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Evaluation of the Impact of the Colombian Scientific Productivity on the Fulfillment of the Sustainable Development Goals

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Abstract:

This research presents the development of an instrument for the evaluation of the contributions of scientific production in Colombia to the development of the main needs of the Sustainable Development Goals (SDG) throughout the country. A data set of national and international science and technology repositories was configured, including those recognized for hosting products highly related to the topics required by the SDGs. Afterward, a topic model was built, in which for each of the sources considered in each SDG, the importance of the number of topics or categories and the distribution of the concepts in each of them was evaluated based on indicators such as perplexity and coherence. Among the most important results, the synchronization of the scientific products related to the objectives “*Fin de la pobreza*”, “*Cero Hambre*” and “*Salud y Bienestar*” stands out, however, despite this decisive result for the fulfillment of the SDGs, the lack of scientific development throughout the national territory limits the impact of the results for the attainment of the agenda for 2030.

Keywords: Sustainable Development Goals (SDG); research; science; technology; evaluation of the impact.

JEL Classification: Q01; Q55; R11.

Introduction

One of the main strategies for the materialization of the SDGs in different territories is the evaluation of the performance of the plans and/or activities of Science, Technology and Innovation (STI). This scientific productivity is stimulated mainly by the elements defined in the 2030 Agenda for Sustainable Development, where 193 States in 2015 adopted this document as the guide for the pursuit of sustainability, from economic, social, human, environmental, and governance perspectives. The 2030 Agenda for Sustainable Development, through its 17 goals (SDG) and 169 targets (see Figure 1), has become a global commitment of a transversal and multidimensional nature, in which the STI has a fundamental role (https://es.unesco.org/creativity/sites/creativity/files/247785sp_1_1_1.compressed.pdf).

Figure 1. Sustainable Development Goals (SDGs) and Disability



Source United Nations, 2018

In Latin America, the analysis of the relationships between STI and the fulfillment of the SDGs must consider the heterogeneity of the region. Although there are common elements to all Latin American countries, their internal situations differ significantly and extend to the social and scientific-technical spheres. At the same time, the maturity of innovation systems and the degree of development of research processes diverge (Instituto Complutense de Estudios Internacionales ICEI 2020).

The Observatory of Science, Technology and Society, coordinated by the Organization of Ibero-American States (OEI) and the Network of Science and Technology Indicators (RICYT), reports that 57% of Ibero-American researchers carry out their activities in universities, 28% in the business sector and 14% in public institutions. Consequently, the axis of research and academic production continues to be concentrated in universities (Instituto Complutense de Estudios Internacionales ICEI 2020).

On the other hand, between 2008 and 2019 the number of articles published from Latin America in scientific journals registered in Scopus has grown by 87%, a volume notably driven by Brazilian production. Likewise, the number of patents has increased and, in general, the capabilities of the research and innovation system have been strengthened. However, it is necessary to reinforce the transfer and exchange of knowledge, between academia and society, in both the national and regional contexts (Instituto Complutense de Estudios Internacionales ICEI 2020).

In 2019, the contribution of Colombia to world scientific production was 0.33%, placing it below Brazil, Mexico, Chile, and Argentina in the region (Bornmann *et al.* 2020). Likewise, 4.5 articles are published in the country per billion dollars of GDP per capita, which is less than what is published by Argentina (6.8), Brazil (9.7), and Chile (13.2). On the other hand, although in 2019 Colombia was ranked 47th out of 231 countries in the world ranking of the H33 index (Bornmann *et al.* 2020) it was not positioned as one of the three best Latin American countries. Finally, even though the total scientific production has increased continuously, between 2008-2017 the participation of STEM areas (science, technology, engineering, and mathematics) in the total scientific production of the country fell 6.5 percentage points in Scopus (Bornmann *et al.* 2020). The development of STEM areas is essential for the fulfillment of the SDGs worldwide (DNP, Documento CONPES 4069 Política Nacional de Ciencia, Tecnología e Innovación 2022 - 2031).

Most of the incentives in the country for research socialization are aimed at the publication of articles in journals indexed in Web of science and Scopus, but the open access to national production has been hindered due to the restrictions of these platforms. On the other hand, as indicated in the CONPES 3920, published in 2018, there is a low culture of open data in the country, which are the main promoters for the development of STEM and the fulfillment of the SDGs (DNP, Documento CONPES 4069 Política Nacional de Ciencia, Tecnología e Innovación 2022 - 2031).

In this way, the present work proposes an evaluation model using natural language processing tools, for the assessment of the production of new knowledge integrated into mainstream journals (Scopus and WoS) as well as in open data repositories of researchers developed in Colombia related to the driving factors of the SDGs in the country.

In correspondence to the objective, the following sections are proposed; In the first section, the data set that will be used for the evaluation of scientific production in Colombia related to the SDGs is established, as well as the selection and parameterization of the model using the Latent Dirillect Allocation technique. In the second and last section, the results and discussion are presented, showing the impact of the country's scientific productivity and its relationship with the fulfillment of the SDGs.

1. Materials and Methods

1.1 Materials

A set of data generated from databases and repositories of science, technology, research, and innovation related to Colombian scientific productivity has been built. Diverse factors were included in the assessment of the impact of the research products in the materialization of the objectives of sustainable development, such as:

- The generation of new knowledge, or the degree of contribution that these products have to face the challenges that exist throughout the country. Additionally, these products must be published in scientific journals indexed in Scopus and Web of Science and must be derived from the research carried out by the actors of the National System of Science and Technology.
- Products with highly significant results and with scalability in the different territorial contexts of the country, according to the needs established by the National Council for Economic and Social Policy within the framework of SDGs in the country.
- Scientific products generated as a result of research calls from the Ministry of Science and Technology of Colombia within the framework of the Horizon 2030 cooperation and financing fund.
- Referents of the Science, Technology and Innovation policy and development plans of the country's provinces and municipalities

Another important criterion for collecting this information was to limit the temporality of each of the records to the last seven years (2014-2021) because it was in that period that the Colombian Science and Technology System generated the greatest promotion of research calls and financing for the training of specialized human talent to meet the demands of the SDGs.

From this information, a data set with the following characteristics was constructed:

- 9566 articles
- 4568 books as a research result
- 2500 book chapters
- 350 documents related to policies, decrees, resolutions, national and regional development plans, as well as the reference documents of the research and funding calls of the Ministry of Science and Technology of Colombia.

1.2 Methods

One of the most important characteristics of the data set formed for this research is that all the information is in text format, and, therefore, the construction of the model that will carry out the evaluation of the scientific relevance for the development of the SDGs in Colombia must consider it. In this sense, two methodological processes have been defined to guarantee the construction of a robust model with significant results. The first is related to the quality of the data, and the second process is where the instrument for the evaluation of scientific productivity is elaborated.

The process of improving the quality of the data consists of carrying out cleansing activities and selecting the most important information. For this reason, the proposal by Rentería-Ramos *et al.* (2019) will be used, where the following algorithmic sequence was established:

1. **Tokenization.** It is a process by which the text is segmented into words, that is, a textual corpus is transformed into a set or list of words. For example, in the text "Sustainable Development Goal", its Tokenization is: "Sustainable", "Development", and "Goal".

2. **Lemmatization.** It is used for the dimensional reduction of a word or sentence transforming it to its base and root form.

3. **Recognition and Debugging.** It is a stage where the selection of main and important words is carried out, based on a heuristic algorithm called a taboo list, which consists of discarding from the document those words that do not provide important information for the compression of the text. Within this debugging, connecting terms such as: "the", and "they", (also known as stopwords) are eliminated.

Once a textual corpus has been obtained, the assessment process begins, to evaluate the configurations of the most important terms of each of the scientific products, considering their co-occurrence, sequentiality and

placement. From these results, the alignment to the most important principles of the SDGs was established (in this case, the first 10 were considered, for which the most resources have been defined in the country). With this aim, topics, categories, and unstructured text documents were built from latent variables and multinomial distributions of words, through the use of Topic modeling as the main tool, which is a technique that belongs to Bayesian statistics (Duran *et al.* 2015). Among the most important topic modeling techniques, Latent Semantic Indexing (LSA) (Deerwester *et al.* 1990), Probabilistic Latent Semantic Analysis (PLSA) (Hofmann 1999, 2001), and Latent Dirichlet Allocation (LDA) (Blei *et al.* 2003) stand out. According to Duran *et al.* (2015), LDA is one of the techniques that has generated the most significant contributions to the study from different areas of knowledge: social sciences (Ramage *et al.* 2009; Li and Lei 2021; Jacobi, Van Atteveldt and Welbers 2016), economics (Hong, Frias-Martinez and Frias-Martinez 2016), health (Paul and Dredze 2014; Blei and Jordan 2003) among others. For this research, the most relevant approach is the LDA, because the topics built with this model are highly coherent (Li and Lei 2021), and, therefore, it is a vital tool for evaluating the relevance of the results obtained from Colombian scientific productivity, related to the challenges established in the SDGs.

For the construction of the LDA algorithm, the proposal of Unesco (2015) (La Agenda del desarrollo sostenible 2030) was used, where given a textual corpus D composed of M documents, with a document d with N_d words ($d \in \{1 \dots, M\}$), the construction of topics was done as follows:

1. Select a multinomial distribution ϕ_t for topic t ($t \in \{1 \dots, T\}$), from a Dirichlet distribution with parameter β .
2. Select a multinomial distribution θ_d for ($d \in \{1 \dots, M\}$), from a Dirichlet distribution with parameter α
3. For a word w_n ($n \in \{1 \dots, N_d\}$) in a document d ,
 - i. Select a topic z_n from θ_d
 - ii. Select a word w_d from ϕ_{z_n}

One of the most important aspects for this algorithm are the variables ϕ and θ , and the hyperparameters α and β that, as recommended by Unesco (2015) (La Agenda del desarrollo sostenible 2030), must be defined from the perspective of latent variables. Therefore, under this principle for the estimation of the parameters in the textual corpus D .

$$P(D|\alpha, \beta) = \prod_{d=1}^M \int P(\theta_d|\alpha) \left(\sum_{n=1}^{N_d} P(z_{dn}|\theta_d) P(w_{dn}|z_{dn}, \phi) P(\phi|\beta) \right) d\theta_d d\phi \quad 1.1$$

As the parameters θ and ϕ are part of the integration, it is necessary to build simulation models to establish the inference of these values, according to Rogers *et al.* (2005) and Griffiths and Steyvers (2004) the best computational alternative for this inference is Markov Chain Monte Carlo. Once the topics have been generated, it is necessary to establish a quality metric for the results obtained, which means, to define the optimal number of topics required to adequately classify all the words of the textual corpus D . In this sense, the most appropriate indicator is Perplexity, which is a measure of information theory, to evaluate how well a statistical model describes a data set (Unesco 2015 La Agenda del desarrollo sostenible 2030), therefore, the lower the quantification of Perplexity, the quality of the results obtained with the model is more reliable. The Perplexity equation (ς) that will be used in this research is the one proposed by Duran *et al.* (2015), Mei, Shen and Zhai (2007):

$$\varsigma = \exp \left\{ -\frac{\sum_{d=1}^M \log p(w_d)}{\sum_{d=1}^M N_d} \right\} \quad 1.2$$

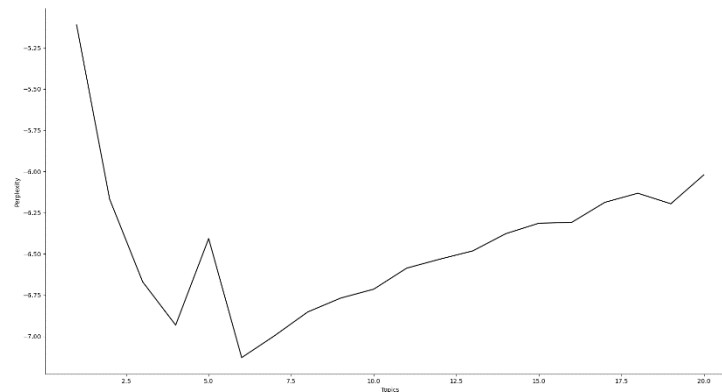
In addition to Perplexity, the coherence indicator (ϑ) is adhered to evaluate the consistency of the words that make up each topic ϕ_i, ϕ_j (see Equation 1.3), to later make a paired comparison based on the Kullback divergence metrics – Leiber (DKL) to establish the main similarities and differences from the distributions of the words in the topics and between the SDGs (Mei, Shen and Zhai (2007).

$$\vartheta = \log \frac{p(\phi_i, \phi_j) + \epsilon}{p(\phi_i)p(\phi_j)} \quad 1.3$$

2. Results and Discussion

One of the first results that must be calculated in this research is the value of α and β , which are adjusted with a symmetric distribution $\left(\frac{1}{T}\right)$, therefore, it is important to define the optimal number of topics (T) of the LDA model, from perplexity using (2), for a randomly selected quantity t (see Figure 2).

Figure 2. Assessment of perplexity according to the number of topics



Source: self made

For this case, the number of categories or topics with which it can be modeled in a robust and statistically significant way is six, because it is where ζ is minimum, a value that is repeated in all the SDGs analyzed in this research. Once this value is obtained, the next procedure is to calculate the value of ϑ , for each ODS, as presented in Table 1.

Table 1. Levels of consistency of the topics for each SDG

SDG	Topics	Coherence	DKL
1	6	0.48	5.10
2	6	0.47	6.10
3	6	0.45	4.98
4	6	0.14	10.01
5	6	0.11	20.02
6	6	0.09	25.05
7	6	0.08	35.02
8	6	0.09	10.05
9	6	0.11	8.02
10	6	0.12	7.85

Source: self made

According to the results presented in Table 1, the first three SDGs, in addition to having the highest coherence values, show the lowest values of divergence with the fundamental principles of the United Nations declaration, and for such reason, they will be the prioritized elements to evaluate in this investigation.

2.1 ODS 1. No Poverty

This SDG highlights the presence of important terms to address a set of solutions to the problematics that underlie the endogenesis of the objective, within these aspects terms such as “*desarrollo*”, “*económico*” and “*salud*” appear, which are determining aspects for provide a solution to the needs of poverty and reduce the level of entrapment of a large part of the population in the country. In fact, these are the aspects included in the multidimensional poverty models proposed by Alkire *et al.* (2015), who calculate poverty from a synthetic indicator, employing a ponderation system based on the importance of each dimension in the configuration of welfare antagonists’ deprivations.

However, it is necessary to achieve more accurate poverty models, which strategically address the reduction of the intensity of poverty traps and prevent them from becoming transgenerational poverty maps. Therefore, in addition to incorporating these factors, it is necessary to involve aspects related to the habitat, and other dynamizers factors of social welfare, such as access to quality public services, health services, among

others. This lack is reflected even in the smaller topics (fewer terms), demonstrating that the scientific development of the country is not generating the evidence to solve the problems of poverty as established by Ramírez *et al.* (2017), Pinilla-Roncancio (2018) and Manzano-Nunez *et al.* (2022). Finally, Cuesta *et al.* (2020) mentions that these poverty and inequality gaps have become more acute as a consequence of the pandemic.

2.2 ODS 2. Zero Hunger

Unlike the SDG "No Poverty", in this objective, the scientific development has led to important results in aspects such as: "*Agricultura*", "*Cambio Climático*", "*Economía*", "*Capital Social*" and "*Bioeconomía*" that according to Khanal *et al.* (2021), are the keys to promote strategies to reduce hunger, because the alterations generated as a result of climate change affect the availability and quality of the product, reducing the presence of some nutrients, proteins and vitamins required for the health wellness. In relation to this last aspect, Blesh *et al.* (2019) mentions that to guarantee the construction of a sustainable model of zero hunger, in addition to a good food security system in the country, it should be considered the support of a good health system, highly inclusive and based on the care prioritization approach from the social determinants of well-being. In addition to a good health system, Sunderland *et al.* (2019), mentions that factors such as adaptation and resilience to climate change must be on the government's agenda to achieve the expected results and impacts boosted by the guarantee of zero hunger in the population. Although these aspects are part of the most important topics (based on the proportion of terms and main components since the creation of the objective) and coherent, the intra-topic analysis shows the lack of a homogeneous model that guarantees its adaptability to the territorial needs of the country, because most of the implemented strategies are focused on the capital cities of the country, and not on rural (and dispersed rural) contexts.

2.3 ODS 3. Good Health and Well-Being

Health and well-being are another of the objectives that has a series of initiatives that have been developed in the country involving plans and programs supported by the Comprehensive Health Care Model (Palma, Núñez, and Cárdenas 2019), and whose key aspects are found in the topics with the highest proportion of objective terms ("*Salud*", "*Calidad-Salud*", "*Atención-Diferenciada*", "*Cobertura-Integral*"). Thus, the fundamental of this model is based on guaranteeing the insurance of the population in the General Health and Social Security System (SGSS), from an inclusive and differentiated approach that guarantees access to health, considering the socioeconomic gaps of the different population groups in the territory. These results are so effective that the country's insurance exceeds 90% of the population in some municipalities, and, in addition, they have established a population screening model considering the vulnerability approaches proposed by Diderichsen *et al.* (2019) [29], which have facilitated access to specialized health services. Part of this contribution is reflected on the presence of these terms in the most important topics: "*salud*", "*cuidado*", "*sanitario*", "*humanización*", "*riesgo*", "*inclusión*", "*clase social*" and "*estratificación*". However, researchers such as Roncancio *et al.* (2020), mention that the development of this SDG in the country is not only achieved by guaranteeing the health system of the entire population, but also it is necessary to improve the incorporation of the social determinants of health, because there are sociodemographic and geographic factors that have had an important impact on the configuration of vulnerability that exacerbates the complications of some pathologies in these population groups. This factor was called differential vulnerability by Roncancio *et al.* (2020) and Diderichsen *et al.* (2019) and establish that a health system must generate elements that mitigate the epidemiological incidence of the differential vulnerability in the welfare of the population. In addition to the above, the Colombian scenario, in most of the territory, converges poverty and a population displaced by internal armed conflict, which also has high rates of morbidity and mortality due to cardiovascular and metabolic diseases, have high prevalence rates in mental illnesses, such as depression and dysthymia, which according to Rentería-Ramos *et al.* (2019) are increasing pre-existing cardiovascular, metabolic and nutritional complications in the poorest population groups.

Conclusions

The scientific contribution in Colombia for the development of the SDGs, has increased notably in recent years, as a consequence of the incentives promoted for the actors of the National System of Science and Technology in the country, since the creation of research financing funds focused especially on the development of the needs that are part of the first ten SDGs. Because the closing of the largest gaps that exist in most of the territories is concentrated in the scope of each one of the dynamic components of these SDGs. In relation to the STI and R&D&i products that are generated because of the funded research calls, they are more focused on following

international patterns and standards (reviewed from publications in journals indexed in Scopus and WOS), which contain completely divergent elements to the territorial needs of the country.

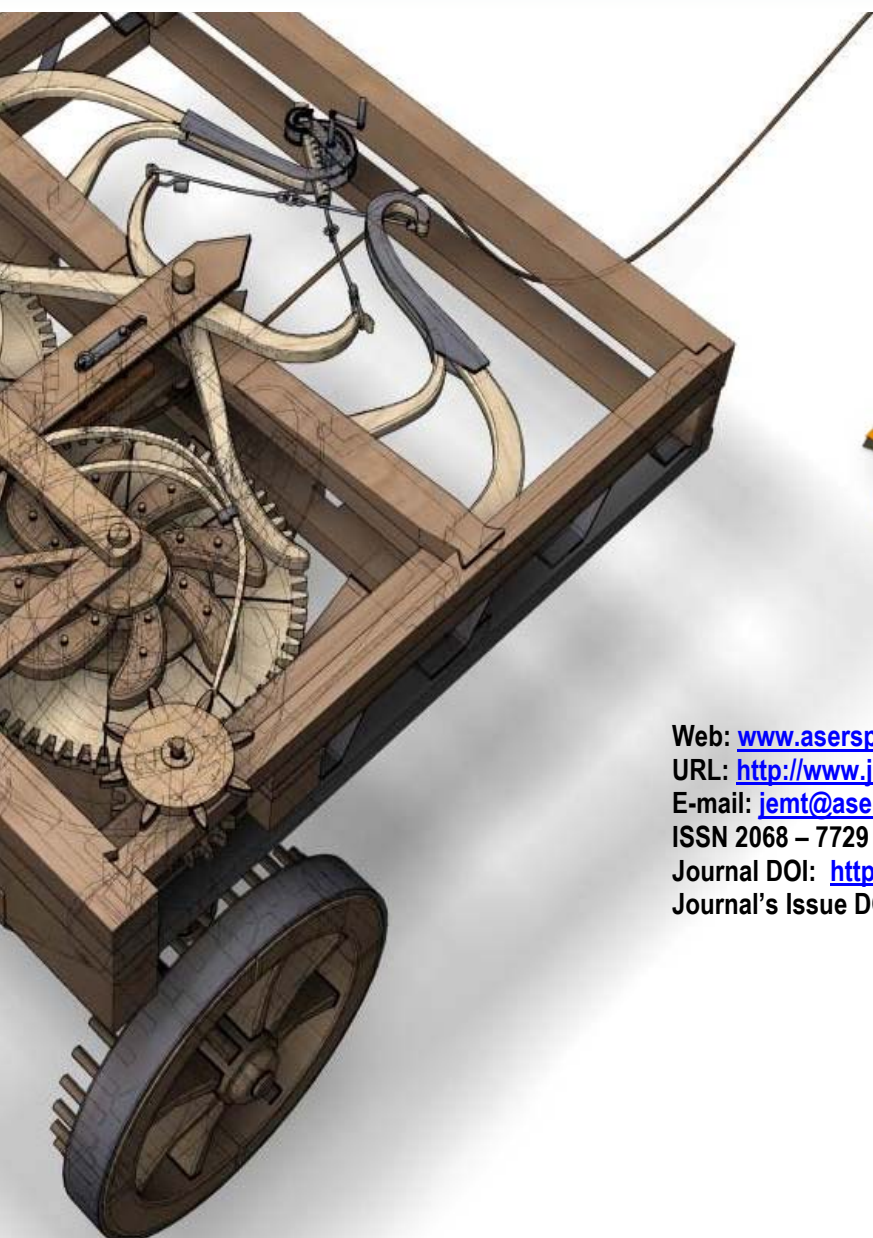
Even this pattern is preserved for the objectives in which there are less divergences (assessed from the DKL), but with little impact at the national level, because it has a very pronounced bias towards the large cities of the country (investigations are directed to those territories). Leaving out the demands of rural contexts and settlements of population groups that have historically been excluded from the main agendas and state plans, whose situation has been considerably aggravated by the declaration of the pandemic generated by Covid-19. Therefore, it is necessary that new impact indicators of the scientific production of the SDGs be promoted at the country level, based more on territorial needs and the promotion of instruments for decision-making by the local and national government, than on the bibliometric compliance or based on international scientific repositories.

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