not only a more competitive, and egalitarian society, but also to greater welfare indices, which when factored in aides in problem-solving through the enrichment of scientific knowledge. Economic growth models based on Research, Development, and Innovation (R D I) have had the following objectives: long-term sustainability, stimulation of the creation of new discoveries that have been adding to the improvement of life quality and the production policies of developing territories. This literature review led to the designating of researchers as generating agents of scientific capital and recognizing them as a means of growth and impact in today's society. However, there is no coherence between the materialization of projects and the coverage of current needs in Latin America and the Caribbean, among some government agents along with the lack of prioritization in relation to the current problems of some developing countries.

**Keywords:** *research, academic growth, science, interdisciplinary, economic limitation, underdevelopment, Latin America*

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## 1. Introduction

The development of knowledge in society has highlighted the great importance that innovation and intellectual resources have both as sources of competitiveness and long-term economic development. According to the IDB (Inter-American Development Bank), 2010, the solutions to the most pressing challenges affronted by developing countries, such as climate change, energy accessibility, disease control, among others, increasingly require greater substantial technological progress. [1]

According to the IDB, Latin America and the Caribbean (LAC) have been working on the implementation of adequate means to meet the basic needs of their populations through nutrition and sanitation programs, poverty reduction, universal quality education, and economic modernization. An effort that has helped put into evidence that promoting opportunities provided by technological change in a globalized economy is vital for any emerging economy. Part of this development has been possible thanks to the scientific community that has

taken on different developmental functions such as social, economic, environmental and public health. [1]

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), research has now become the pillar of scientific development; its growth is proven by the professional academic training and the number of university institutions in Latin America that have been working towards the development of scientific application methods material to problem-solving continent-wide.

Taylor and Bogdan, (1992) determined that the application of certain scientific methods depends on how the problems are perceived and the capacitive ability to solve them. Said intellectual capacity is currently being aimed at the identification of vulnerabilities, and at the same time, intervention strategies in the different educational processes, such as in the human, natural, economic, and pure sciences, among others, mediums through which a continual strive to generate innovation processes flourishes. However, despite the low innovation rate in Latin America, its materialization has been recognized in the creation of new products, processes, sectors, and activities that boost transformation and development in a virtuous process of growth in which the

generation of positive changes based on knowledge is increasingly appreciated. [2]

A deeper understanding of this knowledge arises from the implementation of three basic questions that have distinctly marked research approaches in a social context: How is the nature of knowledge and reality conceived? How is the nature of the relationships between the researcher and the knowledge produced? What is the researcher's way of building knowledge? [3]

Based on the above, it is necessary to identify the importance of investment in the researcher education and the implementation of resources in innovation processes, which should go hand in hand with the recognition of the interaction with nature, the needs of society, and intervening discernment of the two. Therefore, this process should not only be reflected in academic setting, but as well as in the ability to execute projects, and in the same breath, in the ability to encourage adherence to public policies in some lagging countries, being this the way attain a better visualization on how to achieve greater contribution to education and scientific training.

The United Nations Economic Commission for Latin America and the Caribbean have stated that innovation policies, in coordination with those of science and technology, are mandatory for efficient linking of efforts from industry, government and academic sectors, which will bring about not only the strengthening of national innovation systems but also synchronization with leading global world economic trends. [4]

Some of the efforts identified in the academic sector have been manifested in the rankings of the best Latin American universities, in which, Rankings. (2019), fourteen Latin American universities are among the top 600 in the world, highlighting that Latin America has to date great recognition across borders, among which, five Nobel prizes in Chemistry, Philology, and Medicine, and twelve more in Literature. [5]

## 2. Academic Evidence

In the last ten years approximately, there has been progressing in the number of university enrollment, as indicated in the total undergraduate alumni, from nearly 1.76 million in 2006 to 2.46 million in 2015. The social sciences fields had the greatest enrollment rate for undergraduate students in Latin America, with 5 out of 10 students coming from said fields. In step, it was noted that the total number of students who completed their doctoral studies in Latin America had significant growth of roughly 23 thousand more students over a nine-year period. Unlike the Undergraduate and Master's degrees, the Ph.D. degrees are distributed evenly among, Natural and Exact Sciences, Social Sciences and Humanities with a rate of 24%, 24%, 21% respectively. [6]

Similarly, according to the Scopus database, the number of articles published in scientific journals registered by LAC authors (Latin America and the Caribbean) between 2006 and 2015 increased 96%, while also highlighting Brazil's growth, the country managed to increase the number of publications in said database by 102%. Latin America also managed to increase its participation by 55%, reaching a score of 7.9% in

worldwide scientific production. In relation to the total number of patents requested in the national offices of Latin American countries, an increase of 32% was achieved between 2006 and 2015, while LAC accounted for 27%. [6]

In comparison with Latin America, within the same time frame, Portugal stood out as one of the most prominent countries in patent production, with an increase of 83%, in comparison to Spain with 14%. In contrast to the above, in LAC the rise was led by Chile with a five-time increase of patent applications while Colombia tripled them, however, its impact was less in relation to total applications in LAC. It should be noted that 9 out of 10 patent applications in Latin America correspond to foreign companies seeking to protect their products in overseas markets. Figure 1, [6].

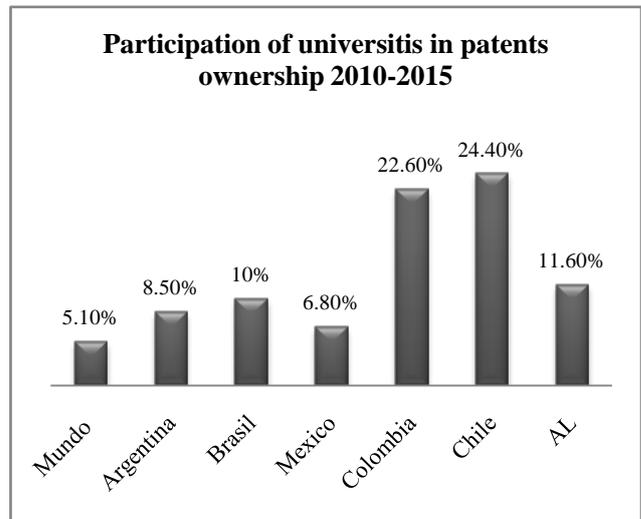


Figure 1. Participation of universities in the ownership of patents 2010-2015

Similarly, the 2015 report of the National Science and Technology Organizations of each country, showed that Brazil concentrated the largest number of researchers, beating Argentina in a 4: 1 ratio. Along the same lines, it was indicated that a tenth of Latin American researchers is mostly Mexican, and to a lesser extent Colombian, Chilean and Ecuadorian Table 1.

Table 1. Total number of researchers in some Latin American countries in 2015

Country	Researchers
Brazil	183,853
Argentina	52,970
Portugal	38,672
Mexico	29,921
Chile	8,175
Ecuador	6,373
Colombia	6,364

According to Mario Albornoz, Coordinator of the Ibero-American Observatory of Science, Technology and Society (OCTS-OEI), the report of the "State of Science" states that the contribution to investment in research and development from companies in industrialized countries is

usually above 60%, while the Latin American average for investment in research is one third, consequently this has generated a very low demand from companies to universities, demonstrating the urgency for support in both the execution and materialization of projects. [6]

The universities of Latin America and the Caribbean have gradually positioned themselves as centers of basic and applied research. This rise is due to greater government support and the creation of policies that fostered innovation. In sharp contrast, according to RICYT (Network on Science and Technology Indicators - Ibero American and Inter-American), one of the characteristics of Latin America has been the low innovation rate of companies and their low involvement in research and development activities. [7]

However, the statistics carried out by the RICYT showed a significant increase in research and development investment in the countries of Latin America and the Caribbean, as well as in the number of people who carry out some type of scientific activity, and hence the results obtained regarding publications. During this period, investment in Research and Development in the region increased by 27%, reaching a large sum of resources which was close to \$ forty billion dollars in 2015. However, in relation to the regional Gross Domestic Product (GDP), the increase accounted for 0.02% in five years, from 0.68% in 2010 to 0.70% in 2015.

Despite the figures, resources were not limited; on the contrary, there was an increase in the effectiveness and success of Latin American research internationally. [7] This can be observed in the number of scientific publications and co-publications at the international level, and as well as in the Scopus database, which showed a

growth of 37% from 2010 to 2015 of articles belonging to Latin American institutions. This growth is not only indicated by the number of publications but also by the participation of Latin America. [8] Figure 2.

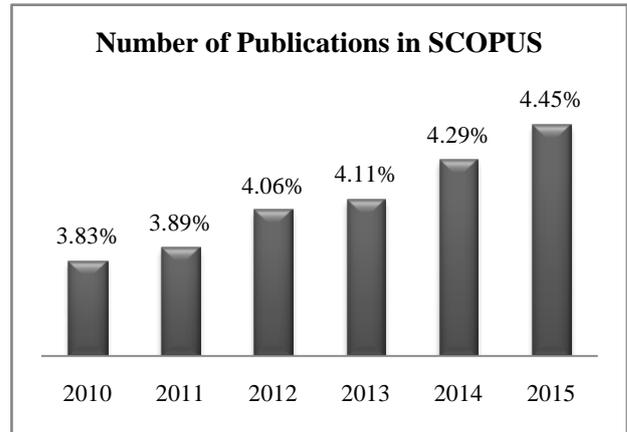


Figure 2. Number of publications in SCOPUS

In relation to the above, it was possible to observe that the number of publications made by Latin American universities on scientific activities has increased since 2010, representing 3.83% of publications and has increased by nearly 1%. This displays a greater scientific activity by Latin American universities.

Upon applying a discriminate analysis on the number of publications by Latin American universities, the University of Sao Paulo pulls ahead of the rest for having the largest number of scientific publications. Worth noting though is that the other Latin American universities show a similar number of publications.

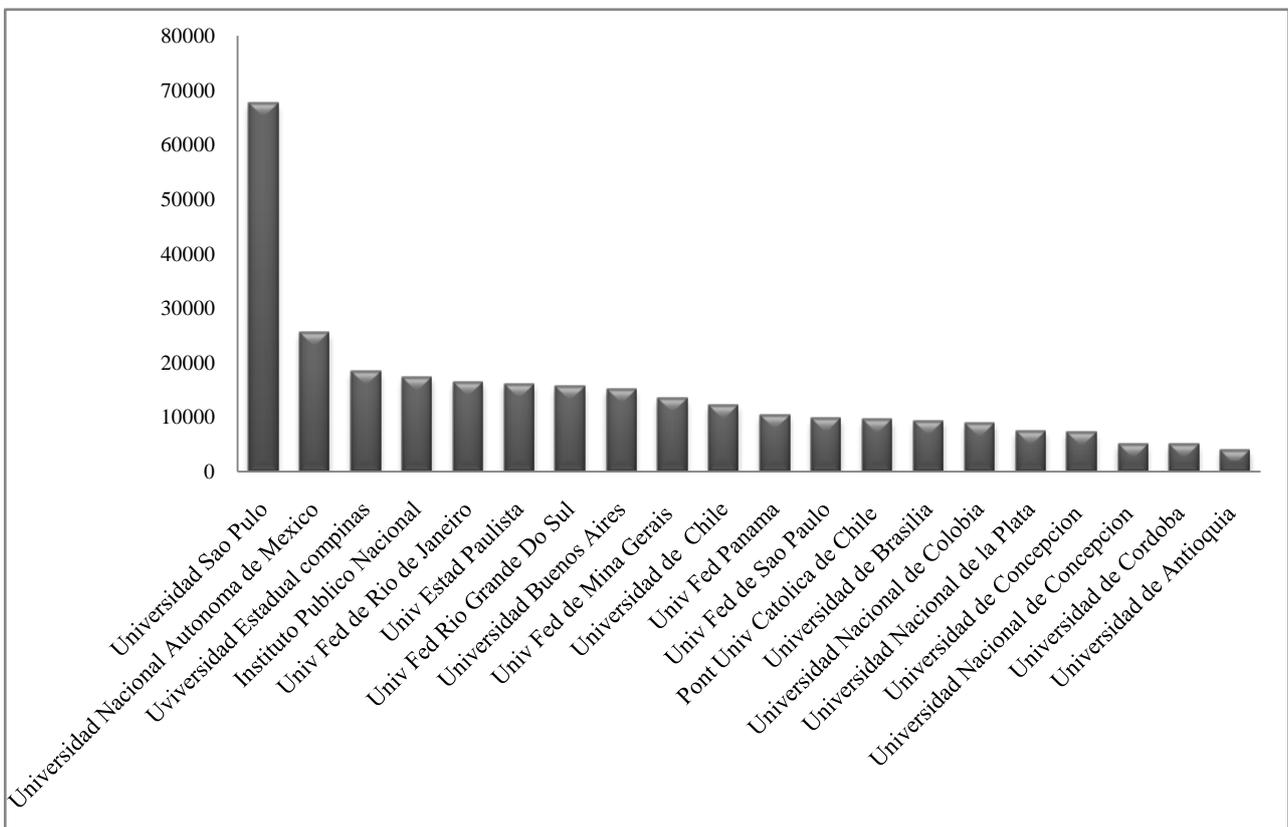


Figure 3. Publications in Scopus by the university (2010-2015)

The above results show the positive progress of Latin America, that goes along the same line as the one presented by Bárcena Alicia at the 5th biennial meeting of the forum on development cooperation of the United Nations Economic and Social Council (ECOSOC), who asserted that the change needed for a) a sustained channeling towards new development, and for 2) the achievement the Sustainable Development Goals (SDGs) requires a new global and regional technological governance, which is aimed at the skills and acquired knowledge, thusly generating a change that goes in favor of science and technological development in Latin America, in order to both continue with research-based progress, and also to compete with countries that are currently the world power on the matter. [9,10]

### 3. Main Science and Technology Producing Countries in Latin America and the Caribbean

Latin America has been characterized as medium-income economy with highly developed levels in countries such as Argentina, Chile, and Uruguay, with Chile, is the country that in 2014 showed the highest GDP per capita and Honduras the lowest, even so, In LAC, one of the greatest inequalities has been evident within a group of countries worldwide as stated by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), making it clear that the four countries with the highest levels of poverty are Honduras, Brazil, the Dominican Republic, and Colombia. [11,12] Figure 4.



Figure 4. GDP growth trends in Latin America 2005-2009 and 2010-2014

Paraguay, Nicaragua, Mexico, Chile, and Ecuador are the countries with the highest GDP growth, while in other countries such as Colombia, Guatemala and El Salvador growth has to be stable. In opposition to this, some countries GDP were observed to have declined due to political and economic situation such as is the case for

Cuba, Venezuela, and Honduras. It should be noted then, that the vast majority of governments in Latin America and the Caribbean dedicate more than 1% of gross domestic product (GDP) to higher education, this being comparable to the investment made in developed countries [11,12].

In the last 20 years, Latin American countries have created specific funds for research and innovation, funds that were originally granted through national loans that were financed through the Inter-American Development Bank (IDB). Said funding has influenced the design of national policies in relation to research and innovation, expressing the required regulations in order to grant such loans as contests, credits, and scholarships [11,13].

Consequently, it was observed that in the last ten years in Colombia and Chile there was a sizeable growth in university enrollments, and as well as in the expenditure that each student generated for the institutions. According to the UNESCO Institute for Statistics, during 2012 in Latin America, two million undergraduate degrees were awarded. With respect to the proportion of doctorates within the general population in the most advanced countries of Latin America, the data proved to be comparable to the figures for China, India, Russia, and South Africa. However, LAC remains far from the most developed countries [6,11,14].

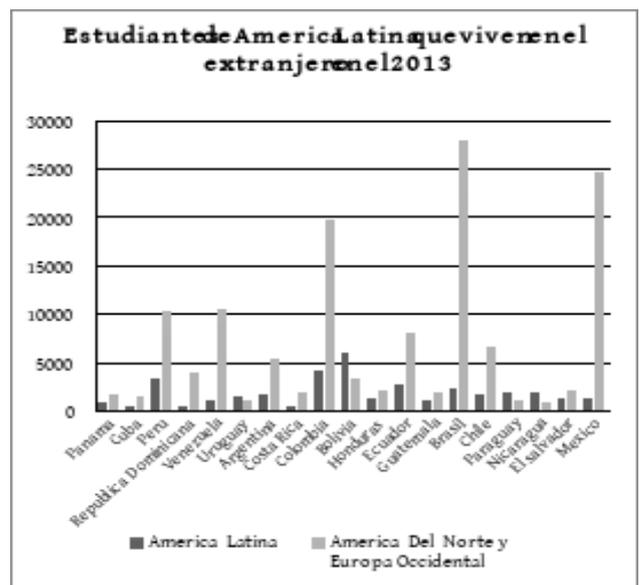


Figure 5. Students from Latin America living abroad in 2013

Brazil with more than 25,000, Mexico around 25,000 and Colombia with about 20,000 students who made the decision to study outside of Latin America, mainly choosing countries located in North America or Western Europe. Although you can still find many students who prefer to stay in Latin America to study.

It is important to recognize that, in recent years, some Latin American countries have worked to strengthen national knowledge networks, in the case of Argentina, with the “Raíces” program, it became state policy in 2008, which has made then permitted the repatriation of 1323 scientists since its inception in 2003, in parallel to the promotion of the creation of networks of Argentine scientists in developed countries. Similarly, Colombia, Ecuador, and Uruguay have taken initiatives to finance the

repatriation of highly competent scientists, in coordination with industrial development and production policies, promoting sophisticated mechanisms to carry out this process, thus facilitating the aggregation of the national staff economy highly qualified. [6,15,16]

In the case of Colombia, according to the National Science and Technology Council (COLCIENCIAS), they have established the recognition of STIs (science, technology and innovation) as the supports for the increase of productivity and competitiveness, which highlights the need for certain adequate policies and resources to boost the generation, use and appropriation of knowledge, necessary for profitable innovation at the social level, as the country currently requires. [16]

In the year 2008, Colombian former President Álvaro Uribe Vélez introduced the national policy coined "Colombia Siembra Futuro" that called for the promotion of research and innovation, based on the generation of scientific and technological knowledge, painting contributions to development as a generator of economic growth and the main axis for the reduction of inequality, making it clear that this goal is not only a responsibility of COLCIENCIAS, nor anyone sector be it, entrepreneurship, the public sector or even the scientific community, but as a responsibility of the entire community as a whole, having as its primary objectives for 2019 sustained social development through the reduction of: poverty, inequality, insufficient coverage and improvement of the quality of health and educational services. [16]

On January 25, 2019 the congress of the Republic of Colombia signed into law the approval of the creation of the Ministry of Science, Technology and Innovation through which it intends to build capacities, promote scientific and technological knowledge, contributing to the development and growth of the country and anticipate to future technological challenges, always seeking the well-being of Colombians and consolidating not only a more productive, competitive economy but also a more equitable society.

Juan Francisco Miranda Acosta, for his part, asserted that the investment destined to research should be greater, since, by 2010, Colombia was below countries such as Brazil, Mexico, and Argentina with respect to scientific production, this is because, for that year the goal in national investment in science, technology, and innovation was to reach 1% of gross domestic product (GDP), moreover, he made reference to generation of more economic and social incentives for those dedicated exclusively to research, in order not to have to look for new horizons in other countries.

In relation to the above, it should be noted that interdisciplinary in labor development, and the execution of ideas, has become complex when reaching an agreement that inclines towards the development of knowledge and new opinions, not of any specialty, but rather of a high intellectual complex structure that generates results. Whose effects obtained to date are not satisfactory, acknowledging some irregularities in the fulfillment of certain goals, which is evidenced in the updating of the National Science, Technology and Innovation Policy 2016-2025, prepared by the Council National Economic and Social Policy Republic of Colombia (CONPES), who readjusted the policy reform

due to the low effectiveness and non-compliance they had with the following factors: The generation of knowledge for the solution of national and regional problems (CONPES 3080 of 2000). [17] The generative capacities, use and transfer of knowledge relevant to competitiveness and development (CONPES 3527 of 2009), [18] the increase of the country's generative capacity and in the use of scientific and technological knowledge, with the purpose of contributing to the productive transformation of the country (CONPES 3582 of 2009). [19]

This managed to ignite an alarm in Colombia, forcing the government to make decisions in favor of the fulfillment of the new approaches, which as was to be expected, were reflected in the scientific production, and its applicability. Annexed to the above, is the National Science Foundation's (NSF) confirmation that in 2009: 121.2 articles in biology, 105.8 articles in medicine, 85.4 in chemistry, 73.1 in agriculture were published in Colombia, 69 in engineering, 26.4 in social sciences and 16.1 in mathematics were published.

In a global view, it could be said that the results have had a reciprocal positive impact on scientific productivity. However, globally and in the same year, 179,021 articles in medicine and 19,214 mathematical articles were published. This is to say that Colombia's global participation is 0.06% for medical articles and 0.08% in the mathematical articles. The foregoing shreds of evidence they need to bear the needs that the country has presented to date in relation to the percentage of investment in science, technology, and innovation. [20]

To the extent that Colombia takes advantage of the potential of science and technology, new development models can be organized in collaboration with the government where knowledge deemed as "public property for all" is guaranteed in such a way that it is accessible, allowing capacity building in the entire population and thus determine the role of technology, where the ultimate goal is human development. A more empowered society from a scientific and technological knowledge standpoint requires greater investments in education, research, and development, policies, and strategies where the citizen can assess the importance of knowledge and its application from the scientific and technological results generated in the country. [22]

Finally, there is acknowledgment that each of the Latin American countries has a diversity of knowledge, for this reason it is necessary to work in an interdisciplinary manner, so that this knowledge is disseminated in the national and international community, and that this is represented in the economic knowledge model, where its various forms are valued which in turn generates better results in terms of economic growth, social equality, political decisions based on facts, greater transparency and ethics, these being the key components in societies based on knowledge. [23]

These types of societies are built from the diversity of knowledge and culture that is a public good available to all, being influenced by scientific advances and the use of cutting-edge technologies, where education, critical thinking, the promotion of Diversity and innovation are fundamental for the implementation of a knowledge society.

Knowledge-based societies generate greater awareness about the importance of science and technology as a key

element to assess and optimize the use of goods, products, and services that a country has, generating citizens with greater skills to face current changes and greater awareness in decisions that promote social welfare, respect for others and equality.

#### 4. Discussion

The Universities of Latin America have increased their participation in the national science and technology systems of each country, and not only that, but they have also increased the quality of their scientific processes, furthermore, they have also worked to improve investment conditions, which has led to the strengthening of research centers. In terms of counterpart analysis, a greater industrial participation in strengthening of research and development is lacking, given that a low rate of innovation in the Latin American business system is evident, so it could be said that greater integration between entrepreneurs and producers of science and technology, this in order to boost the demand for technological knowledge from companies to universities.

Little by little, Latin American universities have positioned themselves as high-level research centers, this has been demonstrated with a significant increase in the number of articles that have been registered in international databases, taking as an example 82% of the articles published in Latin America, which have been by university authors. In some countries such as Chile, Colombia, and Brazil, participation has been greater and is close to 90% of the total scientific articles published in the database (SCOPUS) [24]

One of the countries with the greatest scientific production has been Brazil, of the twenty most productive institutions in Latin America, ten are Brazilian, three Argentine, three Chilean, two Mexican and two Colombian. What continues to confirm that Latin American universities are leading actors in science and technology at the international level.

According to Carlos G. Mejía in his article "Notes From a Researcher" the main aspects that should be taken into account in the educational, research and quality context, is the way people handle knowledge and achieved with this great social relevance. In turn, he argues that the engine of human growth and development is based on the way in which an economy develops, uses and extracts value from knowledge, which finds its innovative foundation in the ability to articulate different kinds of knowledge such as: The combination of modern information technologies with a new accounting system, graphic design with the technical skills for creating Web pages, among others. [25]

To the extent that countries take advantage of the potential of science and technology, new development models can be organized in collaboration with the government where knowledge as "public property for all" is guaranteed in such a way that it is accessible, allowing development capacities in the entire population and thus determine the role of technology, where the ultimate goal is human development. A more empowered society of scientific and technological knowledge requires greater investments in education, research, and development,

policies, and strategies where the citizen can assess the importance of knowledge and its application from the scientific and technological results generated in the country. [26]

Thus, the applicability of what has been learned will be the manifestation of scientific growth in countries that still demand attention, and investment in their academic, political and economic development. That is why the effectiveness of a tax correlation between science and democracy will improve to the extent that scientific dynamism incurs development, and in turn, the ability of the government to implement approvals in order to achieve the expected impact. [26]

#### 5. Conclusions

Knowledge of information and telecommunications has been inducing great impact in all sectors of social activity, from production processes to educational components and in health services. However, government support must be consolidated in order to materialize the ideas that have been developed in Latin America and the Caribbean. [27]

Latin America, despite not being the most vulnerable region in the world at a socioeconomic level, has been one of the most inequitable economically speaking, which in some way has been reflected in the per capita investment that has even been generated in most representative countries in the scientific field. Therefore, it is essential to strengthening the annual investment not only in science and technology but also in the training of professionals that allow the viability of project execution.

It is important to recognize that the foundations of the scientific pillars in Latin America have gone against the current needs of each country. Therefore, there must be greater coherence between what is done and what each region urges. This point is one of the biggest differentiators among the most developed countries in terms of science and innovation. Unfortunately, this reality has been pressing as underdeveloped societies more than 40 years ago, showing the little impact that the materialization of projects has had at present. [28]

A minimal relationship was identified between scientific and technological activity and the basic development problems facing some countries. In turn, there is a poor relationship between university institutions with some government agencies. As far as the implementation of professionals specialized in different areas of knowledge, they have been forced in decision-making with little scientific evidence, showing the rush to implement more practical aspects that provide better results in terms of solution, more counting on the tools and evidence that allow classifying possible levels of intervention. [28]

Research, science, and technology are an effective instrument of the transformation of society. Therefore, it is necessary to counteract the attitudinal processes of some rulers lagging behind the progress that still think that research is a luxury for some first world countries and in turn some companies that close their occupation in passive attitudes, leaving in danger a scientifically inactive nation and also completely uncommunicated with the most advanced countries.

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