# Identification of Research Growth and Decline in Countries Based on the Growth Rate of SCI Paper Citation Frequency

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ABSTRACT

This study examines global research productivity, international collaboration, and citation growth trends from 1980 to 2023 using Web of Science data. Bibliometric analysis assessed national publication shares, collaboration rates, and five-year average citations per paper. Regression and correlation analyses explored relationships between these variables, while publication trends across 22 fields identified significant national research growth or decline. Findings reveal a weak negative correlation (-0.3937 to -0.0935) between research productivity and collaboration. China, South Korea, and Saudi Arabia showed increased publication shares, while the United States and Japan declined. Singapore and Estonia exhibited strong citation growth, whereas the United States maintained high citation counts despite slower growth. Russia excelled in microbiology and engineering, while the United States and Luxembourg saw declines in multiple fields. The study's reliance on Web of Science data may underrepresent certain regions or disciplines, and qualitative aspects of collaboration were not assessed. Future research should integrate broader data sources. This research informs national strategies, investment decisions, and global partnerships. By identifying research trends, it supports policy decisions influencing economic and technological progress, highlighting the role of science in national development.

## 1. Introduction

Over the past decades, scientific and technological research has advanced rapidly worldwide, becoming a key factor in fostering both competition and collaboration among nations. Scientific research outputs significantly influence a country's economic, social, and technological growth. Metrics such as SCI papers, international collaboration, and citation counts are widely utilized as primary indicators to evaluate national research capabilities and academic impact. Consequently, comparing national research performance and identifying trends in specific research fields are essential for allocating research resources and formulating strategic plans at the national level. Specifically, the

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share of research publications by country reflects research productivity, while the proportion of internationally collaborative papers highlights the interdependence and cooperative relationships within the global research network. Additionally, the average citations per paper serve as a critical measure of the quality of research outputs. High citation counts indicate substantial academic influence, offering insights into a country's competitiveness in science and technology. Therefore, a comprehensive analysis of these metrics is crucial to accurately assess national research capacity and explore potential avenues for development. Furthermore, analyzing the changes in publication rates across standard research fields, as classified by the Web of Science, helps identify areas of exceptional growth or decline for specific countries. Such an analysis sheds light on the strategic focus of national research efforts and provides foundational data for optimizing research and development support and resource allocation. This study is necessary to conduct a multifaceted analysis of national research performance and influence using SCI data. It aims to understand each country's position within the global research landscape and propose research fields to strengthen. The findings will not only contribute to academic discourse but also offer strategic insights for policymakers and research administrators, facilitating effective decision-making.

## 2. Material and Methods

The objective of this study is to conduct a comprehensive analysis of the research activities and influence of major countries using SCI paper data from 1980 to 2023. Specifically, this study aims to assess the research performance and collaboration status of each country by examining national publication shares and international collaboration shares. Additionally, it seeks to analyze the five-year periodic changes in average citations per paper to identify trends of growth or decline in citation influence across countries. Furthermore, by analyzing the publication rate changes across 22 standard research fields defined by the Web of Science, this study aims to identify countries showing remarkable growth or decline in specific fields, thereby exploring research intensity and trends at the field level. Through this systematic analysis, the study intends to provide insights into national research capacities, collaboration patterns, field-specific research focus, and changes in citation influence. These findings will aid in understanding the global research environment, the positioning of nations within it, and offer actionable insights for the development of national research strategies. The following research hypotheses will guide the analysis. In this study, generative AI was utilized to calculate correlation coefficients and generate regression analysis graphs. Additionally, generative AI was employed in extracting and processing data from raw datasets.

- **Research Question 1.** Relationship between National Publication Share and International Collaboration Share

- Hypothesis. Countries with a higher SCI publication share will also exhibit a higher international collaboration share.
- This hypothesis tests the prediction that a positive correlation exists between a country's total

publication share and its share of internationally collaborative papers.

- **Research Question 2.** Differences in Citation Influence Based on Changes in Average Citations per Paper
  - Hypothesis. Countries with higher average citations per paper will experience continued growth in citation influence.
  - This hypothesis examines whether countries with high or increasing average citations per paper will expand their citation influence over time.
- **Research Question 3.** Growth or Decline Trends of Countries in Standard Research Fields
  - Hypothesis. Certain standard research fields will exhibit distinct growth or decline trends in publication rates for specific countries.
  - This hypothesis tests whether annual changes in publication rates vary across standard research fields and whether specific countries can be identified as leaders or laggards in these fields.

By addressing these research questions, this study aims to analyze the changes in publication shares, field-specific trends, and citation influence at a national level. This will enable the identification of strategic differences in academic influence across countries, contributing to a deeper understanding of global research dynamics.

## 3. Proceeding Studies

Chen et al. (2022) analyzed over 63 million articles and 1.45 billion citations in the Web of Science database, proposing a new metric called ASP (Article's Scientific Prestige) to measure the scientific prominence of individual articles. ASP is used to evaluate the influence of articles in comparison to traditional metrics such as citation counts and journal rankings. Iqbal et al. (2021) conducted a comprehensive review of citation analysis studies over the past decade, focusing on advancements in natural language processing and machine learning techniques. Their study explored citation context and content analysis, citation classification, sentiment analysis of citations, citation summarization, and citation-based recommendation systems, highlighting technological advancements in these areas. Additionally, many studies have utilized both Web of Science (WoS) and Scopus databases for citation analysis. Khurana et al. (2021) proposed a system that integrates data from Scopus and WoS to create a unified metric for comparative analysis at researcher, institutional, and journal levels. Their work also introduced a mapping between research publications and distributed ledger technologies, offering a transparent and decentralized perspective. Leyva et al. (2024) conducted a bibliometric analysis of literacy in the tourism labor market using data from both WoS and Scopus. They compared publication counts, citation impact, and collaboration networks, concluding that Scopus exhibits broader influence and sustained citation relevance. Zhu (2020) analyzed the use of WoS and Scopus in academic publications from 2004 to 2018, revealing that both databases are increasingly utilized, with Scopus challenging WoS's dominant role. The study also examined usage patterns across countries and disciplines. These studies highlight the utility of WoS and Scopus data in citation analysis, bibliometric applications, and academic impact

evaluation.

In contrast to these prior works, this study focuses on SCI articles from 1980 to 2023, analyzing national research output shares and international collaboration shares. Furthermore, it examines five-year periodic changes in average citations per paper to identify countries experiencing growth or decline in citation impact. Additionally, this research analyzes publication rate changes across 22 standard fields defined by WoS, identifying countries with significant growth or decline trends in these areas. By doing so, this study contributes a comprehensive longitudinal perspective to the analysis of global research trends and national performance.

## 4. Data Analysis

### *4.1 Analysis of the Relationship Between National Research Output and International Collaboration Papers*

This study conducted a correlation analysis using the number of research papers and the number of international collaboration papers indexed in the Web of Science to understand the strength and direction of the linear relationship between these variables. The goal was to examine how national research productivity is associated with international collaboration activities, specifically whether an increase in one variable correlates with an increase or decrease in the other. Additionally, regression analysis was performed to quantitatively assess the impact of national research output on international collaboration papers and to develop a predictive model for this relationship. This analysis aimed to provide a clearer understanding of the interdependence between the two variables and to predict changes in one based on changes in the other.

The results showed that the correlation coefficient ranged from -0.0935 to -0.3937, indicating a weak negative correlation. This suggests that countries with a higher share of global research output tend to have a slightly lower share of global international collaboration papers. The weak negative correlation implies that strong connections between national research productivity and international collaboration activities may not exist. It also suggests that highly productive countries may not necessarily engage heavily in producing international collaboration papers.

The regression analysis combining all years showed a slope of -0.7871 and an intercept of 40.7229. The negative slope (-0.7871) indicates a negative linear relationship between national research output and international collaboration papers. Figure 1 illustrates the linear relationship and regression line, showing that an increase in a country's share of global research output is associated with a decrease in its share of international collaboration papers. This trend may reflect that some countries focus more on domestic research and perceive a relatively lower need for international collaboration.

In summary, the correlation and regression analyses confirmed a weak negative relationship between the two variables. This finding highlights that the degree of international collaboration can vary depending on national research productivity and may be influenced by a complex set of factors. These results underscore that highly productive countries may not always prioritize international collaboration, pointing to the diversity in research strategies and priorities among nations.

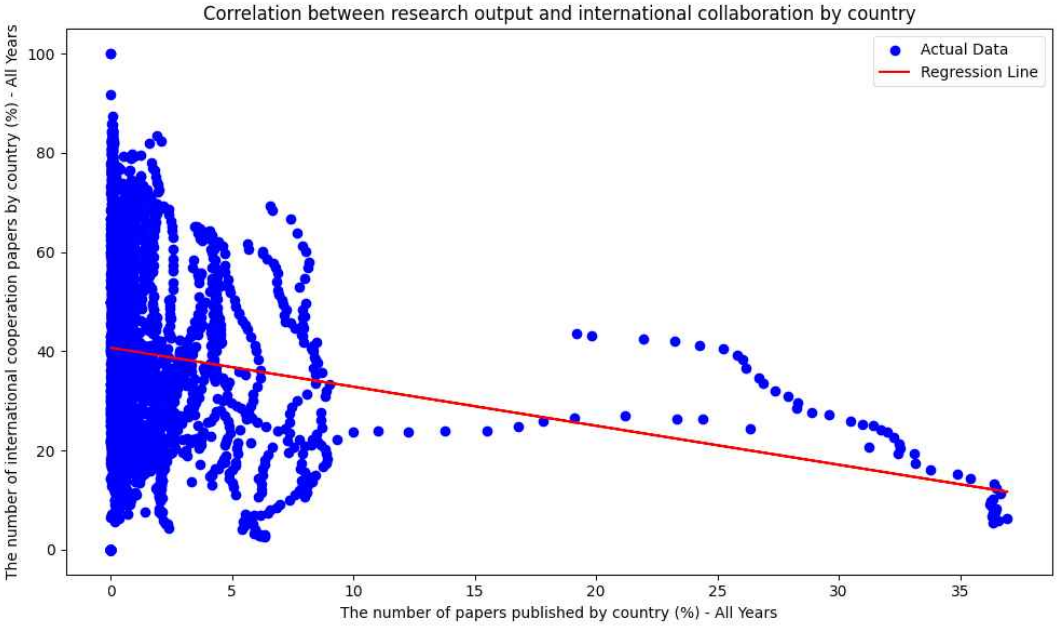


Fig. 1. Correlation between research output and international collaboration by country

### *4.2 Analysis of Global Share in National Research Output*

The shifts in the global market share of scientific publications have significantly transformed the landscape of major scientific contributors over the past decades. This analysis examines the changes in the global publication shares of countries and regions from 1980 to 2023 to explore new trends and dynamics in scientific research. Table 1 investigates the global share of research output by country, identifying the top 10 countries with rapid growth and the bottom 10 countries with significant declines. It highlights each country's change in market share (MarketShare_Change) and its classification as growth or decline (Change_Type). Similarly, Table 2 examines the global share of international collaboration papers, identifying the top 10 countries with rapid growth and the bottom 10 countries with declines, presenting their market share changes and classifications. Through this analysis, the study uncovers emerging patterns in global scientific research contributions, revealing regions and countries driving growth and those experiencing decline. These results provide insights into shifts in the global research ecosystem and contribute to understanding the strategic focus of countries in maintaining or improving their scientific standing.

Table 1. Top 10 Countries with Rapid Growth and Decline in Global Share (%) of National Research Output

| Country | MarketShare_Change | Change_Type |
|---|---|---|
| CHINA MAINLAND | 32.25750815 | HighGrowth |
| SOUTH KOREA | 3.313208211 | HighGrowth |
| INDIA | 3.131479691 | HighGrowth |
| SPAIN | 2.712039466 | HighGrowth |
| ITALY | 2.253195193 | HighGrowth |
| TURKIYE | 2.094852245 | HighGrowth |
| BRAZIL | 2.051486555 | HighGrowth |
| SAUDI ARABIA | 2.023946861 | HighGrowth |
| IRAN | 1.948239202 | HighGrowth |
| RUSSIA | 1.919681902 | HighGrowth |
| USA | -17.1320015 | HighDecline |
| USSR | -6.134883961 | HighDecline |
| JAPAN | -1.610126686 | HighDecline |
| FRANCE | -1.591537825 | HighDecline |
| UNITED KINGDOM | -1.44220703 | HighDecline |
| CZECHOSLOVAKIA | -0.5172998072 | HighDecline |
| CANADA | -0.5116384988 | HighDecline |
| GERMANY (FED REP GER) | -0.4731075642 | HighDecline |
| ISRAEL | -0.2020237781 | HighDecline |
| HUNGARY | -0.1461086241 | HighDecline |

The analysis reveals that countries in Asia and the Middle East are rapidly growing in their contribution to scientific publications, while traditional Western scientific powerhouses are experiencing a relative decline in global share. Among the countries with significant growth, China stands out due to its continuous investment in research and development (R&D) and strong national support. Recognizing science and technology as critical components of economic growth, China has become one of the fastest-growing contributors to global scientific research. South Korea has also emerged as a key scientific hub in Asia, driven by substantial investments in science and engineering and the achievements of its universities and research institutions. Similarly, India has increased its global share in scientific publications through active investment in higher education and research infrastructure. In the Middle East, countries like Saudi Arabia, Türkiye, and Iran are expanding their influence on global science through policies that promote research and innovation. Saudi Arabia, in particular, is enhancing its research environment and increasing support for innovation, while countries like Brazil in South America are also improving their global share through government-led scientific development. In contrast, traditional leaders in scientific research, such as Western countries, have experienced a relative decline in their global share.

Table 2. Top 10 Countries with Rapid Growth and Decline in Global Share (%) of International Collaboration Papers

| Country | MarketShare_Change | Change_Type |
|---|---|---|
| COSTA RICA | 69.35 | HighGrowth |
| SLOVAKIA | 63.95 | HighGrowth |
| KUWAIT | 62.26 | HighGrowth |
| AUSTRIA | 61.98 | HighGrowth |
| SLOVENIA | 61.89 | HighGrowth |
| SINGAPORE | 61.04 | HighGrowth |
| CZECH REPUBLIC | 58.81 | HighGrowth |
| UNITED KINGDOM | 58.66 | HighGrowth |
| SAUDI ARABIA | 58.54 | HighGrowth |
| VIETNAM | 58.39 | HighGrowth |
| CZECHOSLOVAKIA | -10.37 | HighDecline |
| KAZAKHSTAN | -7.71 | HighDecline |
| SOUTH KOREA | -7.34 | HighDecline |
| USSR | -2.78 | HighDecline |
| RUSSIA | 3.4 | HighDecline |
| LITHUANIA | 5.89 | HighDecline |
| INDONESIA | 7.48 | HighDecline |
| IRAN | 7.8 | HighDecline |
| TURKIYE | 10.83 | HighDecline |
| LATVIA | 13.15 | HighDecline |

The United States remains a major contributor to global science; however, its relative share has declined as Asian countries have significantly increased their contributions. This trend is particularly evident when comparing the U.S. with China, which has seen a dramatic rise in scientific publication output. To maintain its position as a leading scientific powerhouse, the U.S. needs to adopt additional strategic measures. Similarly, Japan, once a dominant scientific leader in Asia, has experienced slower growth due to a combination of concentrated research efforts and an economic slowdown. European nations, including the United Kingdom, France, and Germany, have also witnessed a decline in their global share of scientific contributions. These countries face new challenges in maintaining their scientific influence amidst competition from rapidly growing nations in Asia and the Middle East. These shifts highlight a global realignment in the landscape of scientific research. Historically dominated by Western nations, the center of global scientific activity is now becoming more multipolar, with Asia and the Middle East emerging as key players. This trend underscores the close connection between economic development and advancements in science and technology. Countries with strong economic growth tend to invest more in scientific research, which, in turn, leads to increased scientific publication output. Strategic investment and support in research have proven to significantly influence a country's scientific contributions, and this pattern is expected

to continue in the future.

In conclusion, the growth of scientific contributions from Asia and the Middle East reflects the recognition of science and technology as critical drivers of national development. To remain competitive, established scientific powerhouses must make sustained and strategic investments in research and innovation. Furthermore, a new approach is needed to strengthen global collaboration and competitiveness in scientific research. This analysis provides valuable insights for nations seeking to maintain their competitiveness and achieve better research outcomes in an evolving global scientific landscape. It also validates the findings based on the data presented earlier on the "Top 10 Countries with Rapid Growth and Decline in Global Share (%) of National Research Output" and "Top 10 Countries with Rapid Growth and Decline in Global Share (%) of International Collaboration Papers."

Based on the above analysis, Research Question 1 was validated. To validate this, countries included in both datasets were compared, and the consistency of change types and directions was examined. As a result, the countries that were commonly included were Saudi Arabia, South Korea, the USSR, Russia, Türkiye, and Iran. Among them, Saudi Arabia was classified as HighGrowth in both publication share and international collaboration share, showing consistency with the research question. In the case of South Korea, although it was classified as HighGrowth in publication share, it was classified as HighDecline in international collaboration share, which contradicts the research question. Similarly, the USSR was classified as HighDecline in both publication share and international collaboration share, aligning with the research question. Russia, on the other hand, was classified as HighGrowth in publication share but HighDecline in international collaboration share, showing inconsistency. Türkiye was also classified as HighGrowth in publication share but HighDecline in international collaboration share, which does not support the research question. Lastly, Iran was classified as HighGrowth in publication share but HighDecline in international collaboration share, which also contradicts the research question.

As a result of the analysis, Research Question 1 was consistent with some countries, such as Saudi Arabia and the USSR, but inconsistent with the majority of countries, including South Korea, Russia, Türkiye, and Iran. This indicates that the trends of increase or decrease in national publication share and international collaboration share do not align in many cases, making it difficult to generalize Research Question 1. Therefore, it can be concluded that a higher national publication share does not necessarily lead to a higher international collaboration share.

### *4.3 Analysis of the 5-Year Average Citations per Paper by Country*

Following the analysis of national publication shares and international collaboration shares, the 5-year average citations per paper by country were analyzed. This analysis identified countries with high 5-year average citation rates (top growing countries) and those with low growth rates (top declining countries), and the implications of these findings were explored. Table 3 presents the top growing countries in terms of 5-year average citations per paper, along with their average growth rates and the number of citations per paper for the period 2019–2023. Table 4 displays the top declining countries in terms of 5-year average citations per paper, their average growth rates, and the number of citations per paper for the same period.

Table 3. 5-Year Period Top Growing Countries

| Country | Growth | The number of citations per paper for the period 2019–2023 |
|---|---|---|
| LITHUANIA | 54.5351146 | 8.850628174 |
| LATVIA | 34.90699856 | 11.27174062 |
| KAZAKHSTAN | 25.70188358 | 8.612954889 |
| SLOVAKIA | 21.8151462 | 8.251524164 |
| SLOVENIA | 15.82241799 | 10.22846058 |
| ESTONIA | 13.41685733 | 15.48311235 |
| CZECHOSLOVAKIA | 13.3177264 | 0 |
| LUXEMBOURG | 8.732039371 | 13.00063837 |
| VIETNAM | 8.617488161 | 12.36848983 |
| SINGAPORE | 8.264372749 | 17.0945187 |

The analysis of the Top Growing Countries (5-Year Period) highlights significant trends in the growth of research impact among various nations. Lithuania emerges as the leader with an average growth rate of 54.54%, achieving 8.85 citations per paper. Although the citation rate is moderate, the rapid growth underscores the country's improving research performance over the period. Similarly, Latvia, with a growth rate of 34.91% and 11.27 citations per paper, demonstrates both strong growth and a relatively high citation rate, reflecting its rising research influence.

Kazakhstan shows notable progress with a growth rate of 25.70% and 8.61 citations per paper, indicating fast growth despite a slightly lower citation rate. Slovakia, with a growth rate of 21.82% and 8.25 citations per paper, demonstrates steady performance, while Slovenia, at 15.82% growth and 10.23 citations per paper, maintains a balanced position with a mid-level citation rate.

Estonia, with a growth rate of 13.42%, achieves the highest citation rate among the top growing countries at 15.48 citations per paper, highlighting its substantial research impact. Czechoslovakia, despite a growth rate of 13.32%, faces challenges in sustaining its research impact due to data limitations, with 0 citations recorded per paper. Luxembourg exhibits a growth rate of 8.73% and 13.00 citations per paper, reflecting stable research performance.

Vietnam, with a growth rate of 8.62% and 12.37 citations per paper, shows steady progress and a reliable citation rate. Singapore, at a growth rate of 8.26%, achieves the highest citation rate of 17.09 citations per paper, signifying its dominant research influence and consistent excellence.

This analysis reveals the diverse strengths of the top growing countries, with some excelling in rapid growth and others maintaining high citation performance, illustrating their increasing prominence in the global research landscape.

The analysis of the Top Declining Countries (5-Year Period) provides meaningful insights into countries with low growth rates but significant citation impact. The United States, for instance, recorded a growth rate of only 2.91%, but achieved 11.05 citations per paper, indicating the presence of numerous influential publications. Sweden exhibited a growth rate of 3.30%, with an impressive 12.94 citations per paper, highlighting its strong research impact. Switzerland, with the same growth rate of 3.30%, achieved an even higher citation rate of 14.13 citations per paper, demonstrating

exceptional academic influence. Japan, on the other hand, showed a growth rate of 3.35% and a citation rate of 8.64 per paper, which places it at a moderate level of influence. Denmark recorded a growth rate of 3.47% with a notable citation rate of 13.95 per paper, underscoring its research relevance. Similarly, the United Kingdom achieved a growth rate of 3.48% and a citation rate of 12.18 per paper, which is considerably high. The Netherlands demonstrated a growth rate of 3.64% and a citation rate of 13.73 per paper, maintaining significant research impact despite a relatively low growth rate. Israel, with a growth rate of 3.68% and a citation rate of 10.78 per paper, exhibited above-average academic influence. Norway recorded a growth rate of 3.80%, with 11.82 citations per paper, reflecting steady performance. Finally, Germany (Federal Republic of Germany) achieved a growth rate of 3.81% and a citation rate of 11.38 per paper, indicating consistent research influence over time.

Table 4. 5-Year Period Top Declining Countries

| Country | Growth | The number of citations per paper for the period 2019–2023 |
|---|---|---|
| USA | 2.914180165 | 11.05100736 |
| SWEDEN | 3.298288308 | 12.94333796 |
| SWITZERLAND | 3.298402353 | 14.13167903 |
| JAPAN | 3.346866546 | 8.641347619 |
| DENMARK | 3.47041153 | 13.94971066 |
| UNITED KINGDOM | 3.484469611 | 12.18431237 |
| NETHERLANDS | 3.63738352 | 13.72647417 |
| ISRAEL | 3.675414565 | 10.77903188 |
| NORWAY | 3.79785135 | 11.8178105 |
| GERMANY (FED REP GER) | 3.805098498 | 11.37815922 |

Building on this analysis, Research Question 2 was validated by comparing the average citations per paper and growth rates for each country. This aimed to determine whether countries with high average citation counts continued to experience growth in their influence. The validation process revealed the following findings. First, in the case of the Top Growing Countries, countries with high citation impact, such as Singapore with 17.09 citations per paper, as well as Estonia and Luxembourg with citation rates of 15.48 and 13.00 respectively, demonstrated not only strong citation performance but also sustained growth rates. These results suggest a positive correlation between high citation rates and growth, supporting Research Question 2. Second, the analysis of the Top Declining Countries examined whether countries with low growth rates but high average citations could sustain their influence. Countries such as Switzerland, Sweden, and the Netherlands, which all recorded over 13 citations per paper, continue to maintain significant academic impact despite their stagnating or low growth rates. This indicates that while high citation rates are an indicator of strong research influence, they do not necessarily guarantee sustained growth, thereby providing a mixed validation of Research Question 2.

In conclusion, the findings partially support the hypothesis that countries with high average citations

tend to expand their citation influence. However, there are cases where high citation counts are sustained even without corresponding growth rates. This indicates that while high average citation rates often correlate with expanded influence, this trend is not universal and can vary depending on the specific research environment and academic disciplines.

### *4.4 Analysis of Growth and Decline in Average Citations per Paper by Standard Research Fields for Major Countries*

The Web of Science categorizes research outputs into 22 standard research fields. This analysis focused on identifying countries that demonstrated either growth or decline in their annual average citations per paper across these fields and examined the characteristics of these trends.

Using annual average citation data for each field, the analysis highlighted key performers. Table 5 provides a list of countries with the highest average growth rates in their respective fields (Standard field name) and showcases their research progress. The findings reveal areas where nations are excelling and expanding their influence, offering insights into the evolving dynamics of global academic contributions.

Table 5. Countries with the Highest Growth Rates in Average Citations per Paper by Standard Research Fields

| Standard field name | Country name | Average Growth Rate |
|---|---|---|
| Agricultural Sciences | RUSSIA | 71.36438727 |
| Biology & Biochemistry | SLOVAKIA | 99.2012338 |
| Chemistry | RUSSIA | 127.7532234 |
| Clinical Medicine | SLOVENIA | 51.19131529 |
| Computer Science | CHINA MAINLAND | 54.26015192 |
| Economics & Business | CZECH REPUBLIC | 48.5236103 |
| Engineering | RUSSIA | 178.3177458 |
| Environment Ecology | RUSSIA | 72.00293737 |
| Geosciences | COLOMBIA | 58.03001141 |
| Immunology | RUSSIA | 158.5702744 |
| Materials Science | LUXEMBOURG | 32.68907787 |
| Mathematics | RUSSIA | 97.35396557 |
| Microbiology | RUSSIA | 395.79791 |
| **Molecular Biology & Genetics** | **SOUTH KOREA** | 33.62235543 |
| Multidisciplinary | CHINA MAINLAND | 349.9193987 |
| Neuroscience & Behavior | RUSSIA | 161.2343803 |
| Pharmacology & Toxicology | LATVIA | 52.85282246 |
| Physics | RUSSIA | 171.0720549 |
| Plant & Animal Science | RUSSIA | 49.18174768 |
| **Psychiatry Psychology** | **SOUTH KOREA** | 44.4557221 |
| Social Sciences, general | RUSSIA | 70.9104238 |
| Space Science | RUSSIA | 69.68775127 |

This dataset highlights the countries with the highest growth rates in each standard research field, along with their corresponding averages. A high growth rate indicates that a country has significantly increased its research activity within a particular field. The data shows that Russia stands out across numerous fields, recording exceptional growth rates such as 395.80% in Microbiology, 158.57% in Immunology, and 178.32% in Engineering. Additionally, Russia demonstrates strong growth in fields like Chemistry, Environment & Ecology, Neuroscience & Behavior, Physics, and Space Science, reflecting its comprehensive advancements in scientific research. Slovakia has shown remarkable progress in Biology & Biochemistry, achieving a growth rate of 99.20%, which highlights its active research development in this domain. Similarly, China Mainland demonstrates impressive growth in Computer Science with 54.26% and an extraordinary 349.92% in Multidisciplinary Research, indicating a significant expansion of cross-disciplinary research initiatives. South Korea recorded growth rates of 33.62% in Molecular Biology & Genetics and 44.46% in Psychiatry & Psychology, showcasing its active focus on these areas. Slovenia achieved a growth rate of 51.19% in Clinical Medicine, highlighting advancements in medical research. Colombia, with a growth rate of 58.03% in Geosciences, illustrates growing interest and investment in earth science research. In Pharmacology & Toxicology, Latvia reached a growth rate of 52.85%, reflecting a strong engagement in this field. Luxembourg reported a growth rate of 32.69% in Materials Science, showing steady research development. The Czech Republic achieved a growth rate of 48.52% in Economics & Business, signaling its increasing focus on economic and business studies.

In summary, these results show that many countries are increasing their investments in diverse scientific and social science fields. Russia demonstrates particularly remarkable growth across multiple fields, including Microbiology, Engineering, and Physics, signifying its wide-ranging scientific development. Other nations, such as China, South Korea, Slovenia, and Colombia, are also displaying notable advancements in their respective areas of research.

On the other hand, Table 6 provides a list of countries with the lowest average growth rates in standard research fields. These countries show a decline in their average citations per paper, with negative growth rates reflecting a decrease in research impact or activity in specific fields.

Table 6. Countries with the Lowest Growth Rates in Average Citations per Paper by Standard Research Fields

| Standard field name | Country name | Average Growth Rate |
|---|---|---|
| Agricultural Sciences | USA | 1.879472083 |
| Biology & Biochemistry | USA | 1.348142021 |
| Chemistry | JAPAN | 1.82153298 |
| Clinical Medicine | USA | 3.155332184 |
| Computer Science | USA | 4.368631894 |
| Economics & Business | ISRAEL | 3.040823587 |
| Engineering | USA | 3.488055264 |
| Environment Ecology | SLOVAKIA | 2.834561732 |
| Geosciences | USA | 3.048796436 |

| Standard field name | Country name | Average Growth Rate |
|---|---|---|
| Immunology | SWEDEN | 2.716467202 |
| Materials Science | RUSSIA | 1.835679901 |
| Mathematics | LUXEMBOURG | 1.08386502 |
| Microbiology | USA | 3.26979072 |
| Molecular Biology & Genetics | RUSSIA | -2.162935355 |
| Multidisciplinary | LUXEMBOURG | -27.88888889 |
| Neuroscience & Behavior | USA | 3.34579857 |
| Pharmacology & Toxicology | JAPAN | 1.725998073 |
| Physics | USA | 1.517746352 |
| Plant & Animal Science | CANADA | 1.703752108 |
| Psychiatry Psychology | USA | 2.484207745 |
| Social Sciences, general | USA | 3.081781626 |
| Space Science | LUXEMBOURG | -13.33333333 |

The analysis of the above data reveals that the United States exhibited the highest decline rates across multiple standard research fields. Notably, it showed a decrease of -1.879% in Agricultural Sciences, -1.348% in Biology & Biochemistry, -3.155% in Clinical Medicine, -4.368% in Computer Science, and -3.488% in Engineering. These results suggest that research activity in the United States has decreased significantly across various scientific fields. Japan recorded the highest decline rates in Chemistry (-1.821%) and Pharmacology & Toxicology (-1.725%), indicating a possible reduction in research investment or output in these fields. Similarly, Israel experienced a decline of -3.040% in Economics & Business, reflecting reduced research activity in this area. Slovakia showed a decline of -2.834% in Environment & Ecology, while Sweden experienced a decline of -2.716% in Immunology, indicating a reduction in research activity in immunology. Russia recorded decline rates of -1.835% in Materials Science and -2.162% in Molecular Biology & Genetics. The decrease in molecular biology and genetics suggests that Russia's focus on these fields may have diminished. Luxembourg exhibited significant declines across multiple fields, with the most dramatic reductions observed in Multidisciplinary Research (-27.88%) and Space Science (-13.33%). These figures indicate a sharp reduction in research activity in these domains. Canada also experienced a decline of -1.703% in Plant & Animal Science, further illustrating a decrease in research intensity.

In summary, Luxembourg saw a steep decline in multidisciplinary and space science research, while the United States showed a downward trend across several major scientific fields. These results may reflect reductions in research investments or shifts in national research priorities in these countries. Based on this analysis, the validation results for Research Question 3 are as follows. To validate this research question, the growth or decline trends of specific countries across standard research fields were examined using the data provided in Table 5 and Table 6. The results show that certain countries, such as Russia, China, and Slovakia, have demonstrated notable growth trends in specific fields. This confirms that research intensity and focus vary by field across countries. Therefore, this study contributes to understanding national research strategies by analyzing the concen-

tration and trends of research in specific fields. It highlights how countries prioritize certain research areas and provides insights that can inform national research policy and investment decisions.

## 5. Conclusion

This study analyzed national research productivity, international collaboration, average citations per paper, and research trends across standard fields to explore the relationship between research collaboration and impact among countries. The findings can be summarized as follows:

First, the correlation and regression analysis of national publication counts and international collaboration counts revealed a weak negative relationship (-0.3937 to -0.0935), indicating that higher research productivity does not necessarily correspond to more active international collaboration. Validation of Research Question 1 showed that while certain countries (e.g., Saudi Arabia and the Soviet Union) exhibited trends aligned with the hypothesis, others, including South Korea, Russia, Türkiye, and Iran, displayed inconsistencies between publication share and international collaboration share. This suggests that national research output and collaboration strategies vary significantly, and a high publication share does not guarantee a proportionally high collaboration share. Second, an analysis of changes in global publication share revealed notable growth in countries such as China, South Korea, and India, as well as Middle Eastern countries like Saudi Arabia. In contrast, traditional scientific powerhouses such as the United States and Japan experienced a decline in their shares. Validation of Research Question 2 indicated that countries like Singapore and Estonia, with both high growth rates and citation counts, continued to expand their research influence. However, examples like the United States and Switzerland demonstrated that even countries with low growth rates could maintain high citation counts. Thus, while a high average citation count increases the likelihood of expanding research influence, it is not a universal rule. Third, the analysis of the 5-year average citations per paper revealed that countries such as Singapore and Estonia significantly increased their research impact through high citation counts, whereas countries like the United States and Japan, despite low growth rates, continued to maintain high citation counts. Fourth, an analysis of research trends in standard fields demonstrated that Russia achieved high growth rates in areas such as microbiology, engineering, and physics, while China excelled in multidisciplinary research. Conversely, the United States and Luxembourg exhibited declines across multiple fields. Validation of Research Question 3 confirmed that countries such as Russia, China, and Slovakia demonstrated significant growth in specific fields (e.g., microbiology, engineering, and multidisciplinary research), while others, such as the United States and Luxembourg, experienced declines in some areas. These findings highlight that the focus of research varies by country and field, influencing national scientific strategies.

This study provides several key implications. First, it offers foundational data for developing national research strategies and policy frameworks. Second, it enables an understanding of the research focus and collaboration trends of specific countries or regions, contributing to insights into the global direction of scientific research. Third, it presents actionable recommendations for strengthening international collaboration or adjusting investments in specific research areas. However, this study

is limited by its reliance on Web of Science data, which may underestimate research activity in specific disciplines or regions compared to other databases. Additionally, the relationship between international collaboration and research impact may not fully account for qualitative factors such as the significance of research content.

In conclusion, this study elucidates the complex correlations between national scientific research activity and international collaboration, offering valuable insights that can contribute to enhancing research productivity and shaping collaboration strategies.

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