Using bibliometrics to detect questionable authorship and affiliation practices and their impact on global research metrics: A case study of 14 universities

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ABSTRACT

From 2019 to 2023, a subset of 80 highly published universities demonstrated research output increases exceeding 100%, compared to the global average of 20%. Among these, 14 institutions showed significant declines in first authorship rates, raising questions about their authorship and affiliation practices. This study employed bibliometric analysis to examine shifts in authorship and affiliation dynamics at these universities. Key findings include a 234% rise in total publications, a 23 percentage point drop in first authorship rates, and an increase in hyper-prolific authors from 23 to 177. International collaborations surged, and several universities exhibited sharp rises in multiaffiliated publications. Additionally, the proportion of articles published in top 10% journals increased by 11 percentage points, and the proportion of articles ranked among the world's top 10% most cited grew by 12 percentage points. These trends raise concerns about the integrity of authorship and affiliation practices as they deviate from normative behavior, far exceeding those observed nationally and at top-ranked universities—Caltech, MIT, Princeton, and UC Berkeley. The study emphasizes the need for collaborative reforms by universities, ranking agencies, publishers, and other entities, highlighting the importance of each entity's role in preserving academic integrity and ensuring the reliability of global research metrics.

1. INTRODUCTION

In today's increasingly competitive higher education landscape, universities face immense pressure to improve their global rankings. These rankings influence institutional decisions, from student admissions and faculty recruitment to funding allocation and strategic policy formulation (Hazelkorn, 2015; Hazelkorn & Mihut, 2021; Rovito, Kaushik, & Aggarwal, 2021). Central to these rankings is the focus on research, which prompts many institutions to prioritize publication and citation metrics (Rhein & Nanni, 2023; Sheeja, Mathew, & Cherukodan, 2018; Vernon, Andrew Balas, & Momani, 2018). While many efforts to enhance research metrics are legitimate, some involve questionable and potentially unethical practices, raising concerns about the integrity of academic publishing and the reliability of the ranking systems that depend on these metrics. Practices such as gift authorship, ghost authorship, guest authorship, honorary authorship, sold authorship, paid affiliation, and

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multiaffiliation have become increasingly prevalent, distorting the evaluation of university research performance (Bhattacharjee, 2011; Biagioli & Lippman, 2020; Halevi, Rogers et al., 2023; Hottenrott, Rose, & Lawson, 2021; Moosa, 2024; Pachter, 2014; Trung, 2020).

These practices and their impact on academia align with Goodhart's Law, which states, "When a measure becomes a target, it ceases to be a good measure" (Dezhina, 2022; Fire & Guestrin, 2019), further undermining the value of research metrics as indicators of academic success. The proliferation of these questionable behaviors or practices signals an urgent need for reforms to maintain research integrity and preserve the credibility of ranking systems (see Box 1 for definitions of these practices).

Box 1. Definitions.

- **Gift and guest authorship**: Often used interchangeably and refer to cases where an individual is listed as an author despite not meeting authorship standards (Ali, 2021; Ioannidis & Maniadis, 2024; Morreim & Winer, 2023).
- **Ghost authorship**: Occurs when individuals who have made significant contributions to the research, such as drafting the manuscript, are not listed as coauthors (Chirico & Bramstedt, 2023; Gureyev & Mazov, 2022).
- **Honorary authorship**: Involves including an individual, typically a senior or influential researcher, as an author despite their minimal or nonexistent contribution to the research (Kwee, Almaghrabi, & Kwee, 2023; Meursinge Reynders, ter Riet et al., 2024).
- **Multiaffiliation**: Refers to authors including multiple institutional affiliations in their published research articles, reflecting their connections to various organizations, many of which are not necessarily legitimate or genuine (Halevi et al., 2023; Hottenrott et al., 2021; Kuan, Chen, & Huang, 2024).
- **Paid affiliation**: Involves paying individuals to list an institution as their affiliation in published research, even if they have no substantial connection to the institution (Abalkina, 2023; Halevi et al., 2023; Hottenrott et al., 2021; Rowe, Alexander et al., 2009; Teixeira da Silva, 2024).
- **Sold authorship**: Refers to cases where individuals or institutions are included as authors on a research publication in exchange for payment despite not having made any significant contributions to the study (Abalkina, 2023; Teixeira da Silva et al., 2024).
- **Questionable authorship and affiliation practices**: Refers to any practice that undermines the integrity of authorship or affiliation attribution, including guest, gift, ghost, honorary, sold authorship, or paid affiliation (Biagioli, Kenney et al., 2019; Teixeira da Silva & Dobránszki, 2016).

Recent analyses have identified significant declines in first authorship rates and sharp increases in research output, hyper-authorship (excessive numbers of authors per paper), multiaffiliation (excessive numbers of affiliations), and hyper-prolific authorship (individuals with high numbers of articles per year) at specific institutions, raising concerns about authorship attribution and its implications for research evaluation (Biagioli & Lippman, 2020; Catanzaro, 2024; Fire & Guestrin, 2019; Gureev, Lakizo, & Mazov, 2019; Ioannidis, Klavans, & Boyack, 2018; Jakab, Kittl, & Kiesslich, 2024; Teixeira da Silva & Dobránszki, 2016). Despite the establishment of ethical guidelines, such as those from the International Committee of Medical Journal Editors (ICMJE), questionable authorship and affiliation practices persist, often evading

detection due to their complexity and the scale at which they occur (Resnik, Rasmussen, & Kissling, 2015; Teixeira da Silva, 2023). Current detection methods focus on individual misconduct (Barta, 2022; Whetstone et al., 2022), leaving a gap in identifying institutional-level practices that distort global research metrics.

While bibliometric techniques cannot definitively prove questionable authorship and affiliation practices, they serve as valuable methods for identifying anomalies in research output and performance (Delgado López-Cózar & Martín Martín, 2024). These anomalies may appear as sudden spikes in publication volume, high instances of hyper-authorship, concentrated coauthorship in specific venues, excessive multiaffiliation, or sharp increases in hyper-prolific authors, among others (Biagioli & Lippman, 2020). Bibliometric analyses, therefore, play a crucial role in safeguarding research integrity by detecting deviations from normative authorship and affiliation practices and providing data for studying relevant questionable behaviors.

Using bibliometric analysis, we examine 14 universities that demonstrate significant anomalies in research output and authorship and affiliation patterns. We assess the consequences of these deviations on institutional rankings and research performance.

2. MATERIALS AND METHODS

2.1. Study Group Selection and Rationale

The study group was selected through a structured multi-stage process to identify universities exhibiting extraordinary growth in research output and significant declines in first authorship rates between 2019 and 2023. The selection of the 2019–2023 period was driven by the need to capture recent considerable shifts in research output and authorship dynamics over a short period, often influenced by institutional policies, government incentives, or the pressures of global ranking systems (Ahlers & Christmann-Budian, 2023; Lee, Liu, & Wu, 2020; Shattock, 2017; Shen, Zha, & Liu, 2023). This period is important as it coincides with the rise of hyper-prolific authorship, a growing phenomenon in academic publishing (Moreira, Meira et al., 2023).

Additionally, using these years helped minimize distortions that might or could have been caused by the COVID-19 pandemic, which disproportionately impacted disciplines and institutions (Raynaud, Goutaudier et al., 2021; Zammarchi, Carta et al., 2024). Indeed, global research output experienced irregular annual growth rates during the pandemic, increasing by 10% in 2020 and 8% in 2021 before slowing to 3% in 2022 and declining by 3% in 2023 (based on data from Scopus and corroborated via Web of Science). By selecting 2019 and 2023 as focal points, we aimed to isolate genuine shifts in research productivity and authorship and affiliation practices from pandemic-related anomalies (Ioannidis, Salholz-Hillel et al., 2021).

Our initial selection process began with identifying all academic institutions that published at least 2,000 documents during the five years from 2019 to 2023, using data from SciVal. This produced a data set of 2,740 institutions worldwide. For each institution, we retrieved two key bibliometric indicators: total journal articles published annually from 2019 to 2023 and the first nine months of 2024; and first authorship rates for these years (via InCites). These two metrics—research output and first authorship rates—were chosen because they are critical for understanding institutional productivity and changes in research contribution patterns. See Box 2 for a description of the data sources and software used in the study.

Box 2.   Data sources and software.

- **Scopus**: Developed by Elsevier, Scopus is one of the largest and most comprehensive multidisciplinary abstract and citation databases globally. As of September 2024, it included over 98.5 million records, with 69.5 million classified as articles and 4.8 million as reviews (Baas, Schotten et al., 2020; Pranckutė, 2021).
- **Web of Science (WoS)**: Provided by Clarivate, WoS is a multidisciplinary abstract and citation database that indexes over 23,300 journals and 10 million conference proceedings. As of September 2024, it contained 90 million records, including 55 million articles and 2.9 million reviews (Birkle, Pendlebury et al., 2020; Pranckutė, 2021).
- **InCites (Clarivate) and SciVal (Elsevier)**: These are research analytics platforms designed to assess the research performance of individuals, institutions, countries, and journals, among others. They offer a range of metrics derived from the Web of Science and Scopus databases, respectively, to evaluate productivity, collaboration patterns, and research impact (Jiajia & Wei, 2014).
- **VOSviewer**: A tool for constructing and visualizing bibliometric networks, including coauthorship, citation, and keyword co-occurrence maps. It is used to create visual representations of research data. It works with various bibliographic databases, including Scopus, Web of Science, PubMed, and Dimensions, making it a versatile and powerful tool for bibliometric studies (Moral-Muñoz, Herrera-Viedma et al., 2020; van Eck & Waltman, 2010).

To focus the analysis on institutions with a substantial impact on global research metrics, we narrowed the data set to the top 1,000 universities based on the number of journal articles published in 2023. This step ensured the exclusion of smaller or less research-intensive institutions. We then refined the selection by identifying institutions with publication growth rates exceeding 100% between 2019 and 2023, more than five times the global average growth of 20% (per SciVal). A total of 80 institutions met this criterion, signifying exceptional growth and potential deviations from typical global research trends.

Next, we focused on institutions with notable shifts in authorship practices, particularly first authorship rates. First authorship is a recognized marker of scholarly leadership, often signifying the primary intellectual contributor to a study (Chinchilla-Rodríguez, Costas et al., 2024; Kharasch, Avram et al., 2021; Marušić, Bošnjak, & Jeroňčić, 2011). The first author typically leads research design, data collection, and analysis. Therefore, a sharp decline in first authorship rates can indicate changes in research contribution dynamics, such as the rise of hyperauthorship and possibly questionable authorship and affiliation practices like gift, honorary, or sold authorship.

Accordingly, from the 80 high-growth universities, we applied a rigorous selection criterion to identify institutions experiencing significant shifts in authorship dynamics. Specifically, we focused on those whose first authorship rates declined by more than 15 percentage points between 2019 and 2023. This threshold, which is over five times the global average decrease of 3%, was carefully chosen to pinpoint institutions undergoing substantial changes in research leadership patterns. Such a dramatic decline often indicates a fundamental shift in how research contributions are distributed within an institution. It may suggest an influx of external collaborators taking lead roles or, potentially, the emergence of questionable authorship and affiliation practices. By setting this stringent criterion, we ensured that our study group comprised only those universities demonstrating the most pronounced and potentially concerning changes in authorship dynamics. Ultimately, this selection process yielded 14 universities that met both criteria: exceptional growth in research output and a marked decline in first authorship rates, both exceeding five times their respective global averages from 2019 to 2023.
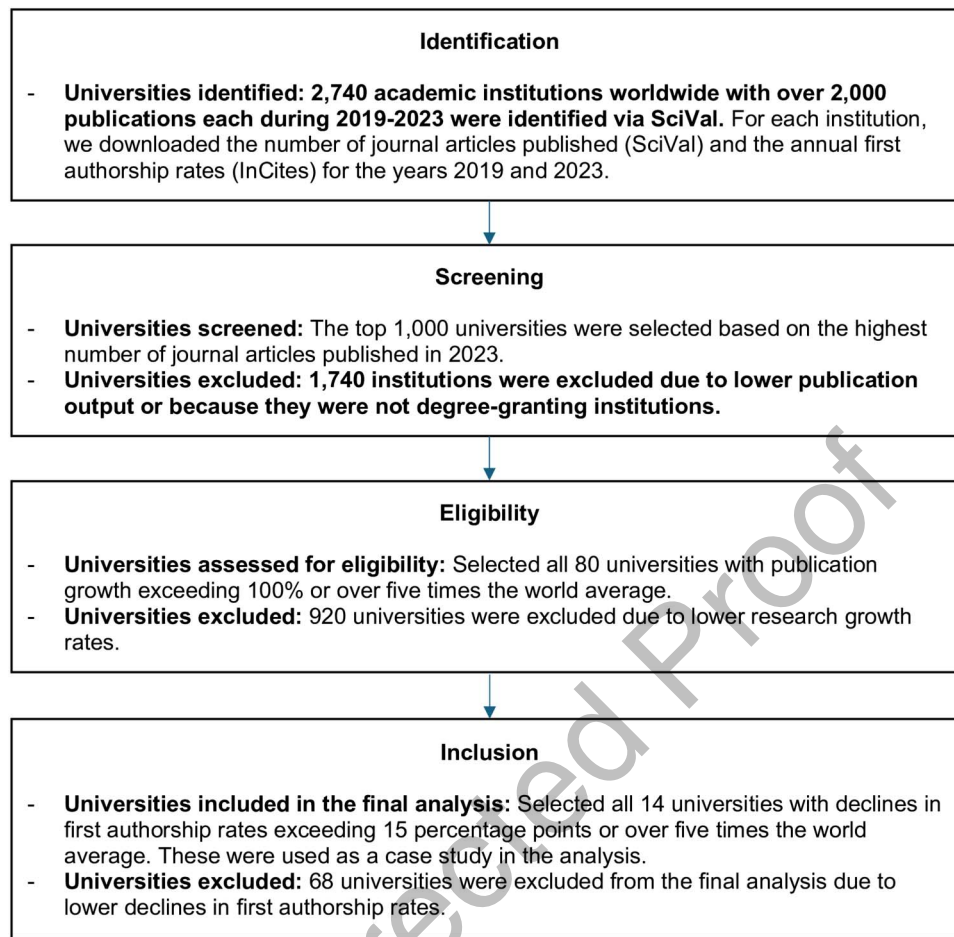
Identification

- **Universities identified: 2,740 academic institutions worldwide with over 2,000 publications each during 2019-2023 were identified via SciVal.** For each institution, we downloaded the number of journal articles published (SciVal) and the annual first authorship rates (InCites) for the years 2019 and 2023.

Screening

- **Universities screened:** The top 1,000 universities were selected based on the highest number of journal articles published in 2023.
- **Universities excluded: 1,740 institutions were excluded due to lower publication output or because they were not degree-granting institutions.**

Eligibility

- **Universities assessed for eligibility:** Selected all 80 universities with publication growth exceeding 100% or over five times the world average.
- **Universities excluded:** 920 universities were excluded due to lower research growth rates.

Inclusion

- **Universities included in the final analysis:** Selected all 14 universities with declines in first authorship rates exceeding 15 percentage points or over five times the world average. These were used as a case study in the analysis.
- **Universities excluded:** 68 universities were excluded from the final analysis due to lower declines in first authorship rates.

Figure 1. Summary of the process for identifying and selecting the study group universities.

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The two key metrics—research output growth and first authorship decline—are complementary, representing different facets of institutional research behavior. A substantial increase in research output typically signals institutional productivity, driven by strategic responses to rankings, funding, or external incentives. However, rapid growth in publication volume can also be associated with potential engagement in practices designed to inflate research metrics artificially. Conversely, declines in first authorship rates provide insight into institutions' evolving structure of research contributions. A marked reduction in first authorship may indicate shifts towards authorship and affiliation practices that could obscure genuine academic leadership. This imbalance between research output growth and first authorship decline offers a critical lens through which to examine the implications of current authorship and research practices across institutions.

The 14 universities comprising the final study group represent diverse geographic and institutional backgrounds. Six are public universities in Saudi Arabia and eight are private universities in Egypt, India, Iraq, and Lebanon. One is relatively young, having been established less than 15 years ago; eight were founded within the last 15 to 25 years, while four have a history spanning over five decades. According to several ranking agencies (e.g., QS and U.S. News), these universities also vary in size, with six institutions each employing between 500 and

1,000 academic staff members, four somewhere between 1,000 and 2,500 academic staff members, and four hosting over 2,500 such members each.

2.2. Control Group Selection and Rationale

To ensure a reliable and meaningful comparison, we adopted a two-pronged approach for benchmarking: a national benchmark based on aggregated data from the study group countries—Egypt, India, Iraq, Lebanon, and Saudi Arabia; and a global control group comprising well-established universities known for their adherence to high-standard conventional authorship practices. This approach allowed for a broad, stable comparison, mitigating the distortions that the peculiarities of national institutions in the study group countries might introduce.

For the global control group, we selected four internationally renowned universities that consistently rank among the top 10 in the Academic Ranking of World Universities (Shanghai Ranking): California Institute of Technology (Caltech), Massachusetts Institute of Technology (MIT), Princeton University, and the University of California, Berkeley. These universities were chosen for several reasons:

- **Research stability**: These institutions have consistently high research output, providing a solid benchmark against which to assess the rapid and significant growth seen in the study group universities.
- **Global influence**: As global leaders in research, their practices set a high bar, making them ideal comparators for assessing the broader implications of questionable authorship and affiliation behaviors.
- **Disciplinary balance:** According to Scopus, the study and control groups share the same top seven subject categories as their main research strengths, reinforcing the comparability of their research portfolios (see more below).

We deliberately excluded universities with medical schools from the control group to avoid distortions in publication patterns and authorship dynamics, which differ between medical and nonmedical disciplines. Only 12% of the study group's research output is classified under Medicine (per Scopus), a figure close to the 14% observed among the selected control group universities. Including institutions with medical schools from the Shanghai top 10 universities—Chicago, Columbia, Harvard, Stanford, Oxford, and Cambridge—would have skewed the comparison, as 48% of their research output stemmed from the medical field. By excluding these universities, we ensured a more accurate comparison of research output and authorship trends across institutions with similar research focus.

2.3. Bibliometric Analysis

In addition to using national data to make comparisons, we compared the study group and control group universities on several key metrics: overall and subject-specific publication growth, first authorship trends, number of authors per article, hyper-prolific authorship, multiple institutional affiliations, and levels of international collaboration. We concentrated on two primary types of documents—articles and reviews—excluding other formats such as conference papers and editorials to maintain consistency and focus on core academic output across disciplines. For each country represented in the study group, we excluded publications where the study group university was an author. This exclusion ensured that national

benchmarks remained independent of the study group's output, providing a more transparent and objective comparative framework.

Unless otherwise stated below, we sourced our data from Scopus and its analytical tool—SciVal—employing data collection methods similar to those outlined in Halevi et al. (2023). We tracked each author's publication counts, institutional affiliations, and country affiliations. In addition to 2019–2023, we collected publication and authorship data for 2014–2018 (and January–September 2024 to use where needed). We performed sensitivity analyses to validate the robustness of our findings, cross-referencing data between Scopus and Web of Science and utilizing both SciVal and InCites to ensure comprehensive coverage and accuracy.

A significant aspect of this analysis was the examination of hyper-prolific authorship, a term introduced by Ioannidis et al. (2018) to describe researchers who publish a high number of papers in any one calendar year (in their case, 72 articles, conference papers, substantive comments, or reviews). This phenomenon has raised concerns regarding adherence to the four ICMJE authorship criteria. Ioannidis found that 70% of hyper-prolific authors admitted to not fulfilling these criteria more than 25% of the time. Moreira et al. (2023) further characterized these authors as "anomalous" due to their sudden and unsustainable spikes in productivity, often concentrated in specific venues and collaborations. In this study, we adopted a more conservative threshold of 40 articles in a calendar year between 2019 and 2023 to capture a broader spectrum of potential anomalies.

To identify hyper-prolific authors, we initially downloaded data for the 500 most published authors during 2014–2024 in each of the 27 major academic disciplines represented in SciVal (e.g., mathematics, psychology). For large disciplines, such as engineering and medicine, we supplemented this with data on the top 500 most published authors within their specific subdisciplines (e.g., biomedical engineering, oncology). Additionally, we extracted the top 500 authors from each major global region (e.g., Central Asia) and countries with large numbers of productive authors (e.g., Canada, India, Saudi Arabia). After removing duplicates, we compiled a comprehensive list of 53,630 highly published authors. We then tracked the annual publication count of each author from 2014 to 2023 and during the first nine months of 2024. Using these data, and excluding physicists, we identified 11,838 hyper-prolific authors globally, 9,011 of whom achieved this status at least once from 2019 to September 2024. These 9,011 hyper-prolific authors represent 0.05% of the 18 million authors during this timeframe.

We excluded physicists to avoid skewed results, as many of these scientists participate in large international collaborations with over 1,000 members, where authorship is granted based on team membership rather than individual contributions. This decision aligns with the rationale provided by Ioannidis et al. (2018), ensuring that the data more accurately reflects individual research productivity and potential authorship anomalies. Notably, the number of hyper-prolific authors worldwide (i.e., those who published 40 or more journal articles in a calendar year) increased by 66%, from 2,517 in 2019 to 4,189 in 2023, against an increase of 15% for all authors during the same period (InCites).

In addition to hyper-prolific authorship, we also explored the growing trend of multiple institutional affiliations—authors listing affiliations with numerous institutions, often across different countries (Hottenrott et al., 2021). This phenomenon has seen a marked increase over the past decade, with some authors listing affiliations with more than 20 institutions (Halevi et al., 2023), raising significant concerns regarding the legitimacy of their contributions to each institution (Gök & Karaulova, 2024). These individuals often serve as "external authors" to

3. RESULTS

3.1. Overall Research Output Surge

Research output is a core indicator in global university rankings, with institutions often ranked based on the volume of their publications. A substantial increase in research output can propel universities up the rankings, influencing decisions around faculty recruitment, funding, and international collaborations. Figure 2 highlights the contrasting trajectories of research output between the study group and the control group from 2019 to 2023. The 14 universities in the study group demonstrated substantial increases in publication output, ranging from 100% to 1457%, resulting in an overall increase of 234%, nearly 12 times the 20% world average. In contrast, the control group universities exhibited only modest changes in publication output, with increases ranging from 1% to 6%, leading to an overall increase of 3% over the same period, significantly below the world average but slightly above the 2% average for the United States, where all the control group members are based.

To provide a deeper perspective, Table 1 compares each institution's growth in the study group with their respective national averages. For example, Future University in Egypt
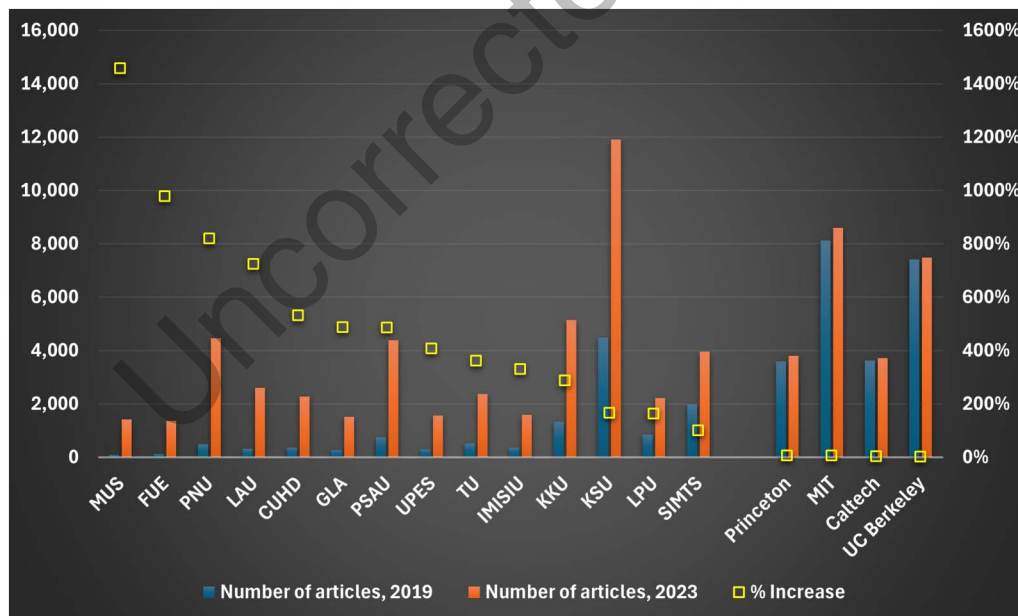

Figure 2. Percentage change in publication counts for universities in the study and control groups between 2019 and 2023. A blank space separates the study group (left) from the control group (right). Caltech = California Institute of Technology, CUHD = Chandigarh University (India), FUE = Future University in Egypt (Egypt), GLA = GLA University (India), IMISIU = Al-Imam Mohammad Ibn Saud Islamic University (Saudi Arabia), KKU = King Khalid University (Saudi Arabia), KSU = King Saud University (Saudi Arabia), LAU = Lebanese American University (Lebanon), LPU = Lovely Professional University (India), MIT = Massachusetts institute of Technology, MUS = Al-Mustaqbal University (Iraq), PNU = Princess Nourah Bint Abdulrahman University (Saudi Arabia), PSAU = Prince Sattam Bin Abdulaziz University (Saudi Arabia), SIMTS = Saveetha Institute of Medical and Technical Sciences (India), TU = Taif University (Saudi Arabia), UC Berkeley = University of California Berkeley (United States), UPES = University of Petroleum and Energy Studies (India). (Source: SciVal, September 2024).

Table 1. Publication counts and rankings 2019 vs. 2023 of study and control group universities

University (year founded)	Type	Number of articles published		Increase from 2019 to 2023 (%)		World ranking in # of articles		ARWU PUB world ranking	
		2019	2023	Institution	Country	2019	2023	2020	2024
Study group									
FUE (Egypt, 2006)	Private	127	1,368	977	71	2,000+	970	NR	NR
CUHD (India, 2012)	Private	362	2,281	530	36	2,000+	578	NR	NR
GLA (India, 2010)	Private	259	1,521	487	36	2,000+	880	NR	NR
LPU (India, 2005)	Private	847	2,219	162	36	1,001–1,500	597	NR	NR
SIMTS (India, 2005)	Private	1,984	3,959	100	36	520	300	NR	463
UPES (India, 2003)	Private	307	1,557	407	36	2,000+	865	NR	NR
MUS (Iraq, 2010)	Private	91	1,417	1,457	63	2,000+	935	NR	NR
LAU (Lebanon, 1924)	Private	316	2,600	723	18	2,000+	500	NR	444
IMISIU (Saudi Arabia, 1974)	Public	370	1,591	330	109	2,000+	850	NR	NR
KKU (Saudi Arabia, 1988)	Public	1,329	5,145	287	109	765	198	NR	182
KSU (Saudi Arabia, 1957)	Public	4,493	11,906	165	109	174	31	161	21
PNU (Saudi Arabia, 1970)	Public	486	4,465	819	109	1,501–2,000	245	NR	199
PSAU (Saudi Arabia, 2009)	Public	750	4,388	485	109	1,001–1,500	250	NR	267
TU (Saudi Arabia, 2004)	Public	516	2,381	361	109	1,501–2,000	555	NR	497
Control group									
Caltech (U.S., 1891)	Private	3,633	3,720	2	2	256	334	206	257
MIT (U.S., 1861)	Private	8,127	8,592	6	2	56	70	49	63
Princeton (U.S., 1746)	Private	3,595	3,806	6	2	260	323	197	235
UC Berkeley (U.S., 1868)	Public	7,410	7,484	1	2	73	97	51	77

Data sources: SciVal for publications. ARWU = Academic Ranking of World Universities (Shanghai Ranking) and PUB = Publications. The 2020 ranking is based on papers indexed in the Science Citation Index-Expanded and Social Sciences Citation Index (Web of Science) published in 2019, and the 2024 ranking is based on papers published in 2023. Caltech = California Institute of Technology, CUHD = Chandigarh University, FUE = Future University in Egypt, GLA = GLA University, IMISIU = Al-Imam Mohammad Ibn Saud Islamic University, KKU = King Khalid University, KSU = King Saud University, LAU = Lebanese American University, Lovely = Lovely Professional University, MIT = Massachusetts institute of Technology, MUS = Al-Mustaqbal University, PNU = Princess Nourah Bint Abdulrahman University, PSAU = Prince Sattam Bin Abdulaziz University, Saveetha Institute of Medical and Technical Sciences, Taif = Taif University, UC Berkeley = University of California Berkeley, UPES = University of Petroleum and Energy Studies.

exhibited a 977% increase in research output, significantly outpacing the national average of 71%. Similarly, Indian universities in the study group, such as Chandigarh University and GLA University, grew by 530% and 485%, respectively, both far surpassing India's national average of 36%. In Iraq, Al-Mustaqbal University saw its research output soar by 1,457%, dwarfing the national average increase of 63%. The Lebanese American University, with a 723% growth, exceeded Lebanon's national average of 18%, while Saudi institutions in the study group also performed well above the national average of 109%, with Prince Sattam Bin Abdulaziz University growing by 485% and Princess Nourah Bint Abdulrahman University achieving an

819% increase. These figures highlight the extraordinary research output growth at study group universities compared to their national contexts and global trends.

By comparison, the universities in the control group, based in the United States, showed much smaller increases in research output. For instance, the University of California, Berkeley, recorded only a 1% increase, while MIT and Princeton saw a modest 6% rise. These figures align with the US national average growth rate of 2%, reflecting stable research output levels at top-tier institutions.

The substantial increases in research output among the study group universities have led to a significant rise in their global rankings, underscoring the strategic focus on expanding publication volume. In 2019, only one study group institution ranked within the top 300 most-published universities globally, per Shanghai Ranking. By 2023, this number had risen to five, reflecting a dramatic surge in research productivity. This trend is further corroborated by the Shanghai "research output" (PUB) rankings, where the number of study group universities listed among the world's top 500 most-published institutions increased from one in 2020 (which is based on articles published in 2019) to seven in 2024 (based on articles published in 2023). Conversely, control group universities showed a modest decline in research output rankings. The median rank of the control group universities fell from 165th in 2019 to 210th in 2023, with two institutions dropping out of the top 300 altogether. Additionally, their Shanghai rankings declined from an average of 126 in 2020 to 158 in 2024.

3.2. Inflation in Discipline-Specific Research

The dramatic increase in research output among the 14 study group universities is further underscored when analyzed by discipline. Discipline-specific research productivity impacts subject area rankings and can notably affect a university's standing. In 2019, only one of the study group universities ranked among the world's top 100 most-published institutions in any of the 21 subject categories tracked by Clarivate's Essential Science Indicators. By 2023, however, seven universities had broken into the top 100 a total of 35 times across 13 subject categories, with significant representation in science, technology, engineering, and mathematics (STEM). In contrast, the control group declined in several areas, having its representation among the world's top 100 most-published universities reduced from 36 appearances in 17 subject categories in 2019 to 28 appearances in 13 categories in 2023 (Table 2).

The study group's presence becomes even more pronounced by expanding the analysis to include the 300 most published universities globally in each subject category. Moving from 17 representations in 2019 by two universities to 13 universities appearing 77 times across 18 subject categories in 2023, the study group showed substantial gains in fields such as chemistry, computer science, engineering, environment and ecology, materials science, mathematics, pharmacology and toxicology, and physics, with six or more universities in each category. Shifts in research output rankings were less pronounced in the medical, health, and social sciences. Conversely, the control group saw a decrease in representation among the world's 300 most published universities by field, dropping from 54 appearances in 2019 to 48 in 2023.

3.3. Decline in First Author Publications

First authorship in publications is a key indicator of intellectual leadership within research projects. It offers insight into the balance between internal and external contributions from researchers at a given institution. Globally, first authorship rates have slightly declined, with the average among academic institutions dropping from 53% in 2019 to 50% in 2023 (InCites).

Table 2. Universities' change in the number of articles and top 100 world rank by subject category between 2019 and 2023

Name	# of articles, 2019	# of articles, 2023	World rank in # of articles, 2019	World rank in # of articles, 2023
Agricultural Sciences (*n* = 1)				
Study group				
King Saud University	188	510	72	12
Control group				
None ranked among the world's 100 most published				
Biology & Biochemistry (*n* = 1)				
Study group				
King Saud University	321	611	71	7
Control group				
Massachusetts Institute of Technology	495	475	21	21
University of California, Berkeley	385	339	44	53
Chemistry (*n* = 3)				
Study group				
King Saud University	603	2,266	58	2
King Khalid University	200	957	446	33
Princess Nourah Bint Abdulrahman University	61	658	1,266	60
Control group				
Massachusetts Institute of Technology	590	468	62	Dropped out
University of California, Berkeley	558	483	75	Dropped out
Computer Science (*n* = 5)				
Study group				
King Saud University	198	297	55	53
Lebanese American University	21	289	1,053	57
Prince Sattam Bin Abdulaziz University	20	278	1,085	61
Princess Nourah Bint Abdulrahman University	13	266	1,466	67
King Khalid University	32	202	752	96
Control group				
Massachusetts Institute of Technology	236	243	46	76
University of California, Berkeley	165	121	79	Dropped out

Name	# of articles, 2019	# of articles, 2023	World rank in # of articles, 2019	World rank in # of articles, 2023
Economics & Business (*n* = 1)				
Study group				
Lebanese American University	26	235	731	24
Control group				
Massachusetts Institute of Technology	235	229	11	25
University of California, Berkeley	192	207	30	37
Engineering (*n* = 4)				
Study group				
King Saud University	459	1,487	131	38
King Khalid University	171	988	469	58
Prince Sattam Bin Abdulaziz University	98	918	775	66
Princess Nourah Bint Abdulrahman University	23	706	1,994	100
Control group				
Massachusetts Institute of Technology	839	634	48	Dropped out
University of California, Berkeley	614	417	87	Dropped out
Environment/Ecology (*n* = 2)				
Study group				
King Saud University	184	946	195	4
Saveetha Institute of Medical & Technical Science	7	356	2640	64
Control group				
University of California, Berkeley	458	412	24	46
Geosciences (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
California Institute of Technology	721	576	7	21
Massachusetts Institute of Technology	290	275	72	71
University of California, Berkeley	314	257	57	79
Princeton University	257	231	89	100

Above the table: **Table 2.** (*continued*)

Name	# of articles, 2019	# of articles, 2023	World rank in # of articles, 2019	World rank in # of articles, 2023
Table 2. (*continued*)				
Immunology (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
Massachusetts Institute of Technology	141	168	100	89
Materials Science (*n* = 2)				
Study group				
King Saud University	374	1,006	111	33
King Khalid University	189	598	275	71
Control group				
Massachusetts Institute of Technology	597	461	51	Dropped out
University of California, Berkeley	419	337	90	Dropped out
Mathematics (*n* = 6)				
Study group				
King Saud University	151	470	94	2
Princess Nourah Bint Abdulrahman University	18	328	1,195	7
Prince Sattam Bin Abdulaziz University	46	297	578	13
King Khalid University	51	252	504	18
Al-Imam Mohammad Ibn Saud Islamic University	25	163	955	70
Lebanese American University	2	149	2,825	98
Control group				
University of California, Berkeley	245	223	17	30
Massachusetts Institute of Technology	257	216	15	33
Princeton University	214	184	30	50
Microbiology (*n* = 1)				
Study group				
King Saud University	55	148	192	37
Control group				
Massachusetts Institute of Technology	124	120	41	57
University of California, Berkeley	120	108	48	71

Table 2. (*continued*)

Name	# of articles, 2019	# of articles, 2023	World rank in # of articles, 2019	World rank in # of articles, 2023
Molecular Biology & Genetics (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
Massachusetts Institute of Technology	651	589	11	8
University of California, Berkeley	291	223	78	89
Neuroscience & Behavior (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
Massachusetts Institute of Technology	292	276	100	96
Pharmacology & Toxicology (*n* = 5)				
Study group				
King Saud University	263	685	28	1
Prince Sattam Bin Abdulaziz University	73	284	310	37
King Khalid University	76	226	292	64
Princess Nourah Bint Abdulrahman University	26	183	822	89
Saveetha Institute of Medical & Technical Science	19	165	1,018	100
Control group				
None ranked among the world's 100 most published				
Physics (*n* = 3)				
Study group				
King Saud University	168	416	283	66
King Khalid University	165	367	294	78
Princess Nourah Bint Abdulrahman University	17	338	1,661	90
Control group				
Massachusetts Institute of Technology	985	852	8	13
Princeton University	655	555	29	32
University of California, Berkeley	584	514	32	41
California Institute of Technology	482	436	50	60

Table 2. (*continued*)

Name	# of articles, 2019	# of articles, 2023	World rank in # of articles, 2019	World rank in # of articles, 2023
Plant & Animal Science (*n* = 1)				
Study group				
King Saud University	225	703	132	10
Control group				
None ranked among the world's 100 most published				
Psychiatry/Psychology (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
University of California, Berkeley	265	228	94	Dropped out
Social Sciences, general (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
University of California, Berkeley	638	539	39	59
Space Science (*n* = 0)				
Study group				
None ranked among the world's 100 most published				
Control group				
California Institute of Technology	956	1,030	1	1
University of California, Berkeley	573	647	7	8
Princeton University	423	526	16	14
Massachusetts Institute of Technology	415	512	17	15

Source: Essential Science Indicators, via InCites (September 2024).

This trend varies across disciplines, with rates ranging from 42% in clinical medicine to around 47–49% in environmental science, ecology, geosciences, and physics, 52% in computer science and social sciences, and 56–57% in engineering and mathematics. The rate in physics would decline to 38% when counting articles with over 1,000 coauthors.

The 14 universities in the study group experienced a dramatic decline in first authorship rates, from an average of 50% in 2019 to just 27% in 2023—an eightfold drop compared to the global average. This downward trend reflects a significant shift in how research contributions are attributed, with several universities falling far below the global and disciplinary

Table 3. Decline in the proportion of and world rank in first authorship for universities in the study and control groups between 2019 and 2023

Institution	% first author, 2019	% first author, 2023	World rank in % articles as first author, 2019	World rank in % articles as first author, 2023
Study group				
Lovely Professional University	67	48	188	452
GLA University	72	37	78	969
Al-Imam Muhammad Ibn Saud Islamic University	49	34	630	979
University of Petroleum and Energy Studies	63	31	279	985
King Saud University	48	25	723	987
Prince Sattam Bin Abdulaziz University	49	28	662	989
Princess Nourah Bint Abdulrahman University	47	28	920	990
Chandigarh University	60	28	285	993
Saveetha Institute of Medical and Technical Sciences*	89	25	1	994
Taif University	58	23	419	995
King Khalid University	49	17	710	996
Lebanese American University	57	17	408	997
Al-Mustaqbal University College	38	12	995	999
Future University in Egypt	47	11	925	1,000
Control group				
Princeton University	51	47	568	558
University of California at Berkeley	49	44	677	719
Massachusetts Institute of Technology	47	42	795	799
California Institute of Technology	42	36	955	961

Source: InCites (September 2024).

* We used Scopus to determine first authorship rates because 84% of the universitie's articles in 2019 were published in journals covered by Scopus but not Web of Science and its InCites analytical tool.

averages. Notably, eight of the 14 study group universities saw the most significant declines in first authorship rates among the 1,000 most published universities worldwide. By 2023, 11 of these institutions were ranked among the world's 15 lowest for first authorship rates, a considerable drop from their median rank of 662 in 2019 (Table 3). For instance, Saveetha Institute of Medical and Technical Sciences, which had the highest first authorship rate in the world in 2019 (89%), saw its rate plummet to 25% in 2023, ranking it among the lowest globally. Similarly, GLA University dropped from 78th to 969th place during the same period.

In contrast, the universities in the control group experienced only modest declines in first authorship rates, dropping from 46% in 2019 to 42% in 2023. The median rank for this group remained relatively stable, moving slightly from 736th in 2019 to 759th in 2023. Control group

members rank 759th because a significant proportion of their research output is published by sizeable research groups (23% are articles with over 10 coauthors each, compared to 8% among the study group members). The relatively stable performance of the control group suggests that, while there has been a general decline in first authorship globally, the sharp drop in the study group universities may indicate institutional strategies prioritizing output quantity over research leadership.

3.4. Rise in Hyper-Prolific Authorship: Core and Noncore

Hyper-prolific authorship, defined in this study as publishing 40 or more journal articles in a calendar year, is becoming a significant feature of global academia. However, the universities in the study group have exhibited a far more pronounced increase in hyper-prolific authorship compared to global trends. Between 2019 and 2023, the number of hyper-prolific authors at these institutions rose by 670%, increasing from 23 authors in 2019 to 177 in 2023. This growth rate is 10 times the global average increase of 66% over the same period, underscoring the distinct authorship dynamics within the study group.

The increase in hyper-prolific authorship varied across the institutions in the study group. For example, King Saud University in Saudi Arabia experienced an extraordinary rise from four hyper-prolific authors in 2019 to 63 in 2023, a remarkable growth of 1,475%. Similarly, the Lebanese American University, which had no hyper-prolific authors in 2019, had 18 by 2023. Chandigarh University in India, which also had no hyper-prolific authors in 2019, saw the emergence of eight by 2023 (Table 4).

In contrast, the universities in the control group, including Caltech, MIT, Princeton, and UC Berkeley, showed far smaller increases in hyper-prolific authorship, adhering more closely to traditional authorship norms. For instance, Princeton University had just two hyper-prolific authors in 2019 and 2023, while Caltech maintained a steady number of three in both years. Overall, the control group saw a modest increase of 100%, with hyper-prolific authors growing from seven in 2019 to 14 in 2023—substantially lower than the rates observed in the study group.

Further data analysis revealed a notable presence of noncore hyper-prolific authors (HPAs)—researchers who published 40 or more articles in a calendar year, with their publications attributed to multiple institutions in different periods. This phenomenon often arises when authors affiliate with or depart from institutions during a calendar year, leading to their contributions being split across different affiliations. These noncore HPAs differ from core HPAs, who contribute at least 40 articles to a single institution during a calendar year. Notably, an author can simultaneously be a core HPA at one institution and a noncore HPA at another, and their status may shift over time—for instance, transitioning from noncore to core in subsequent years. Moreover, while some noncore HPAs contribute only a handful of articles annually to an institution, others may contribute as many as 39. For this study, any noncore HPA contributing more than 10 articles per year to an institution was deemed to have a significant impact on that institution's research output. This nuanced categorization underscores the complexity of hyper-prolific authorship and its implications for institutional research metrics, highlighting the need for further scrutiny of these patterns to ensure academic integrity and transparency.

Our data show that noncore HPAs significantly impact the research output of several study group universities. For instance, at the Lebanese American University, the 48 noncore HPAs accounted for 29% of the university's total research output in 2023–2024, while the 30 core HPAs contributed 47%. At Chandigarh University, 20 noncore HPAs were responsible for 14%

Table 4. Changes in the number of hyper-prolific authors at universities in the study and control groups between 2019 and 2023

	Count of core hyper-prolific authors (HPAs)							% recruited in 2022–24	Noncore HPAs
	2019	2020	2021	2022	2023	2024	2019–2024		
Study group									
Al-Imam Muhammad Ibn Saud Islamic University					2	4	4	25	1
Al-Mustaqbal University College				4	5	2	5	20	1
Chandigarh University				2	8	6	13	77	20
Future University in Egypt				3	5	3	6	50	2
GLA University				3	4	2	4	0	0
King Khalid University	5	7	19	38	21	23	54	0	1
King Saud University	4	64	36	31	63	82	127	2	6
Lebanese American University			1	2	18	22	30	93	48
Lovely Professional University			1	4	4	5	7	57	11
Prince Sattam Bin Abdulaziz University	1	4	11	27	14	7	42	17	3
Princess Nourah Bint Abdulrahman University		1	2	7	10	7	17	6	2
Saveetha Institute of Medical and Technical Sciences	13	18	5	9	18	20	54	30	29
Taif University			16	26	7	4	35	3	4
University of Petroleum and Energy Studies			1	5	6	2	9	44	11
Total (after excluding overlap)	**23**	**64**	**92**	**160**	**177**	**186**	**396**	**18**	**125**
Control group									
California Institute of Technology	3	2	1	2	3		7	0	3
Massachusetts Institute of Technology	1	7	8	7	7	3	12	0	10
Princeton University	2	3	2	3	2	1	4	0	0
University of California at Berkeley	1	8	2	1	2	2	11	18	3
Total (after excluding overlap)	7	20	13	13	14	6	33	6	16

Source: SciVal (September 2024).

of the research output, compared to 19% for the 13 core HPAs. These figures underscore non-core HPAs' critical role in enhancing overall productivity, even at institutions where core HPAs are already present in substantial numbers.

In contrast, institutions in the control group, such as MIT and UC Berkeley, also had non-core HPAs—10 and 11, respectively—though their contribution was relatively modest, reflecting more traditional authorship patterns at these universities. This distinction highlights the amplifying effect of noncore HPAs on research output, particularly at institutions with high concentrations of core HPAs, as seen in the study group.

3.4.1. Discrepancies in hyper-prolific authorship patterns

The analysis of hyper-prolific authorship from January 2019 to September 2024 reveals notable differences between the study and control groups regarding raw numbers and the nature of their productivity trends. During this period, the study group had 396 hyper-prolific authors compared to 33 in the control group, highlighting a striking disparity in prevalence (see Table 4). However, the contrast extends beyond these figures and reflects fundamental differences in the authors' publication histories and productivity growth.

A key observation in the study group is the relatively recent emergence of hyper-prolific authorship. Only 7% of hyper-prolific authors in the study group consistently published more than 10 articles annually during the five years before 2019, and just 9% were classified as hyper-prolific during that earlier period. This indicates that most hyper-prolific authors in the study group achieved this status only recently, reflecting a sharp, sudden surge in their output.

In contrast, hyper-prolific authors in the control group displayed a far more consistent history of high productivity. Among control group institutions, 45% of hyper-prolific authors published more than 10 articles annually between 2014 and 2018, and 21% had already attained hyper-prolific status in that period. This indicates a steady and sustained pattern of scholarly output, demonstrating that hyper-prolific authors in the control group were long-term high producers before the study period.

The differences in productivity growth further highlight the contrast between the two groups. Hyper-prolific authors in the study group saw their average output soar from seven articles per year between 2014 and 2018 to 33 articles per year between 2019 and 2023, marking a staggering 371% increase. By comparison, the control group's hyper-prolific authors experienced a more moderate rise in productivity, increasing from 18 articles per year in 2014–2018 to 40 articles per year between 2019 and 2023—a 122% increase.

When viewed globally, the growth of hyper-prolific authorship in the study group is even more pronounced. Globally, excluding the study and control groups, hyper-prolific authors increased their output by 81%, from an average of 21 articles per year during 2014–2018 to 38 articles per year during 2019–2023.

Furthermore, among the study group universities, 57% of the hyper-prolific authors show sudden surges from a maximum of 20 articles in any year before 2021 to an average of 50 articles annually during 2022–2024. For example, one engineering faculty member's output spiked from one article annually from 2001 to 2021 to 231 articles in 2022 and 541 articles in 2023, contributing 40% of their institution's research output in the latter year. Five per cent of the study group's 396 hyper-prolific authors exhibit similar trends. By contrast, none of the control group's hyper-prolific authors exhibited similar sudden spikes.

3.4.2. Recent affiliation of hyper-prolific authors

Another key distinction between the groups lies in the affiliation history patterns of hyper-prolific authors. On average, hyper-prolific authors in the study group had been affiliated with their institutions for nine years, compared to an average of 17 years for those in the control group.[1] This pattern was especially evident at the Lebanese American University, where 28 out of 30 hyper-prolific authors emerged as affiliates in 2022 and 2023, and Chandigarh University, where nine of 13 hyper-prolific authors emerged as affiliates during the same period. No comparable surges in recent affiliations were observed within the control group, where hyper-prolific authorship remained more stable and was primarily linked to longstanding faculty members.

3.4.3. Disciplinary distribution of hyper-prolific authors

Both the study and control groups feature hyper-prolific authorship concentrated in fields with high publication outputs. However, notable disciplinary distinctions emerge between the two groups, reflecting differences in research practices and institutional strategies.

In the control group, hyper-prolific authorship is most prominent in earth and planetary sciences (61%), where large-scale international collaborations, particularly in space sciences and related fields, are common. These collaborations, often involving large numbers of researchers, naturally lead to high publication counts per author. Other fields with significant representation in the control group include medicine, biochemistry, genetics, and molecular biology (24%), where multiauthor papers and high-output research are typical. Engineering represents 12% of the hyper-prolific authors in the control group, with a minor presence in materials science (3%).

In contrast, the study group exhibits a broader disciplinary spread, with distinct areas of concentration. Materials science (32%) dominates hyper-prolific authorship in the study group. Engineering (24%) and chemistry (20%) also represent substantial portions of hyper-prolific authorship. Other significant disciplines include biochemistry, genetics, and molecular biology (15%), pharmacology (14%), and computer science (13%), highlighting the influence of fields with high potential for interdisciplinary research and fast publication cycles. Mathematics (10%) is also prominently featured in the study group. Additionally, more minor but notable contributions in the study group come from agricultural and biological sciences, chemical engineering, energy, and environmental science, each accounting for 5–10% of hyper-prolific authors. Eleven other subject categories have between one and 11 hyper-prolific authors, underscoring the study group's diverse and multidisciplinary nature of high-output research. The sum of the percentages is over 100% due to overlap.

3.5. Increase in Multiaffiliated Publications

Multiaffiliation, especially across institutions in different countries, can boost an institution's perceived research collaboration and international reach, which are critical metrics in global rankings. While these affiliations can signify genuine collaborations, such as joint appointments or research partnerships, a sharp and rapid rise in multiaffiliations within a short period,

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[1] To determine the affiliation year of these authors, we used SciVal, which provides a comprehensive list of all authors who have published at least one work in the institution's name during the current year plus the previous 10 full calendar years. SciVal indicates the earliest work published by each author under the institution's name. Although imperfect, we used this date as a proxy for the year the author initiated affiliation with each institution. This approach allowed us to systematically assess when hyper-prolific authors began contributing to each institution's research output, providing insights into their publication trajectories within these universities.

as seen among some study group universities, may point to strategic efforts to amplify research output.

As with other indicators examined earlier, the analysis of multiaffiliation practices between the study and control groups revealed significant differences. The study group exhibited marked changes in the proportion of multiaffiliated publications between 2019 and 2023, signaling a divergence in author affiliation behaviors. In 2019, 18% of articles authored by study group institutions involved multiaffiliated authors. By 2023, the percentage remained stable; however, notable increases occurred at specific universities.

Three institutions demonstrated particularly sharp rises in multiaffiliated publications: the Lebanese American University saw a 60 percentage point jump (from 15% in 2019 to 75% in 2023), Chandigarh University increased by 30 percentage points (from 9% to 39%), and the University of Petroleum and Energy Studies saw a 29 percentage point rise (from 5% to 34%).

Conversely, two other universities—Prince Sattam Bin Abdulaziz University and Al-Imam Mohammad Ibn Saud Islamic University—experienced moderate declines in multiaffiliated publications, by five and seven percentage points, respectively. However, despite these reductions, both institutions reported relatively high levels of multiaffiliation in 2023 (24% and 21%), indicating that the practice remains prevalent. All other institutions in the study group recorded around 10% levels in 2023.

An illustrative example of multiaffiliation practices can be seen in the case of a faculty member affiliated with multiple study group institutions. This researcher, averaging five articles per year from 2016 to 2020, saw their output surge to over 50 articles in 2021 and over 100 annually since 2022. Notably, they listed multiple affiliations in 80% of their publications, with an average of 3.5 affiliations per article, often including two to six international institutions.

In contrast, the control group maintained a stable proportion of multiaffiliated publications throughout the same period, consistently at 6% in 2019 and 2023. This stability reflects the adherence of control group institutions to more conventional and consistent authorship and affiliation practices.

3.6. Growth in Authorship Per Publication

This section limits the analysis to articles with up to 100 coauthors. The exclusion of articles with more than 100 coauthors is justified by the unique nature of large collaborative projects, particularly in fields like physics, where the number of contributors can reach thousands. Such large-scale collaborations often follow different authorship norms and would distort the trends observed in smaller-scale research efforts.

From 2019 to 2023, the study group demonstrated a considerable increase in the average number of authors per article, rising from 4.8 in 2019 to 6.4 in 2023, an increase of 33%. The control group also exhibited growth in the number of authors per article, though at a slower pace. The average number of authors per article in the control group increased from 7.5 in 2019 to 9.0 in 2023, representing a 20% increase over the same period. These differences suggest that while both groups are trending toward greater multiauthorship, the study group institutions are exhibiting a more rapid shift. It is worth noting that, according to InCites data, the global average number of authors per article increased by only 5%, from 3.7 authors per article in 2019 to 3.9 in 2023. This comparison highlights the distinctive rise in multiauthorship within both the study and control groups, though the study group appears to be diverging more sharply from global increase trends.

3.7. Surge in International Collaboration

The period between 2019 and 2023 showed substantial increases in international research collaboration among the universities in the study group, contributing to significant improvements in their global rankings in this category. International collaboration, measured by the percentage of publications coauthored with researchers who list foreign affiliations, became a crucial metric in global university rankings, reflecting the increasing globalization of academic research. The study group universities exhibited notable gains, with international research collaboration rates rising by as much as 64 percentage points. In contrast, the control group universities experienced only marginal increases or remained static (Table 5).

Table 5. Trends in the proportion of articles with international collaboration in the study and control groups from 2019 to 2023

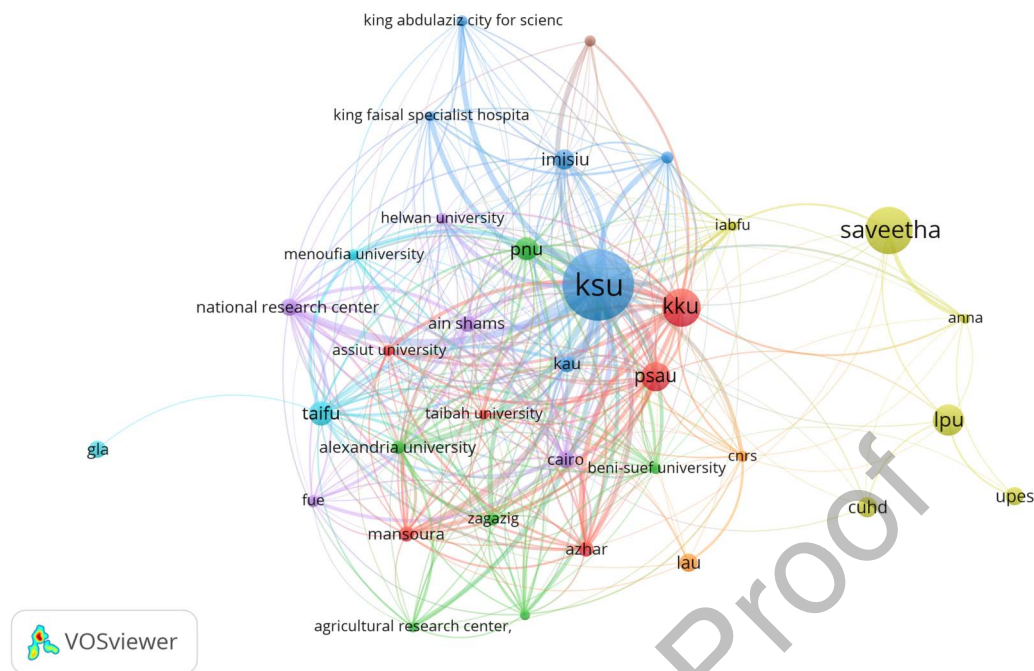|	% articles with international collaboration in 2023		Increase in percentage points from 2019		University world rank in % articles with international collaboration	
	Country	University	Country	University	2019	2023
Study group						
Lebanese American University	75	94	10	39	260	1
King Khalid University	75	90	1	11	4	2
Princess Nourah Bint Abdulrahman University	75	89	1	18	31	3
Future University in Egypt	60	87	9	61	816	5
Prince Sattam Bin Abdulaziz University	75	85	1	11	18	6
Taif University	75	86	1	9	12	11
Al-Mustaqbal University College	38	73	12	52	914	18
King Saud University	75	78	1	4	16	21
Al-Imam Muhammad Ibn Saud Islamic University	75	80	1	12	56	23
University of Petroleum and Energy Studies	28	60	9	48	992	121
Chandigarh University	28	61	9	45	974	132
Saveetha Institute of Medical and Technical Sciences	28	68	9	64	1000	134
GLA University	28	53	9	42	995	272
Lovely Professional University	28	46	9	23	889	364
Overall		**75**		**22**		
Control group						
California Institute of Technology	41	62	0	0	118	196
Massachusetts Institute of Technology	41	59	0	0	187	268
University of California at Berkeley	41	52	0	1	330	329
Princeton University	41	53	0	1	304	333
Overall		**54**		**0**		

Figure 3. Institutional coauthorship network map of the study group in 2019 (i.e., at the beginning or before publication inflation). This map includes only institutions with over 90 articles (the minimum number of articles published by a member of the study group). The interactive version[2] allows viewers to explore the connections and intensity of collaboration between institutions. Overall, 11,679 articles were published by the study group in 2019.

The universities in the study group demonstrated marked increases in international collaboration rates, leading to significant shifts in their global rankings in this area. For example, the Lebanese American University (LAU) saw an increase of 39 percentage points in its international collaboration rate, rising from 55% in 2019 to 94% in 2023. This surge propelled LAU to first place globally in international collaboration rankings, substantially improving from its rank of 260th in 2019. Similarly, the University of Petroleum and Energy Studies (UPES) in India improved its international collaboration rate by 48 percentage points, from 12% in 2019 to 60% in 2023. As a result, the university climbed from 992nd in 2019 to 121st globally in 2023.

In contrast, the universities in the control group, such as the California Institute of Technology (Caltech) and Princeton University, exhibited much more minor changes in their international collaboration rates. For instance, Caltech's international collaboration rate remained steady at 62%, dropping its global rank from 118th in 2019 to 196th in 2023. Similarly, Princeton saw only a one percentage point increase in its collaboration rate, leading to a decline in its global international collaboration ranking from 304th in 2019 to 333rd in 2023.

The increased international collaboration among study group universities has substantially improved their global rankings in this area. In 2019, the median global rank of the study group universities in international research collaboration was 538th; by 2023, this had improved dramatically to 20th, with nine institutions ranked among the top 25 globally. In contrast, the control group universities showed minimal changes in international collaboration rankings. The median rank of the control group fell slightly from 235th in 2019 to 282nd in 2023, reflecting the relative stability of their international collaborations over this period.

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[2] https://app.vosviewer.com/?json=https://drive.google.com/uc?id=1FqKru8wDIJ3YO3g5qhDwALxtKZim2Xeo.
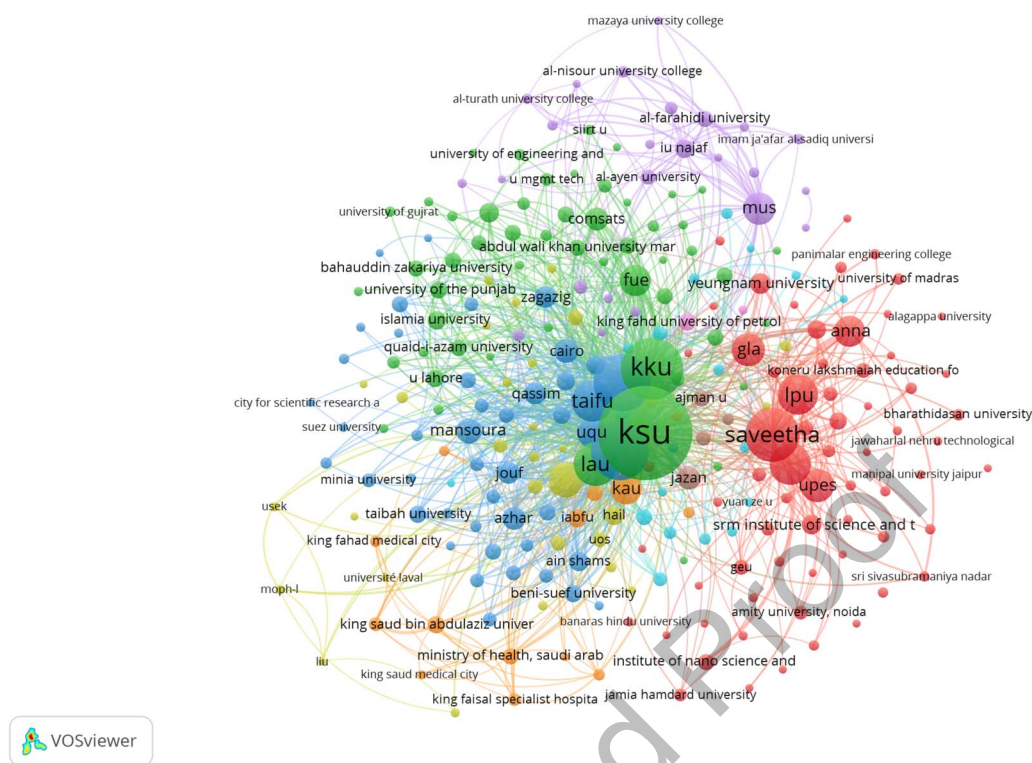
Figure 4. Institutional coauthorship network map of the study group in 2023. This map includes only institutions with more than 90 articles. The interactive version[3] allows viewers to explore the connections and intensity of collaboration between institutions. The total number of articles published by the study group in 2023 = 38,969. Note the nearly 12-fold increase in the number of external institutions added to the network (from 21 in 2019 to 244 in 2023) among institutions that published over 90 articles in collaboration with the study group members.

VOSviewer-generated maps further illuminate the collaboration dynamics within the study group and beyond. Figure 3 shows the institutional coauthorship network at the beginning of our study period in 2019, highlighting a network involving only 21 external institutions collaborating with any study group member on more than 90 articles (the minimum number of articles published by a group member in that year). In contrast, Figure 4 from 2023 reveals a dramatic expansion, with the number of collaborating institutions skyrocketing to 244, representing a nearly 12-fold increase. This map illustrates a vastly more connected and seemingly collaborative environment, although the validity of these collaborations is questionable, given the unusual collaborative group publication activity patterns.

For comparative context, Figures 5 and 6 depict the institutional coauthorship network maps for the control group in 2019 and 2023, respectively. These universities maintained a more stable collaboration landscape, with a moderate increase in collaborating institutions (from 166 in 2019 to 203 in 2023—a 22% increase).

3.8. Change in Top Journal Publications From 2019 to 2023

Publications in high-impact journals are among the important factors influencing university rankings. Institutions that publish more of their research in top-tier journals are often viewed

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3 https://app.vosviewer.com/?json=https://drive.google.com/uc?id=1s3rNnbRFsVsb9RGsji4z9CKGACJM-2TI.
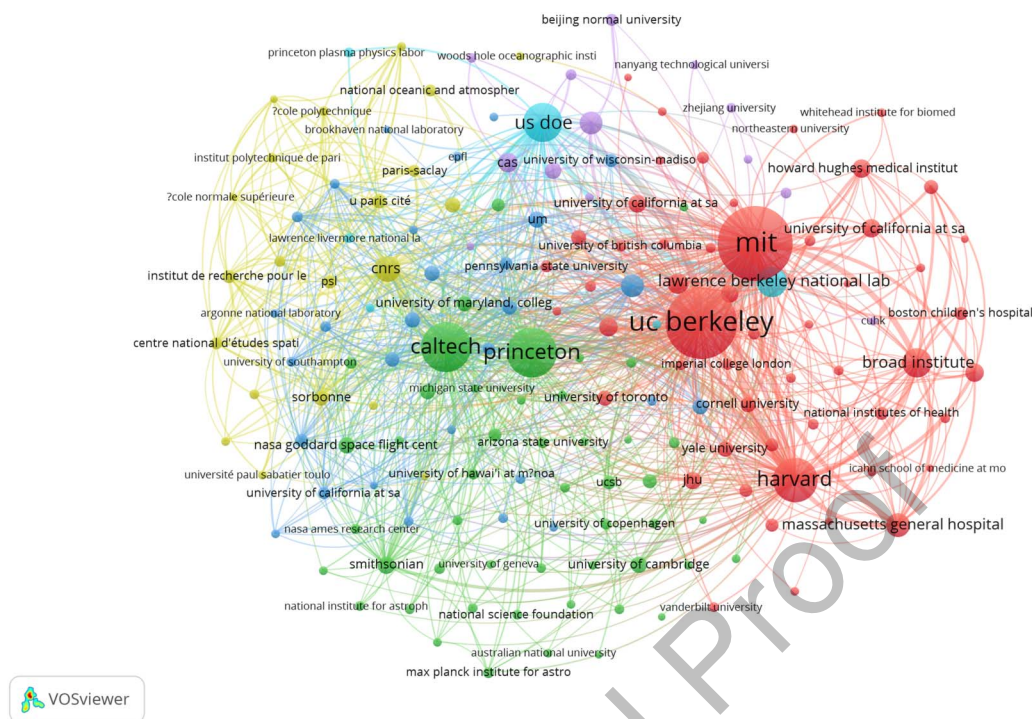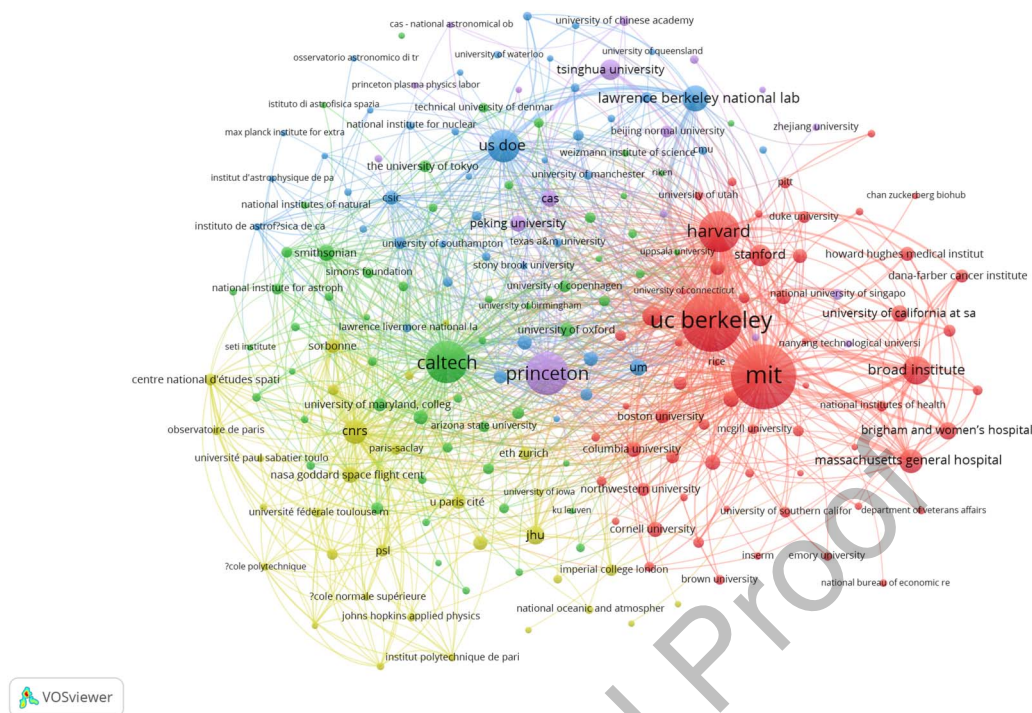
Figure 5. Institutional coauthorship network map of the control group in 2019. This map includes only institutions with more than 90 articles. The interactive version[4] allows viewers to explore the connections and intensity of collaboration between institutions. Overall, 20,920 articles were published by the study group in 2019.

as producing higher-quality research, leading to improved rankings. The study group institutions showed a marked shift in publishing their research in top-tier journals between 2019 and 2023. On average, the proportion of articles published in top 10% journals by impact increased from 15% in 2019 to 26% in 2023, reflecting an overall rise of 11 percentage points. In contrast, the control group experienced a slight decline, with their proportion decreasing from 54% in 2019 to 51% in 2023, a reduction of three percentage points (Table 6).

Individually, the most significant improvements were observed at institutions such as Saveetha Institute of Medical and Technical Sciences in India, where the proportion of articles in top journals surged by 29 percentage points, from 1% in 2019 to 30% in 2023. Similarly, the University of Petroleum and Energy Studies in India saw a significant increase of 24 percentage points, while Future University in Egypt improved by 23 percentage points over the same period.

At the national level, institutions from Saudi Arabia, such as King Khalid University and Prince Sattam Bin Abdulaziz University, outperformed the national average increase of four percentage points, achieving growth rates of 19 and 16 percentage points, respectively. Indian universities, such as Chandigarh University and GLA University, also saw notable gains, though the national average increase was more modest at two percentage points.

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[4] https://app.vosviewer.com/?json=https://drive.google.com/uc?id=17v6Qd5LRB1uUF7S9bMEhgnHT8bgryNwT.

Figure 6. Institutional coauthorship network map of the control group in 2023. This map includes only institutions with more than 90 articles. The interactive version[5] allows viewers to explore the connections and intensity of collaboration between institutions. The total number of articles published by the study group in 2023 = 21,399. The group increased its network of institutions with over 90 articles in collaboration with each other by 22% (from 166 in 2019 to 203 in 2023), compared to 1,162% by the study group.

In contrast, all control group members recorded declines in the proportion of articles published in top-tier journals. For instance, MIT's proportion dropped by three points, from 59.6% in 2019 to 56.4% in 2023.

3.9. Change in Citation Impact from 2019 to 2023

Citation impact is another critical metric in university rankings, with highly cited publications indicative of influential research. A large number and proportion of highly cited papers can significantly affect an institution's global standing. The study group institutions experienced a notable increase in the proportion of articles ranked among the world's top 10% most cited, growing from an average of 13% in 2019 to 25% in 2023, a 12 percentage point rise. In contrast, the control group saw a decline in their citation impact, dropping from 28% to 23%, a 5 percentage point decrease (Table 7).

Among the study group, Saveetha Institute of Medical and Technical Sciences again showed the most significant growth, with a 28-point increase, followed by the University of Petroleum and Energy Studies and Future University in Egypt with 27 and 24-point increases, respectively. These increases highlight their growing influence on global research, particularly in regions like India and the Middle East.

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[5] https://app.vosviewer.com/?json=https://drive.google.com/uc?id=1xc57-C_lMoYICt6T9H_8QoMIwulXfCQD.

Table 6. Proportion of articles published in top 10% journals per CiteScore: 2019 vs. 2023

		Institution			Country		
		2019	**2023**	**Change**	**2019**	**2023**	**Change**
Study group							
Future University in Egypt	Egypt	17	39	+23	18	24	+7
Chandigarh University	India	6	27	+21	16	18	+2
GLA University	India	5	22	+17	16	18	+2
Lovely Professional University	India	9	16	+7	16	18	+2
Saveetha Institute of Medical and Technical Sciences	India	1	30	+29	16	18	+2
University of Petroleum and Energy Studies	India	11	35	+24	16	18	+2
Al-Mustaqbal University College	Iraq	4	24	+19	6	11	+4
Lebanese American University	Lebanon	26	43	+17	23	24	+1
Al-Imam Muhammad Ibn Saud Islamic University	Saudi Arabia	17	24	+7	23	27	+4
King Khalid University	Saudi Arabia	9	29	+19	23	27	+4
King Saud University	Saudi Arabia	24	26	+2	23	27	+4
Prince Sattam Bin Abdulaziz University	Saudi Arabia	15	31	+16	23	27	+4
Princess Nourah Bint Abdulrahman University	Saudi Arabia	17	24	+6	23	27	+4
Taif University	Saudi Arabia	13	25	+12	23	27	+4
Total (excluding overlap)		**15**	**26**	**+11**			
Control group							
California Institute of Technology	United States	50	47	−3	37	35	−2
Massachusetts Institute of Technology	United States	60	56	−3	37	35	−2
Princeton University	United States	52	49	−3	37	35	−2
University of California at Berkeley	United States	52	49	−3	37	35	−2
Total (excluding overlap)		**54**	**51**	**−3**			

Source: SciVal (September 2024).

Conversely, institutions in the control group faced declines, with MIT seeing the most significant drop of seven points. This trend may indicate a shift in the global research landscape, where emerging institutions are increasing their global citation presence at the expense of top universities.

Study group institutions additionally often outpaced their national averages. For instance, Al-Mustaqbal University College in Iraq experienced a 22-point rise compared to the national average increase of seven points, while Chandigarh University in India saw a 20-point rise against the country's five-point increase. Such trends underscore the rapid ascent of these institutions in global citation rankings, further distinguishing them from national and global peers.

Table 7. Proportion of articles ranked among the world's 10% most cited: 2019 vs. 2023

		Institution			Country		
		2019	**2023**	**Change**	**2019**	**2023**	**Change**
Study group							
Future University in Egypt	Egypt	16	40	+24	13	19	+6
Chandigarh University	India	11	31	+20	9	14	+5
GLA University	India	11	25	+14	9	14	+5
Lovely Professional University	India	14	24	+11	9	14	+5
Saveetha Institute of Medical and Technical Sciences	India	5	32	+28	9	14	+5
University of Petroleum and Energy Studies	India	8	35	+27	9	14	+5
Al-Mustaqbal University College	Iraq	4	27	+22	6	13	+7
Lebanese American University	Lebanon	13	38	+24	12	13	+1
Al-Imam Muhammad Ibn Saud Islamic University	Saudi Arabia	10	19	+9	17	22	+5
King Khalid University	Saudi Arabia	11	29	+17	17	22	+5
King Saud University	Saudi Arabia	19	20	+2	17	22	+5
Prince Sattam Bin Abdulaziz University	Saudi Arabia	12	26	+13	17	22	+5
Princess Nourah Bint Abdulrahman University	Saudi Arabia	11	25	+14	17	22	+5
Taif University	Saudi Arabia	10	25	+16	17	22	+5
Total (after excluding overlap)		**13**	**25**	**+12**			
Control group							
California Institute of Technology	United States	28	27	−1	15	12	−3
Massachusetts Institute of Technology	United States	33	26	−7	15	12	−3
Princeton University	United States	27	23	−5	15	12	−3
University of California at Berkeley	United States	27	22	−5	15	12	−3
Total (after excluding overlap)	**All**	**28**	**23**	**−5**			

Source: SciVal (September 2024).

4. DISCUSSION

This study used bibliometric methods to identify or detect indicators of questionable authorship and affiliation practices and examine their impact on global research metrics. The findings reveal significant and concerning trends in authorship and affiliation practices at a subset of universities from 2019 to 2023. The dramatic increase in research output among these institutions, far surpassing global averages, coupled with notable changes in authorship dynamics, suggests a potential reliance on gift authorship, ghost authorship, guest authorship, honorary authorship, sold authorship, and paid affiliation practices. These practices have significant implications for academic integrity and the reliability of global research metrics. Goodhart's Law becomes particularly relevant in this context, as the focus on metrics such as publication

and citation counts as targets for ranking purposes has led to the manipulation and distortion of these measures, ultimately compromising their validity as indicators of genuine scholarly contribution.

Specifically, we investigated the publication practices of 14 universities that exhibited extraordinary growth in research output alongside changes in authorship dynamics during this period. Compared to a control group of world-renowned universities and national metrics, the study group displayed considerable surges in publication output, often accompanied by several notable trends.

- **Reduced first authorship**: The study group exhibited a pronounced decline in first authorship publications, which may indicate an increased reliance on external contributions. This trend is particularly noteworthy, as first authorship is often viewed as a marker of a significant contribution to research.
- **Rise in hyper-prolific authors**: The study group saw a dramatic increase in the number of individuals credited with an unusually high volume of publications within a short period. This hyper-prolific authorship raises questions about the sustainability and authenticity of these contributions, as maintaining such high output levels is generally challenging without resorting to questionable practices (Tóth et al., 2024).
- **Increased multiaffiliations**: The percentage of publications in which authors listed affiliations with multiple institutions increased significantly. This trend, which often involves authors affiliated with institutions in different countries (Halevi et al., 2023; Hottenrott et al., 2021), raises concerns about these authors' genuine contributions to each institution's research output. The sharp rise in multiaffiliated publications, particularly at institutions like Chandigarh University and the Lebanese American University, raises concerns about the strategic use of multiple affiliations to enhance perceived research output and international collaboration. This trend calls into question the integrity of the collaborative efforts and may reflect practices aimed at inflating rankings.
- **Inflated authorship**: The study group also showed a considerable increase in the average number of authors per publication compared to the control group. This increase, especially when notably higher than national and international levels, may not always reflect genuine intellectual contributions from all listed authors (Hosseini, Lewis et al., 2022).
- **Amplified growth in international research collaboration (IRC)**: The study group experienced a dramatic increase in the proportion of internationally coauthored publications, far exceeding the global average increase. While the IRC is generally beneficial, such a rapid increase suggests possible overreliance on international entities to enhance research output and global network profile. Previous studies have raised concerns about using international coauthorship as a reliable proxy for IRC measurement due to the variability in its dynamics and underlying motivations (Chen, Zhang, & Fu, 2019; Katz & Martin, 1997; Kuan et al., 2024; Luukkonen, Tijssen et al., 1993; Marginson, 2022). Our findings align with the arguments made by Gök and Karaulova (2024), who suggest that questionable forms of IRC, such as IRC via multiple affiliations, are becoming more prevalent and must be scrutinized to ensure accurate assessments of research collaboration. They found that approximately 20% of co-publications are labeled international solely because of an author's second affiliation, highlighting the need for a nuanced understanding of IRC (Hottenrott et al., 2021). The extraordinary growth in international collaboration, as seen in institutions such as the

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University of Petroleum and Energy Studies, suggests that while international collaboration is crucial, the speed and magnitude of this growth may indicate that these partnerships are strategically curated to boost ranking metrics.

The substantial growth in research output, top-tier journal publications, and the proportion of highly cited papers among the study group institutions will likely enhance their global research visibility and advance their international rankings. However, while such growth improves visibility, assessing whether this rise is sustainable, driven by genuine research impact, or inflated by questionable authorship practices, as observed in other areas of their research output, is critical. The findings suggest that questionable authorship and affiliation practices, such as gift authorship, ghost authorship, guest authorship, honorary authorship, sold authorship, and paid affiliation, may be contributing factors to the observed surge in publication metrics and decline in first authorship. While not inherently illegal, these practices raise concerns about the integrity of academic publishing and the reliability of university ranking systems. By identifying institutions with unusual publication patterns, we hope to foster a dialog on maintaining high ethical standards in research.

Our findings highlight the potential of bibliometric evaluations in identifying deviations from expected patterns in scholarly output and activity. By leveraging these evaluation methods, we can promote fair authorship and affiliation practices and uphold the integrity of academic publishing.

The concerning trends in authorship dynamics within the study group suggest the need for further examination and dialog among universities, publishers, policymakers, and ranking agencies. The universities in the study group appear to inflate their publication metrics by relying on external authors. This reliance on external collaborators to boost publication output suggests a shift from internally driven scholarly output toward possibly outsourced work that minimally involves the institution's faculty members and researchers in primary roles. The examples of a faculty member with an abrupt increase in publication output and another faculty member listing an unreasonable number of international affiliations illustrate potential nominal authorship and affiliation practices where actual research contributions may be minimal. Furthermore, one university from the study group experienced a 10% decrease in full-time professorial rank faculty members from 2019 to 2023. Nevertheless, the university increased its research output by over 700% during these five years, providing further evidence of attempts at outsourcing research output.

To foster a robust research culture that is sustainable and impactful, universities need to nurture their talented researchers and cultivate a vibrant, collaborative environment without overreliance on external contributors. Current trends in global ranking manipulations underscore the need for international bodies and academic institutions to critically reassess and refine ranking methodologies to ensure that they reflect true academic excellence and integrity, as emphasized by Goodhart's Law.

4.1. Unsustainable Research Growth

An example of the potential consequences of inflated publication rates is observed in the case of Taif University. According to Scopus, the institution peaked in publications in 2022 with 4,678 articles, up from 516 in 2019, only to see a notable decrease to 2,381 in 2023. This drastic fluctuation suggests that the rapid increases seen across some universities will probably not be sustainable in the long term, potentially leading to a loss of trust in their published research. This instability exemplifies the risks associated with aggressive publication strategies

to boost rankings rather than foster genuine academic progress. Moreover, Taif University also experienced a substantial reduction in the number of hyper-prolific authors, dropping from 26 in 2022 to seven in 2023, further illustrating the transient nature of such publication strategies. Similar trends are observed in the cases of Al-Mustaqbal University College and Future University in Egypt, where during January–September 2024, they published only 59% and 38%, respectively, as many articles as in 2023, compared to a world average of 85%.

Parallels have been observed in other institutions in the past (Alhuthali & Sayed, 2022; Ansede, 2023a; Bhattacharjee, 2011; Catanzaro, 2023, 2024; Guskov, Kosyakov, & Selivanova, 2018; SIRSI Academic, 2023). For example, Vietnam's Duy Tan University published 481 articles in 2018, peaking at 2,666 in 2020, but following public scrutiny (Trung, 2020), its output decreased to 848 in 2022 and 852 in 2023. Similarly, the number of publications at Ton Duc Thang University increased from 302 in 2016 to 3,337 in 2020, and after similar public exposure, the number of publications decreased to 756 in 2022 and 551 in 2023. Both universities dropped out of the Shanghai Ranking in 2023 after reaching a peak of 601–700 in 2021.

These cases underscore a challenge where universities may use practices that artificially inflate their research output to enhance their standing in global rankings. This trend not only misrepresents their actual academic contributions but also questions the sustainability and authenticity of their research advancements. Such phenomena, echoing the pitfalls seen at Taif University and possibly other institutions, suggest that initial surges in publication numbers may often be driven by unsustainable practices that do not reflect genuine scholarly activity.

5. URGENCY FOR REFORM: A CALL TO ACTION

The reliance on networks of external authors and questionable authorship and affiliation practices to increase research output might threaten academic research integrity and undermine public trust in academic institutions. This issue also directly biases the outcomes of ranking systems, compromising their reliability and usefulness. To address this systemic challenge effectively, a concerted effort is required from all stakeholders in the academic community. The proposed measures are as follows:

- **Universities**: Establish more stringent guidelines and policies for granting secondary affiliations and allowing primary faculty to hold such affiliations. The use of internal review mechanisms to detect and address suspected authorship patterns should be enhanced. Endorse and communicate institutional values that reflect integrity and ethical conduct. Moreover, universities should make more significant efforts to educate their faculty about appropriate and inappropriate authorship in scientific publications (Ali, 2021; Alshogran & Al-Delaimy, 2018).
- **Policymakers**: Develop and enforce regulations that address questionable publication practices and provide clear guidelines for ethical authorship and collaboration (see, for example, Ansede, 2023b). Transparency in reporting research activities and outputs should be encouraged through legislative and administrative measures.
- **Funding agencies**: Initiate audits to explore the potential misuse of external authors in funded projects and by applicants seeking funding.
- **Ranking agencies**: Reconsider how to account for the number of publications and citations concerning primary versus secondary affiliations—count the first affiliation for each author and disregard others. Red flag indicators, such as those discussed in this paper, should be developed and incorporated into evaluation frameworks. Qualitative

assessments of research and genuine international collaboration should also be incorporated. Consider focusing on metrics that incentivize homegrown research.

- **Accreditation agencies**: Establish review guidelines and initiate audits to detect questionable authorship and affiliation practices to boost publication records. Enforce strict compliance with the relevant accreditation standards. Consider revoking accreditation for repeated implementation of questionable authorship practices.

- **Scholarly publishers**: Strengthen peer review processes to more effectively identify questionable authorship and affiliation claims, especially for networks of hyper-prolific coauthors with multiple affiliations. Require detailed justifications for multiple secondary affiliations.

- **Database producers**: Avoid polluting bibliometric databases by ensuring only high-quality publication venues are covered and deleting records of journals discontinued due to quality issues. For example, one of the study group universities had 85% of its articles in 2019 published in journals discontinued by one of these standard databases. As long as these articles in discontinued journals remain in the databases, universities will continue to receive credit for them in ranking systems because ranking systems do not differentiate between active and discontinued journals in the databases they use to generate publication metrics and rankings. This perpetuates distorted research metrics and undermines the integrity of rankings.

- **Researchers**: To maintain rigorous ethical standards in authorship and promote transparency within their academic environments, researchers should actively report any suspicions of authorship fraud. Resources such as the Center for Scientific Integrity (Retraction Watch, n.d.) can be utilized to provide guidelines on responsible research, including authorship ethics. The Committee on Publication Ethics (COPE) also provides guidelines for responsible authorship (Committee on Publication Ethics, 2019).

The challenges that the control group and other universities encounter underscore the need for comprehensive reforms and stricter guidelines. Addressing the issues highlighted in this study is crucial for maintaining a trustworthy and authentic academic environment.

Implementing the measures mentioned above, coupled with a renewed commitment to conventional publication practices, is essential for preserving the integrity of scholarly work. Without intervention, ongoing trends will continue, eroding trust in the academic record, obstructing true scholarly collaboration, and diverting resources at institutions from truly advancing academic excellence.

6. LIMITATIONS

This study analyzed questionable authorship and affiliation practices among 14 universities exhibiting extraordinary growth in research output, declines in first authorship rates, and increases in hyper-prolific authors, multiaffiliations, and authorship counts. However, several limitations should be acknowledged:

- **Sample size and scope**: The study focused on a cohort of 14 universities that met stringent criteria for research output growth and a significant decline in first authorship rates. While these universities provided valuable insights, the study may not capture the full spectrum of questionable practices globally. Future studies should consider expanding the sample size to include a more diverse set of institutions with varying levels of research activity. Lowering the thresholds for selection could offer a broader understanding of authorship and affiliation behaviors across different institutional types.

- **Control group comparability**: The control group of globally renowned institutions was selected to provide a stable reference point. However, differences between the study and control groups regarding institutional age, size, funding, and governance must be noted. These differences may influence the interpretation of the findings. Nevertheless, the control group offered a high-standard baseline for assessing deviations in research and authorship trends. Future studies could refine control group selection by including more geographically diverse institutions and those from a similar bracket to the study group.
- **Temporal scope**: The data analyzed spanned from 2019 to 2023, a period capturing recent shifts in research output and authorship and affiliation practices. However, it may not fully reflect long-term trends in these areas. Extending the temporal scope in future research could provide more robust conclusions regarding the persistence or evolution of questionable practices.
- **Interpretation of collaborative patterns**: The study identified unusual collaborative patterns, but the mechanisms behind these patterns remain unclear. Further research, incorporating qualitative approaches such as interviews or case studies, would provide deeper insights into the motivations driving these collaborations.
- **Disciplinary variations**: The threshold for defining hyper-prolific authorship—40 or more articles per year—may be appropriate for high-output disciplines but too restrictive for fields with lower publication rates, such as the humanities or social sciences. Future studies should consider using discipline-specific thresholds to more accurately identify hyper-prolific authorship behavior across various fields.
- **Bibliometric limitations**: While bibliometric analysis is a powerful tool for identifying patterns in research output, it has limitations in assessing the qualitative aspects of authorship practices. Multiple affiliations, for example, can reflect legitimate collaborations or strategic attempts to boost institutional metrics. Future research should address these nuances to distinguish between genuine scholarly contributions and questionable practices.

These limitations highlight areas for future research that can build upon and extend our findings, providing a more comprehensive understanding of questionable authorship and affiliation practices and their impact on global research metrics.

7. SUGGESTIONS FOR FUTURE RESEARCH

While this study highlights bibliometric anomalies suggestive of questionable authorship and affiliation practices, direct evidence is limited. Future research should address this gap through more detailed, individual-level analyses. Interviews with hyper-prolific authors and journal editors could reveal more profound insights into the pressures and motivations behind these trends.

- **Online marketplaces for authorship sales**: Investigating online platforms where authorship is sold could shed light on the prevalence of paid authorship practices. Researchers could track the publication histories of individuals who have engaged in these activities to validate the presence of sold authorship and paid affiliations.
- **Cluster analysis**: Employing cluster analysis could help identify groups of universities exhibiting similar questionable practices, allowing for more targeted interventions. This method could also facilitate the categorization of different levels of severity in authorship practices.

- **Content analysis of highly cited papers**: Analyzing the content of highly cited papers from the study group could help differentiate genuine research from metrics inflation. This approach would involve examining the contribution of each listed author and assessing whether the paper reflects true collaborative research or nominal authorship.
- **Distortion of citation metrics**: Future studies should explore how questionable authorship and affiliation practices impact citation-based metrics such as the h-index or highly cited researchers. Investigating the extent to which inflated authorship practices distort these metrics would provide valuable insights for reforming global ranking systems and ensuring they reflect genuine academic contributions.

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