

# Characterization Of Innovation, Scientific Production And Social Progress In Countries With Similar R&D Investment

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## Abstract.

Investment in research and development represents one of the most used indicators in the analysis of economic and social growth and development in innovation in countries. A descriptive analysis of countries with R&D investment between 0.2% and 0.5% is performed, considering data from the World Bank and with data in global ranking as of 2017: Uruguay, Ukraine, Costa Rica, Chile, Mexico, Georgia, Ethiopia, Colombia, Indonesia and Pakistan. The favorable relationship of R&D investment with the country's positioning with respect to innovation and social progress, led by Latin American countries, is validated. No favorable relationship was found between investment in R&D and positioning in scientific production, although the latter does have a significant relationship with social progress and innovation.

**Keywords:** research and development, countries, rankings, innovation, social progress.

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## 1 Introduction

Investment in research and development (R&D) has become one of the indisputable factors in the analysis of economic growth, innovation and social development in countries [1][2][3][3][4]. Investment in research and development, represents current and capital expenditures (public and private) that increase knowledge in various areas, and their applications, covering basic research, applied research and experimental development. In the case of Latin America, according to World Bank data as of 2017, the average is 0.71% of GDP, and worldwide it is 2.14% [5]. In the case of Latin America, all countries are well below these averages, with the exception of Brazil with an investment of over 1%.

UNESCO points out that it is essential to monitor R&D investment in knowledge and technology, which drives innovation in countries, adding that the top five in the ranking, in terms of absolute R&D expenditure, are the world's major economic powers: the United States, China, Japan, Germany and the Republic of Korea; in terms of R&D expenditure as a percentage of GDP: the Republic of Korea ranks first, followed by Israel, Japan and Sweden [6], with percentages above 3% per year, which reflects the importance of this factor in development in various areas, worldwide, varying drastically from 0.01% (Mauritania) to 4.95% (Israel).

Regarding the relationship with scientific production, Alvarez-Muñoz and Perez-Montoro [7] refer to the impact of increased investment in science

in Latin America, as it has favored its sustained growth in the period 2010-2014. Regarding the relationship with technological development, research on patent development shows the close relationship with the investment policies of countries in this area [8][9][10], including the growth of patent applications by universities [11]. Finally, the impact on the development of countries is evidenced by the fact that innovation is considered by the United Nations within the 13 sustainable development goals, specifically the ninth of these goals contemplates the promotion of innovation, which proposes to increase investment in research, scientific innovation and technological progress as a means to discover lasting solutions to economic and environmental challenges [12].

With respect to the above, the question arises: Do countries with similar investments in R&D present similar development and performance in terms of science, innovation and social progress? Based on World Bank data, a cluster of countries whose percentage of investment in research and development is between 0.2% and 0.5% is analyzed, as well as the

relationship with indicators of global positioning with respect to scientific production, innovation and social progress.

## 2 Methodology

For the comparative analysis between countries with similar investment in research and development, the indicators used, the procedure for the selection of countries and the analysis applied are described below.

### 2.1 Description of the indicators to be used in the study

Table 1 presents the collected indicators used for the study, as well as the source from which the data are collected. Table 2 presents the three (3) Global Rankings for evaluating the performance of countries in the scientific, innovation and social areas. Table 3 describes the indicators calculated from those collected.

**Table 1. Indicators of the study.**

| Tag        | Indicator   | Description and Source  |
|------------|---|---|
| RDgdp      | Research and Development Expenditure (% of GDP), year 2017.             | Gross domestic expenditure on R&D, expressed as a percentage of GDP. R&D encompasses basic and applied research and experimental development (World Bank, 2017) [5].                                    |
| Population | Number of inhabitants of the country, expressed in millions. Year 2017. | Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates (World Bank, 2017) [5] |

**Table 2. Global rankings considered for the present study, year 2017.**

| Tag | Ranking                                  | Description of the ranking and source   | Indicators to be collected   |
|-----|--|---|--|
| GII | Global Innovation Index rank 2017        | It provides detailed indicators of innovation performance in 127 countries and economies around the world. Through 80 indicators, it explores innovation from a broad perspective, including the political environment, education, infrastructure and business development. Source: World Intellectual Property Organization (2017) [13]. | - Position of the country in the GIII ranking                                |
| SJR | Scimago Journals and Countries Rank 2017 | It catalogs and ranks countries mainly by the total number of papers published by authors for 234 countries, including metrics developed from information contained in the Scopus® database. Source: Scimago (2017) [14].   | - Position of the country in the SPI ranking<br>- Documents.<br>- Citations. |

| Tag | Ranking                        | Description of the ranking and source  | Indicators to be collected                        |
|-----|--------------------------------|--|---|
| SPI | Social Progress Index 2017     | A set of social and environmental indicators that measures the social progress of 146 countries. Source: Social Progress Imperative (2017), Competitiveness Observatory [15].  | - Position of the country in the SPI ranking      |
| SIR | Scimago Institutions Rank 2017 | It catalogs and ranks Higher Education institutions, for 234 countries, mainly considering the articles published by the authors, including metrics developed from the information contained in the Scopus® database. Source: Scimago (2017) [16]. | - Number of universities ranked in SIR by country |

**Table 3.** Indicators calculated.

| Tag             | Description                                 | Outcomes  |
|-----------------|---|---|
| DocPerMillPop   | Papers published per million of inhabitants | Total number of documents published per country, according to SJR (Scimago), divided by the total number of inhabitants of the country (World Bank), per one million.           |
| CitaPerMillPop  | Citations to papers per million inhabitants | Total citations received in documents published by country, according to SJR (Scimago), divided by the total number of inhabitants of the country (World Bank) per one million. |
| UnivePerMillPop | Universidades por cada millón de habitantes | Total number of universities ranked by country, according to SIR (Scimago), divided by the total number of inhabitants of the country (World Bank), per one million.            |

## 2.2 Country selection

The selection of countries with similar investment in research and development for the comparative analysis was made by applying the following criteria, considering as an initial basis the information published by the World Bank [5].

- a) Have a percentage investment in R&D over their Gross Domestic Product (RDgdp) greater than 0.2% and less than 0.5%

- b) Present RDgdp values updated to 2017.

- c) Present Population values updated to 2017.

- d) The population as of 2017 is greater than three million inhabitants.

Subsequently, the countries that present data as of 2017 in the global rankings SJC, SIR, SPI and GII are filtered. Finally, there is a cluster of 10 countries that complied with the above. Table 4 shows the selected countries with their respective data.

**Table 4.** Countries for the study that met the selection criteria \*.

| Country Name | Country Code | Region | RDgdp | Population (Million) | SJC | GI | SPI | Universities | Documents | Citations |
|--------------|--------------|--------|-------|----------------------|-----|----|-----|--------------|-----------|-----------|
| Uruguay      | URY          | LAC    | 0,48  | 3,4                  | 89  | 67 | 31  | 1            | 1595      | 10160     |
| Ukraine      | UKR          | Europa | 0,45  | 44,8                 | 46  |    | 64  | 11           | 12615     | 48448     |

|            |     |              |      |       |    |     |     |    |       |        |
|------------|-----|--------------|------|-------|----|-----|-----|----|-------|--------|
| Costa Rica | CRI | LAC          | 0,42 | 4,9   | 94 | 53  | 28  | 1  | 1118  | 8888   |
| Chile      | CHL | LAC          | 0,36 | 18,5  | 45 | 46  | 25  | 25 | 13573 | 89551  |
| Mexico     | MEX | LAC          | 0,33 | 124,8 | 29 | 58  | 48  | 34 | 24643 | 123250 |
| Georgia    | GEO | Africa-Asia  | 0,29 | 3,7   | 85 | 68  | 53  | 3  | 1722  | 18171  |
| Ethiopia   | ETH | Africa       | 0,27 | 106,4 | 71 | 110 | 121 | 5  | 2986  | 25508  |
| Colombia   | COL | LAC          | 0,24 | 48,9  | 47 | 65  | 49  | 21 | 11872 | 60202  |
| Indonesia  | IDN | Asia-Oceania | 0,24 | 264,6 | 36 | 87  | 79  | 10 | 21315 | 62408  |
| Pakistan   | PAK | Asia         | 0,24 | 207,9 | 39 | 113 | 105 | 23 | 17866 | 116231 |

\* Sources of data collected are described in Tables 1 and 2.

### 3 Results

Ten countries that report investments in research and development within the range of 0.2% and 0.5% of their gross domestic product are compared. These countries are: Uruguay, Ukraine, Costa Rica, Chile, Mexico, Georgia, Ethiopia, Colombia, Indonesia and Pakistan. Latin America and the Caribbean account for 50%, Europe for 10%, Africa for 20% and Asia for 20%.

Mexico, Chile, Pakistan and Colombia have the highest number of universities positioned in SIR, with 77% of the group analyzed.

#### 3.1 Correlation between RDgdp, Rankings and scientific production.

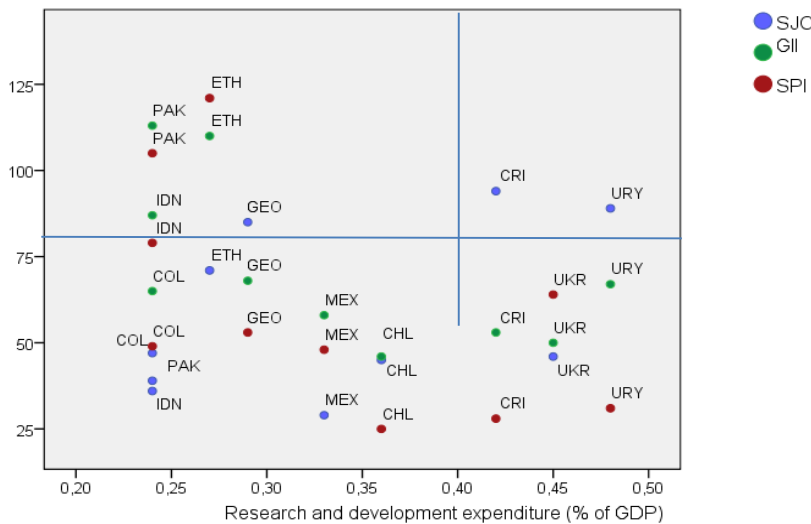
For this group of 10 countries, there is a high correlation between investment in research and development and positioning in innovation (-0.629), as well as with social progress (-0.596), with a negative sign indicating that with high investment in R&D, the associated positioning corresponds to the first places. With respect to the association with positioning in SJR, it is found to be moderately positive (0.445), which is not favorable, i.e., the higher the investment values, the more distant positioning is associated with the first places (Table 3).

On the other hand, there is a high correlation between development in innovation and social progress (0.898), as well as between universities and publications and citations per million inhabitants. Social progress and innovation show significant relationships with scientific production.

The four Latin American countries (Colombia, Costa Rica, Uruguay, Mexico) have better positions in terms of social progress and development in innovation, compared to the rest of the countries in the group under study (see Figure 1). In addition, the figure shows that Pakistan, Ethiopia and Indonesia coincide in terms of the least favorable social progress and development in innovation.

**Table 3.** Correlation between indicators

|                 | RDgdp | SJC   | GII   | SPI   | DocPerMillPop | CitatPerMillPop | UnivPerMillPop |
|-----------------|-------|-------|-------|-------|---------------|-----------------|----------------|
| RDgdp           | 1     | ,445  | -,629 | -,596 | ,464          | ,311            | ,111           |
| SJC             | ,445  | 1     | -,091 | -,260 | ,218          | ,404            | ,022           |
| GII             | -,629 | -,091 | 1     | ,898  | -,674         | -,526           | -,545          |
| SPI             | -,596 | -,260 | ,898  | 1     | -,742         | -,639           | -,563          |
| DocPerMillPop   | ,464  | ,218  | -,674 | -,742 | 1             | ,925            | ,906           |
| CitatPerMillPop | ,311  | ,404  | -,526 | -,639 | ,925          | 1               | ,882           |
| UnivPerMillPop  | ,111  | ,022  | -,545 | -,563 | ,906          | ,882            | 1              |

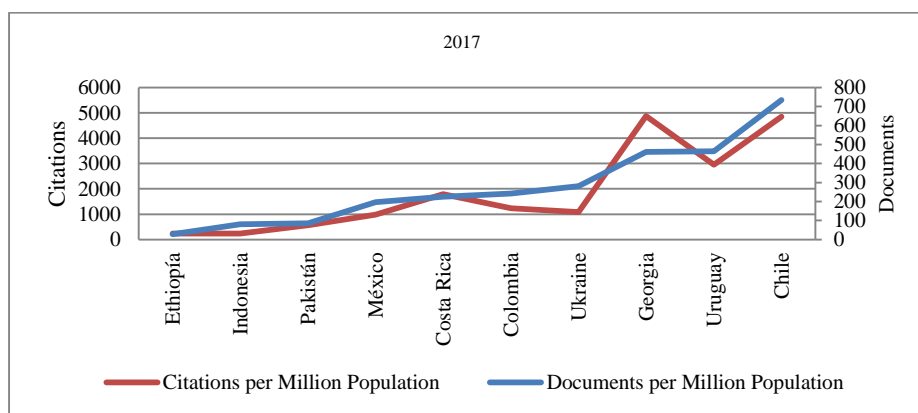


**Fig. 1.** Relationship between Research and development expenditure (% of GDP) and the Rankings of innovation (GII), scientific production (SJR) and social progress (SPI), corresponding to the year 2017.

**3.2 Comparative analysis with respect to scientific production**

For each million inhabitants, there is a high correlation of published papers with citations (0.925) and with the number of universities (0.906), as can be

seen in Fig. 2, where Chile and Uruguay stand out among the first. Chile stands out with 1.35 universities per million inhabitants (Fig. 3).



**Fig. 2.** Citations and documents published per million inhabitants, year 2017.

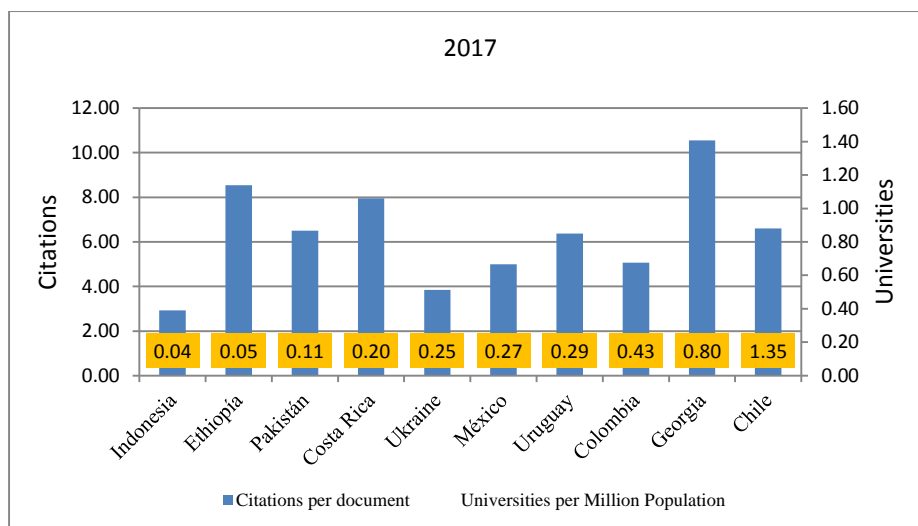


Fig. 3. Citations per document and universities per million inhabitants.

#### 4 Conclusions

Ten countries are analyzed with close percentages of investment in research and development, within the percentage range of 0.2% and 0.5% of their gross domestic product, and data is also compiled associated with their positions in innovation, scientific production and social progress. These countries are: Uruguay, Ukraine, Costa Rica, Chile, Mexico, Georgia, Ethiopia, Colombia, Indonesia and Pakistan. Latin America and the Caribbean account for 50%, Europe for 10%, Africa for 20% and Asia for 20%.

Mexico, Chile, Pakistan and Colombia have the highest number of universities positioned in SIR, with 77% of them with respect to the group analyzed.

This group of countries validates the relationship between investment in research and development with innovation and social progress of the countries, but not with scientific production. On the other hand, there is a high correlation between development in innovation and social progress, as well as between indicators per million inhabitants such as universities and publications and citations.

Thus, this study found that the countries studied show a high correlation between their positioning in innovation and their social progress, as well as with respect to the number of universities per country and their publications and citations per million inhabitants. Social progress and innovation show significant relationships with scientific production. For each million inhabitants, there is a high correlation of published papers with citations and with the number of universities. Chile stands out in the group of countries with the highest value (1.35) of universities per million inhabitants.

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