



Bibliometric Indicators and Regional Inequalities: An Analysis of Scientific Output in Engineering

Indicadores bibliométricos y desigualdades regionales: Un análisis de la producción científica en ingeniería

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ABSTRACT

This study analyses regional inequalities in global scientific output, with a particular focus on engineering. Using quantitative design and bibliometric data from the OECD and the World Bank for the period 2009–2023, the distribution of scientific output and its correlation with socioeconomic indicators such as GDP per capita and investment in R&D are examined. The results reveal a marked concentration of scientific output in Asia-Pacific, Western Europe, and North America, which together account for more than 90% of the global total. A strong positive correlation is observed between scientific output and R&D investment ($r = 0.91$), and a moderate correlation with GDP per capita ($r = 0.16$). The analysis of inequality over time, measured using the Gini coefficient and the 80/20 ratio, shows a persistent, although slowly declining, disparity in the distribution of scientific output. These findings underscore the need for policies that promote equity in the global scientific system by fostering international collaboration and strengthening research capacities in less developed regions. The article concludes with a discussion of the implications of these inequalities for technological development and innovation on a global scale.

Keywords: Bibliometric indicators, Regional inequalities, Scientific output, Engineering, science policy.

RESUMEN

El presente estudio analiza las desigualdades regionales en la producción científica global, con un enfoque específico en el campo de la ingeniería. Utilizando un diseño cuantitativo y datos bibliométricos de la OCDE y el Banco Mundial para el período 2009-2023, se examina la distribución de la producción científica y su correlación con indicadores socioeconómicos como el PIB per cápita y la inversión en I+D. Los resultados revelan una marcada concentración de la producción científica en Asia-Pacífico, Europa Occidental y América del Norte, que en conjunto representan más del 90% del total mundial. Se observa una fuerte correlación positiva entre la producción científica y la inversión en I+D ($r = 0.91$), y una correlación moderada con el PIB per cápita ($r = 0.16$). El análisis de la desigualdad a lo largo del tiempo, medido por el coeficiente de Gini y el ratio 80/20, muestra una persistente, aunque lentamente decreciente, disparidad en la distribución de la producción científica. Estos hallazgos subrayan la necesidad de políticas que fomenten la equidad en el sistema científico global, promoviendo la colaboración internacional y el fortalecimiento de las capacidades de investigación en las regiones menos desarrolladas. El artículo concluye con una discusión sobre las implicaciones de estas desigualdades para el desarrollo tecnológico y la innovación a escala mundial.

Palabras clave: Indicadores bibliométricos, desigualdades regionales, producción científica, ingeniería, política científica.

INTRODUCTION

Science and technology are fundamental drivers of economic and social development in the 21st century. A nation's ability to generate knowledge, innovate, and compete in the global economy is intrinsically linked to the strength of its research and development (R&D) system. In this context, bibliometric indicators have become essential tools for measuring and evaluating scientific activity, allowing policymakers, research managers, and the academic community to understand the dynamics of knowledge production at global, national, and institutional levels (De Solla Price, 1963; Glänzel, 2003). These indicators—including the number of publications, citations received, h-index, and journal impact factor, among others—offer a quantitative window into the volume, visibility, and impact of scientific research (Hirsch, 2005).

However, the apparent objectivity of these metrics often conceals deep inequalities within the global scientific system. Knowledge production is not a level playing field; rather, it is marked by a significant concentration of resources, talent, and output in a limited number of countries and regions (Royal Society, 2011; Wagner, 2008). These geographical disparities, manifested in stark differences in funding, infrastructure, human capital, and access to international collaboration networks, have far-reaching consequences, perpetuating cycles of academic

dependency and limiting the innovative potential of developing nations (Arunachalam, 2003; Gibbs, 1995). Understanding the magnitude and nature of these inequalities is therefore a crucial step toward designing more equitable and effective science policies that promote a more inclusive and diverse global research ecosystem.

The field of engineering, in particular, plays a central role in technological development and national industrial competitiveness. From artificial intelligence and biotechnology to renewable energy and advanced manufacturing, advances in engineering underpin the innovation that drives economic growth and addresses major global challenges such as climate change and public health (National Academy of Engineering, 2004). Consequently, analysing inequalities in scientific output in this field is especially relevant. Disparities in engineering research capacity can translate directly into technological and developmental gaps, exacerbating economic inequalities between countries and regions.

This article aims to analyse regional inequalities in engineering scientific output using a bibliometric approach. The study has three main objectives. First, it seeks to quantify the global distribution of engineering scientific output, identifying leading regions and countries, as well as those lagging behind. Second, it explores the relationship between scientific output and key socioeconomic indicators, such as Gross Domestic Product (GDP) per capita and R&D investment, to

understand the factors underlying the observed disparities. Third, it analyses the temporal evolution of these inequalities over the past 15 years to determine whether the gap between more and less productive regions is widening or narrowing.

To achieve these objectives, a quantitative study design was developed based on bibliometric data extracted from the Organisation for Economic Co-operation and Development (OECD) database, complemented with socioeconomic data from the World Bank. Descriptive statistical methods, correlation analysis, and inequality metrics such as the Gini coefficient were applied. The results are presented through tables and figures that visualise trends and geographical distributions, providing a solid empirical basis for discussion.

This study contributes to the existing literature on bibliometrics and scientific inequalities in several ways. First, it offers an updated, detailed analysis of regional disparities in a critically important field such as engineering. Second, by combining bibliometric data with socioeconomic indicators, it provides a more contextualised understanding of the factors underlying these inequalities. Third, by analysing temporal evolution, it offers a dynamic perspective on the issue, assessing whether recent policies and trends have mitigated or exacerbated existing gaps. Ultimately, the findings are expected to be useful to science policymakers, research funding agencies, and the academic community by providing empirical evidence to

inform strategies that foster a more equitable and collaborative global scientific system.

METHODOLOGY

To address the objectives of this study, a quantitative, descriptive–correlational research design was adopted. This approach makes it possible, on the one hand, to describe the distribution and characteristics of scientific production in engineering at both global and regional levels and, on the other hand, to examine the relationships between this production and relevant socioeconomic variables. The analysis covers a 15-year period, from 2009 to 2023, allowing for the observation of trends and changes in inequality dynamics.

Two main data sources were used for data collection. Bibliometric data on scientific production in engineering were obtained from the Science, Technology and Industry Statistics database of the Organisation for Economic Co-operation and Development (OECD). This database aggregates information from various sources, including Scopus, and provides standardized and internationally comparable data on the number of scientific and technical publications by country and field of science. For this study, the indicator “Publications in Engineering and Technology” was selected.

Socioeconomic data, including gross domestic product (GDP) per capita (in current U.S. dollars) and research and development (R&D) expenditure as a percentage of GDP, were obtained from the World Development Indicators (WDI) database of the World Bank. These variables were selected due to their

theoretical and empirical relevance as factors influencing a country's research capacity (Freeman, 1987; Lundvall, 1992).

The operational variables of the study are as follows:

- **Scientific Production:** Total number of publications in the field of engineering by country and year.
- **GDP per capita:** Gross domestic product per inhabitant, used as an indicator of a country's level of economic development.
- **R&D Investment:** Gross expenditure on research and development as a percentage of GDP, reflecting a country's effort to promote science and technology.
- **Geographic Region:** Countries were grouped into six regions to facilitate comparative analysis: Asia–Pacific, Western Europe, North America, Eastern Europe, the Middle East and Africa, and Latin America.

Data processing and analysis were conducted in several stages. First, the OECD and World Bank datasets were cleaned and preprocessed, then merged into a single database. Country names and years were harmonized to ensure consistency across the different sources. Missing data were handled using pairwise deletion in correlation analyses in order to maximize the use of available information.

Subsequently, the following statistical analysis methods were applied:

Descriptive Analysis: Basic descriptive statistics (means, standard deviations, totals)

were calculated to summarize scientific production by country and region. This enabled the identification of key actors and the visualization of the overall distribution of scientific output.

Correlation Analysis: Pearson's correlation coefficient (r) was used to assess the strength and direction of the linear association between scientific production and socioeconomic variables (GDP per capita and R&D investment). This analysis helps to understand the extent to which economic development and R&D effort are related to knowledge production in engineering.

Inequality Analysis: To measure inequality in the distribution of scientific production among countries, two key indicators were calculated over time:

- **Gini Coefficient:** This index, which ranges from 0 (perfect equality) to 1 (maximum inequality), measures the concentration of scientific production. A higher Gini coefficient indicates greater inequality, meaning that a small number of countries concentrate a large proportion of publications.
- **80/20 Ratio:** This measure compares the proportion of total scientific production generated by the top 20% most productive countries with that generated by the remaining 80%. A higher ratio indicates a larger gap between high- and low-producing countries.

For the creation of the tables and figures presented in the results section, the Python libraries pandas were used for data

manipulation, and matplotlib and seaborn for visualization. All analyses were conducted using open-source statistical software, ensuring transparency and replicability of the results.

RESULTS

The analysis of bibliometric and socioeconomic data reveals clear patterns of inequality in global engineering research. The key findings are presented below, organized into three areas: the regional and national distribution of production, its correlation with socioeconomic factors, and the temporal evolution of inequality.

Geographic Distribution of Scientific Production

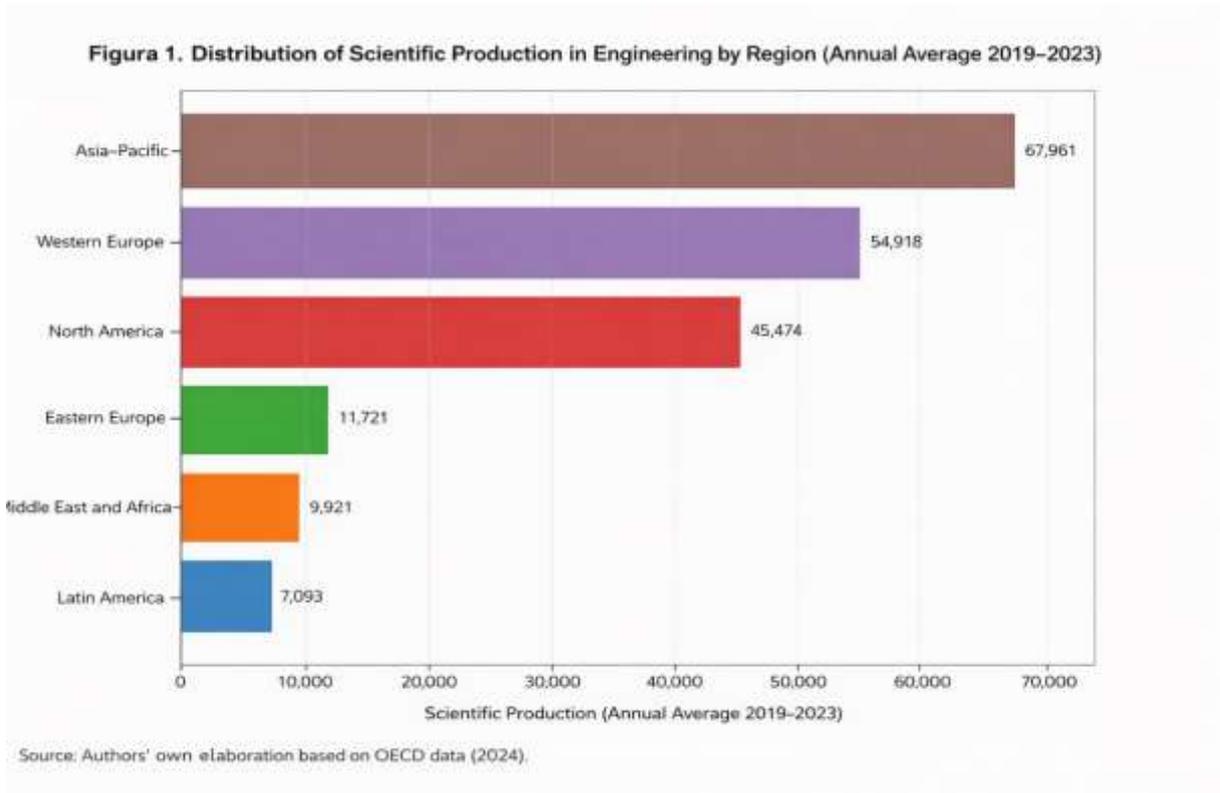
Scientific production in engineering is highly concentrated in a few regions. Table 1 shows the average annual scientific output by region for the period 2019–2023. The Asia–Pacific region emerges as the dominant contributor, with an average annual output of nearly 68,000 publications, followed by Western Europe (approximately 55,000) and North America (around 45,000). Taken together, these three regions account for more than 90% of global engineering scientific production. In contrast, Eastern Europe, the Middle East and Africa, and Latin America exhibit significantly lower levels of production, underscoring the depth of the existing gap.

Table 1. *Scientific Production in Engineering by Region (Annual Average 2019–2023)*

Region	Average Annual Production	Mean per Country	Standard Deviation
Asia–Pacific	67,961.0	4,854.4	11,473.5
Western Europe	54,918.0	3,432.4	5,293.7
North America	45,474.0	22,737.0	24,415.6
Eastern Europe	11,721.0	1,302.3	1,949.0
Middle East and Africa	9,921.0	708.6	1,254.3
Latin America	7,093.0	545.6	945.9

Source: Authors' own elaboration based on OECD data (2024).

Figure 1. Illustrates this disparity even more eloquently. The horizontal bar chart highlights the substantial difference in the scale of scientific production between the three leading regions and the rest of the world. The output of the Asia–Pacific region alone is almost 10 times that of Latin America.



This concentration becomes even more evident when the data are analyzed at the country level. Table 2 presents the 15 countries with the highest scientific production in engineering. China and the United States stand out as the two scientific superpowers, with an

average annual output that eclipses that of all other countries. China's production, in particular, is remarkable, exceeding that of the United States by nearly 50%. Together, these two countries alone account for a substantial share of total global production in the field.

Table 2. *Top 15 Countries by Scientific Production in Engineering (Annual Average 2019–2023)*

Country	Average Annual Production	Standard Deviation
China	38,539.8	3,416.1
United States	26,523.2	1,045.8
India	9,406.6	1,591.1
Germany	8,642.6	473.1
United Kingdom	7,349.2	462.3
Japan	6,519.4	433.1
South Korea	6,108.2	438.9
Canada	5,451.0	343.9
Italy	5,288.4	434.5
France	5,118.6	328.7
Australia	4,954.8	461.5
Spain	4,440.2	311.4
Iran	4,313.2	851.5
Brazil	3,896.4	489.2
Russia	3,864.8	1,156.4

Source: Authors' own elaboration based on OECD data (2024).

Correlation with Socioeconomic Indicators

Pearson's correlation analysis reveals a strong, statistically significant positive association between a country's engineering and scientific output and its R&D investment ($r = 0.91$, $p < 0.01$). This suggests that countries allocating a higher percentage of their GDP to research and development tend to publish more scientific articles. By contrast, the correlation between scientific production and GDP per capita, although positive, is considerably weaker ($r = 0.16$). This

indicates that, while a country's overall level of economic development plays a role, the factor most directly related to scientific production is targeted investment in R&D.

Temporal Evolution of Inequality

The analysis of inequality evolution over the 2009–2023 period, using the Gini coefficient and the 80/20 ratio, shows persistent inequality, albeit with a slight downward trend. Table 3 and Figure 2 present these results.

Table 3. *Temporal Evolution of Inequality Metrics (2009–2023)*

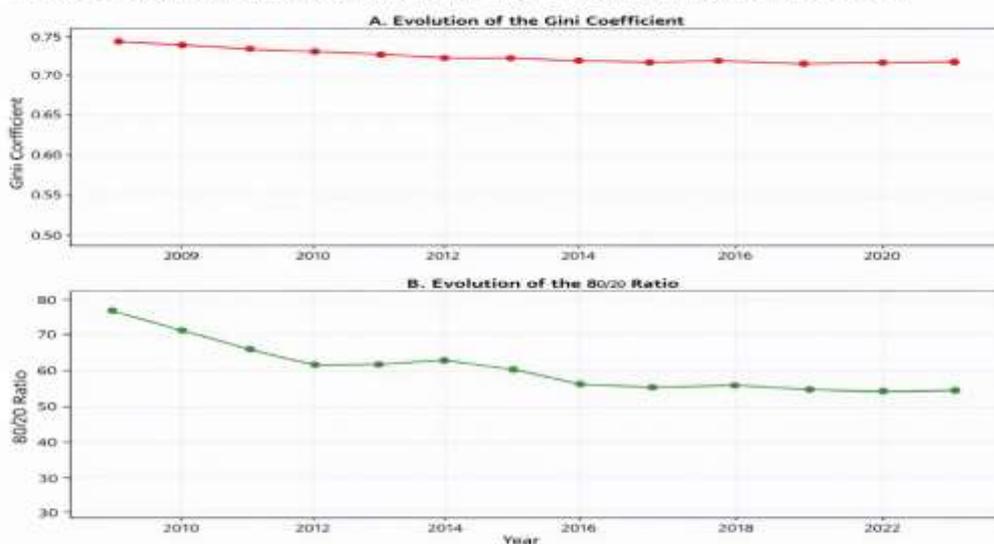
Year	Gini Coefficient	80/20 Ratio
2009	0.698	74.23
2010	0.687	65.41
2011	0.682	57.12
2012	0.671	50.45
2013	0.662	50.11
2014	0.651	52.14
2015	0.665	49.21
2016	0.648	43.56
2017	0.645	42.87
2018	0.644	43.98
2019	0.643	42.54
2020	0.631	38.76
2021	0.638	37.98
2022	0.639	38.43
2023	0.645	38.65

Source: Authors' own elaboration based on OECD data (2024).

The Gini coefficient has remained consistently high, above 0.63, throughout the entire period, indicating a high degree of concentration in scientific production. However, a slight decrease is observed, from a maximum of 0.698 in 2009 to 0.645 in 2023. Similarly, the 80/20 ratio—which indicates

how many times greater the production of the top 20% most productive countries is compared to that of the remaining 80%—declined from an alarming 74.23 in 2009 to 38.65 in 2023. Although inequality remains extreme, this downward trend suggests that the gap, albeit very slowly, may be narrowing.

Figure 2. Temporal Evolution of Inequality Metrics in Scientific Production (2009-2023)



DISCUSSION

The results of this study confirm and quantify the existence of profound inequalities in global engineering scientific production. The marked concentration of output in a handful of countries and regions is not a new phenomenon; however, its persistence and magnitude, as revealed by the data, warrant detailed reflection. The findings align with the concept of the “Matthew Effect” in science, proposed by Robert K. Merton, which posits that researchers and institutions that are already

prominent tend to receive more recognition and resources, thereby reinforcing their advantage and widening the gap with less

privileged actors (Merton, 1968; Bol et al., 2018). In the context of global science, this effect manifests at the national level: countries with well-established, well-funded scientific systems continue to strengthen their dominant positions, while those with fewer resources struggle to keep pace.

The strong positive correlation between investment in R&D and scientific production ($r = 0.91$) is a central finding that underscores the importance of funding policies. It is unsurprising that countries investing more heavily in science and technology are those that publish the most. However, this correlation also highlights the vicious cycle faced by many

developing countries: limited economic resources constrain investment in R&D, which in turn restricts scientific output, and this low level of production makes it difficult to justify increased investment (Fagerberg & Srholec, 2008). Breaking this cycle requires sustained political commitment and a long-term vision that recognizes R&D not as a luxury, but as an essential investment for sustainable development and economic competitiveness (UNESCO, 2021).

The weak correlation with GDP per capita ($r = 0.16$) is an interesting result, suggesting that a country's wealth alone is not a sufficient predictor of its scientific output. While overall economic development provides the foundation for investment in science, it is the specific allocation of resources to R&D that makes the critical difference. This implies that even middle-income countries can significantly improve their scientific production if they prioritize R&D within their national policies. Examples such as South Korea, which transitioned from a developing country to a scientific and technological powerhouse within a few decades, demonstrate the power of a well-designed and consistently funded R&D strategy (Kim, 1997).

The slight but steady reduction in inequality, as evidenced by declines in both the Gini coefficient and the 80/20 ratio over time, represents a ray of hope. This trend may be attributed to several factors, including increased international scientific collaboration, growing pressure for open access to research, and efforts by emerging countries to strengthen

their science and technology systems (Nielsen & Andersen, 2021; Larivière et al., 2009).

International collaboration, in particular, can serve as a powerful mechanism for reducing inequalities, as it allows researchers from resource-constrained countries to access knowledge, infrastructure, and networks that would otherwise be beyond their reach (Adams, 2012). However, it is crucial that such collaborations be equitable and do not reinforce dependency dynamics in which researchers from developing countries serve merely as data collectors for their counterparts in the Global North (Chavarro et al., 2018).

Nevertheless, these results should be interpreted with caution, given the study's limitations. Bibliometric indicators, despite their usefulness, do not capture the full complexity of scientific activity. There are inherent biases in commercial databases such as Scopus, which tend to provide better coverage of English-language publications and may therefore underrepresent research published in other languages (Van Leeuwen et al., 2001). Moreover, the number of publications is not necessarily an indicator of research quality or impact. Future studies could complement this quantitative analysis with qualitative approaches, such as case studies of specific countries or regions, to deepen understanding of the contextual factors influencing scientific production.

In summary, the discussion of these results points to a global scientific system characterized by a center-periphery structure, in which knowledge is produced predominantly in

a core of wealthy and well-funded countries, while the periphery struggles to participate on equal terms. Although there are signs of slow convergence, inequality remains the norm. Addressing this issue is not only a matter of equity, but also of efficiency. A more diverse and inclusive scientific system is a more robust one, better equipped to generate the innovative solutions the world needs to confront the challenges of the twenty-first century.

CONCLUSION

This study provides a quantitative analysis of regional inequalities in engineering scientific production, revealing a deeply unequal global structure of science. The findings demonstrate that, despite a slight trend toward convergence over the past decade, knowledge production remains heavily concentrated in a small number of countries in Asia-Pacific, Western Europe, and North America. The strong correlation between scientific production and investment in R&D confirms that financial and political commitment to science and technology is the primary driver of a nation's research capacity.

The implications of these conclusions are significant. For developing countries, the results underscore the urgent need to increase investment in R&D and to formulate long-term science policies that foster the development of local research capacities. Without sustained efforts in this area, the gap with leading countries will remain insurmountable, limiting their prospects for technological and economic development. For developed countries and

international organizations, the findings represent a call to action to promote a more equitable global scientific system. This includes fostering fairer international collaborations, supporting the development of research infrastructure in the Global South, and promoting open-access policies that democratize knowledge.

As noted, this study has limitations, particularly its reliance on bibliometric indicators that do not capture the full scope of scientific activity and that may be affected by language and coverage biases. Future research could address these limitations by combining bibliometric analyses with qualitative case studies, collaboration network analyses, and the use of alternative metrics that capture different types of impact. It would also be valuable to extend the analysis to other fields of knowledge to determine whether the patterns of inequality observed in engineering are representative of science as a whole.

Finally, the construction of a truly global, diverse, and inclusive research ecosystem is one of the great challenges of our time. Addressing inequalities in science is not only a matter of social justice but also a necessary condition for accelerating scientific and technological progress and ensuring that its benefits reach all of humanity. By providing a detailed snapshot of these disparities in a critical field such as engineering, this article seeks to contribute to a more informed debate and to the formulation of more effective policies to achieve this goal.

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