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International Comparative Performance of India's Research Base: Scholarly Output, Impact, Collaboration, Knowledge Transfer

A study commissioned by the Department of Science & Technology, Government of India, 2011-2016, February 2020

Foreword

We are grateful to the Centre for Human Resource and Organisational Development (CHORD) Division of Department of Science & Technology (DST), Government of India for commissioning to Elsevier this study on *International Comparative Performance of India's Research Base: Scholarly Output Impact, Collaboration, Knowledge Transfer* for the period 2011-2016.

The present study has been carried out by the Analytical Services team using the SCOPUS database. The study is the 3rd in the series, while earlier studies for the DST, Government of India, were carried out for the time periods 2005-10 and 2009-13 by Elsevier in 2012 and 2015 respectively.

The present report further provides advanced trends for the years 2017-2018 to make it more relevant to policy planning.

Acknowledgment

We wish to acknowledge with thanks the valuable contribution and guidance imparted by DST's Expert Committee on Bibliometrics (ECB) in imparting guidance and shaping the outcome of this study.

1.	Dr. B.K. Sen	Chairman, ECB
2.	Prof. I.K. Ravichandra Rao, Former Professor, ISI, Bangalore	Member
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13.	Prof. Giridhar Madras, IISc	Member
14.	Dr. A. N. Rai, Sc-G, CHORD, DST, New Delhi	Member Secretary

Our special thanks to Prof. Ashutosh Sharma, Secretary, Department of Science & Technology (DST), Government of India, for providing his valuable insights.

Contents

Introduction

This study was commissioned by the Department of Science & Technology (DST), an organisation of the government of India, and carried out by Elsevier's Analytical Services under guidance from the ECB.

"The Department of Science & Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology (S&T) and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country."

Source: DST website, introduction available at http://www.dst.gov.in/about-us/introduction

DST's responsibilities include

- Formulating national policies relevant to S&T.
- Promoting new areas of S&T with a specific focus on emerging fields.
- Fostering cross-sector linkages in S&T areas.
- Allocating funding to Scientific Research Institutions and Scientific Associations and Bodies.

Considering these aims, it is crucial for DST to maintain a deep understanding of India's research performance, through time and benchmarked with other nations, overall and for subject areas relevant to S&T. This study aims to provide DST with such necessary insights. In order to do so, this study provides analyses around three main themes:

- India's international comparative research performance (Chapter 1).
- Factors of success of India's research (Chapter 2).
- The Indian research landscape (Chapter 3).

Data are provided overall and for 16 core S&T subject areas selected by DST. This study covers the years 2011-2016 and is derived from the third report commissioned to Elsevier by DST. Previous reports covered publication years 2006–2010 and 2009-2013, respectively.

Methodology is detailed in appendix C-1, and is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. Our analyses of bibliometric data are based upon recognised advanced indicators such as the concept of relative citation impact rates.

Data sources are detailed in appendix C-2, and most analyses are derived from Elsevier's Scopus, an abstract and citation database of peer-reviewed literature covering 75 million documents published in over 22,000 journals, book series, and conference proceedings by some 5,000 publishers.

Comparators used in this study:

- SAARC: South Asian Association for Regional Cooperation, which includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka (aggregated benchmark and individual countries).
- BRICS: Brazil, Russia, India, China, South Africa (aggregated benchmark and individual countries).
- G8: Canada, France, Germany, Italy, Japan, the United Kingdom, the United States, and Russia (aggregated benchmark and individual countries).
- G20: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union (aggregated benchmark and individual countries).
- EU28: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom (aggregated benchmark and individual countries).
- Top20: top 20 countries publishing the most scholarly output: Australia, Brazil, Canada, China, Germany, France, India, Iran, Italy, Japan, Korea, the Netherlands, Poland, Russia, Spain, Switzerland, Turkey, Taiwan, the United Kingdom, and the United States (individual countries)
- WLD: total output in Scopus database regardless of author location (aggregated benchmark)

Executive Summary
India's research performance has improved from 2011 to 2016

Overall research performance of India 2011-2016

Along multiple research indicators, India had small but growing shares of the world's total, as shown in **Figure A**.

- Increasing output: India's share of the world's scholarly output grew from 4.0% in 2011 to 5.4% in 2016. This placed India in 1st place among SAARC countries, 2nd place among BRICS countries, and 5th place among G20 countries. In absolute terms, this 1.4 percentage point increase corresponds to a high Compound Annual Growth Rate (CAGR, see Appendix for term definition) of 8.4%, from 90,864 publications in 2011 to 136,238 publications in 2016. World CAGR is 1.9% over that period.

- Growing impact: India's shares of the world's citations and top cited publications all increased between 1.0 and 1.4 percentage point from 2011 to 2016, to 4.1% of global citations, 4.3% of top 25% cited publications, 3.6% of top 10% cited publications, 3.4% of top 5% cited publications, and 2.8% of top 1% cited publications. Although these values remain lower than India's overall publication share of 5.4%, their increase through time demonstrates that India not only grew in output but also in influence. In terms of citations, India ranked 1st among SAARC countries, 2nd among BRICS countries, and 10th among G20 countries.

- Improving knowledge transfer: India's share of the world's academic-corporate collaborated publications grew from 2.3 in 2011% to 2.7% in 2016. In absolute terms, this corresponds to 3.3% CAGR from 1,506 publications in 2011 to 1,768 publications in 2016.

Overall, India's strong growth in output outpaced its research impact improvement. Increasing collaboration, across countries as well as sectors, might be key to maximise the influence of India's research.

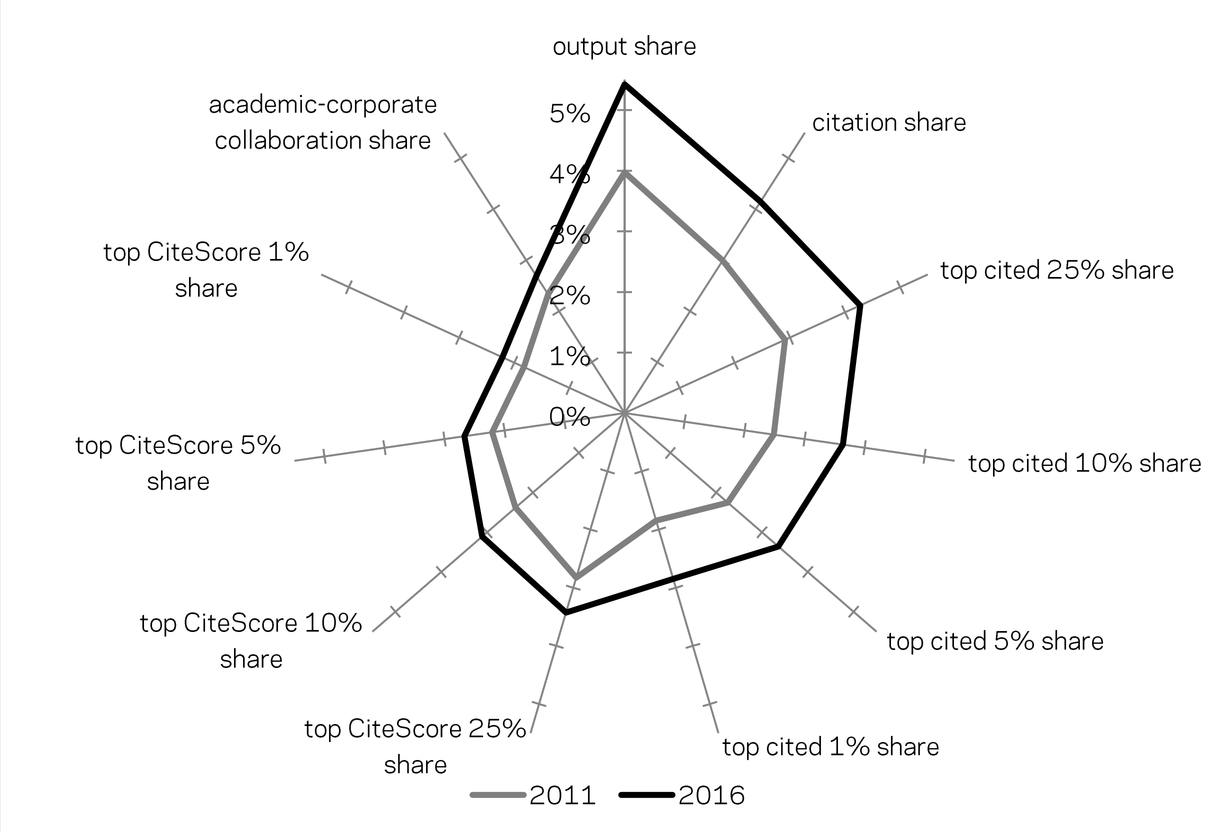

Figure A— *India's global shares of main research indicators, 2011 and 2016; Source: Scopus*

Volume and global share of publications

- India's scientific research publications showed a strongly rising trend over the past few years; research publications increased by 50% from 2011 to 2016. India's scientific research publications grew by 8.4% annually compared to 1.9% for the world during 2011-2016, with annual values of 90,684 in 2011, 99,974 in 2012, 106,957 in 2013, 121,516 in 2014, 128,021 in 2015, and 136,238 in 2016.

- In 2016, India produced more research publications than several countries such as Italy, Canada, Spain, Australia, Korea, Sweden, Singapore, and other BRICS countries, except China.

- India's global share in scientific research publications increased from 4.0% in 2011 to 5.4% in 2016, with annual values of 4.2% in 2013, 4.4% in 2014, 4.8% in 2015, and 5.1% in 2015 (see **Figure B**).

- In 2016, India's share in global research publications by subject areas was highest in Pharmacology and Toxicology (13.5%), followed by Computer Science (8.8%), Earth & Planetary Sciences (7.6%), Veterinary Sciences (7.3%), Chemical Engineering (7.2%), Chemistry (6.8%), Engineering (6.4%), Materials Science (6.4%), Physics & Astronomy (6.0%), Mathematics (5.7%), and Environmental Science 5.6%).
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Research Disciplines and National Output

- India's volume of research publications by discipline was highest in Engineering (34,024), Computer Science (29,434), Medicine (21,469), Physics & Astronomy (19,373), Materials Science (17,309), Biochemistry, Genetics & Molecular Biology (15,926), and Chemistry (15,574) in 2016 (see **Figure G**).

- Publication share of publications by discipline was highest in Engineering (25.0%), Computer Science (21.6%), Medicine (15.8%), Physics & Astronomy (14.2%), Materials Science (12.7%), Biochemistry, Genetics & Molecular Biology (11.7%), and Chemistry (11.4%) in 2016 (see **Figure G**).

- Between 2011 and 2016, high annual growth of research publications was observed in Energy (19.8%), Computer Science (16.9%), Engineering (14.8%), Mathematics (10.8%), and Chemical Engineering (9.3%).

Collaborations

<u>International</u>

- 22,186 of India's publications resulted from international collaboration, comprising 16.4% of India's total research publication output in 2016. Annual values for previous years were 14,780 in 2011 (16.4%), 16,147 in 2012 (16.2%), 17,597 in 2013 (16.5%), 19,414 in 2014 (16.0%), and 20,322 in 2015 (15.9%).

- In parallel to its overall rise in scholarly output, India saw increases in its global share of publications of each collaboration type (see **Figure E**). These increases were comparatively low for internationally collaborated publications (its most impactful collaboration type, increasing by 0.4 percentage point to reach 4.2% in 2016).

- In 2016, India's research publications with international collaboration was highest in Earth & Planetary Sciences (27.4%), followed by Physics & Astronomy (22.5%), Immunology & Microbiology (21.5%), Chemistry (21.5%), Chemical Engineering (21.1%), and Materials Science (20.3%).

- India's top 3 prolific international collaboration partner countries in research publications were the USA, the UK, and Germany.

- India's share of international collaboration in world output increased from 3.8% in 2011 to 4.2% in 2016. Annual values for interim years were 3.9% in 2012 and 2013, and 4.0% in 2014 and 2015.

National

- In 2016, national collaboration accounted for 31.9% of India's total scientific research publications.

Institutional

- In line with its overall rise in scholarly output, India saw increases in its global share of publications of each collaboration type (see **Figure E**). These increases were particularly high for institutionally collaborated publications (its most frequent collaboration type, rising by 2.6 percentage point to reach 7.6% in 2016).

Academic-corporate

- In 2016, academic-corporate collaboration accounted for 2.7% of India's total scientific research publications.

- India's global share of academic-corporate collaborated publications grew by 0.4 percentage point since 2011, reaching 2.7% in 2016. However, it remained lower than its overall share of world scholarly publications (see **Figure F**). India's share of patent citations was also on the increase, by 0.6 percentage point to 2.8% in 2015. Two patent citations were received by

India in 2016, raising its patent citation share for that year to 6.5%. However, this value is not reliable as it is derived from too low a number of occurrences to be meaningful. India's patent citation share was the highest in Chemistry in 2011 (see **Figure G**).

- Globally, academic-corporate collaboration was concentrated in subject areas such as Energy, Engineering, Earth & Planetary Sciences, Computer Science, and Materials Science. In the case of India, it was concentrated in subject areas such as Earth & Planetary Sciences, Computer Science, and Energy. India's academic corporate collaboration share was the highest in Computer Science in 2016 (see **Figure G**).

Citation Impact

- In 2016, India registered a Field-Weighted Citation Impact (FWCI) of 0.76, which means 24% below the global overall average. Subject area-wise, India's FWCI was highest in Chemistry (0.99), followed by Chemical Engineering (0.98), Materials Science (0.97), Energy (0.96), and Physics & Astronomy (0.93).

- In 2016, India's share of scholarly citations was 22% in Engineering and Chemistry (see **Figure G**). India's citation per paper (CPP) was highest in Chemistry (3.8), followed by Chemical Engineering (3.7), and Materials Science (3.0).

- In 2016, India's global citation share was 4.1%, increasing from 3.0% in 2011. Annual values for interim years were 3.2% in 2012, 3.4% in 2013, 3.7% in 2014, and 3.9% in 2015. However, India's citation share remained lower and grew at a slower pace than its share of publications (see **Figure B**). This suggests that although India is rapidly expanding its research publications, it may not be benefiting from similar gains in research impact.

- In 2016, India held 2.8% of the global number of top 1% cited publications, 3.4% of top 5% cited publications, 3.6% of top 10% cited publications, and 4.3% of top 25% cited publications. Although these increased at all measured percentile levels in recent years, they remained lower than India's overall publication share of 5.4% (see **Figure C**). Of particular note, India's share of top 1% cited publications peaked at 3.0% in 2014, and showed minor declines since, indicating that India may be participating less in the most excellent research in recent years. In the top 1%, 5%, 10%, and 25% cited publications, Engineering accounts for more than 30% of India's subject breakdown (see **Figure G**). These highly cited publications tend to be relatively more concentrated in the following fields: Engineering, Physics & Astronomy, Computer Science, and Materials Science, indicating areas of specialisation of India's research excellence.

- Similarly, while India's shares of global publications in top cited journals were also on the rise overall, they too remained lower that its global share of all publications (see **Figure D**). While the rising trend was straightforward at the lower percentile levels, there was some fluctuation regarding publications in the top cited journals. For publications in top cited journals, Engineering had the highest share in the top 1%, Engineering and Material Science in the top 5%, and Chemistry in the top 10% and top 25% (see **Figure G**).

National Research Institutions

- In 2016, the top 5 Indian research institutions in terms of volume of publication were the Vellore Institute of Technology; the Indian Institute of Science Bangalore; the University of Delhi; the Indian Institute of Technology, Bombay; and the Indian Institute of Technology, Kharagpur.

- In 2016, the top 100 research institutions by publications included DST's research institutions such as the Indian Association for Cultivation of Science, the Jawaharlal Nehru Centre for Advanced Scientific Research, and the Bose Institute.

Coverage of Indian journals in Scopus

- The number of Indian journals in Scopus was 426 in 2016. Annual values for previous years were 432 in 2011, 431 in 2012, 433 in 2013, 430 in 2014, and 418 in 2015.

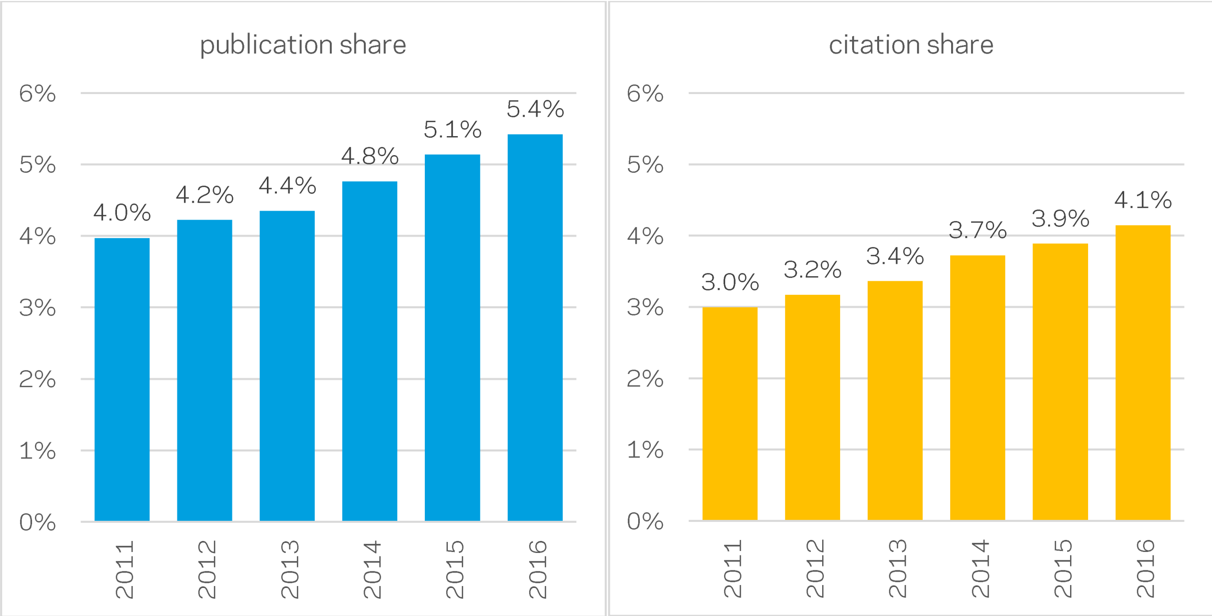

Figure B — *India's global share of scholarly publications and citations, 2011-2016; source: Scopus*

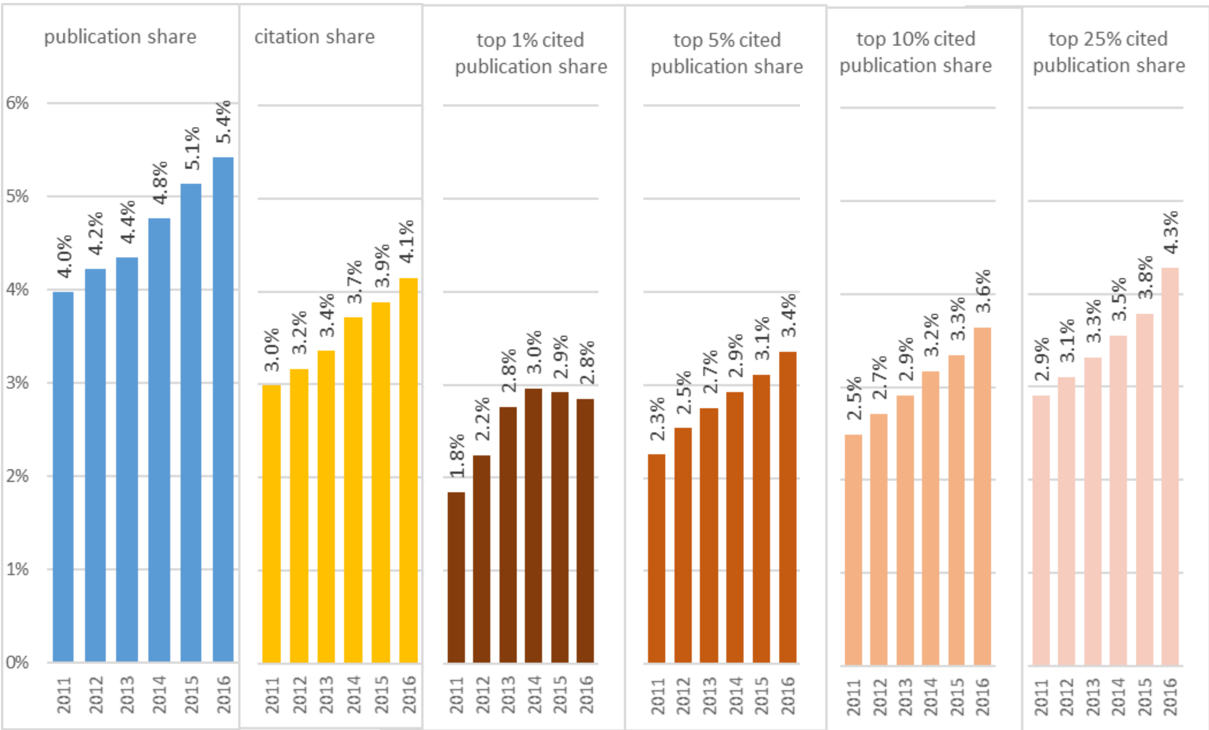

Figure C — *India's global shares of scholarly publications, citations, and top cited publications share, 2001-2016; source: Scopus*

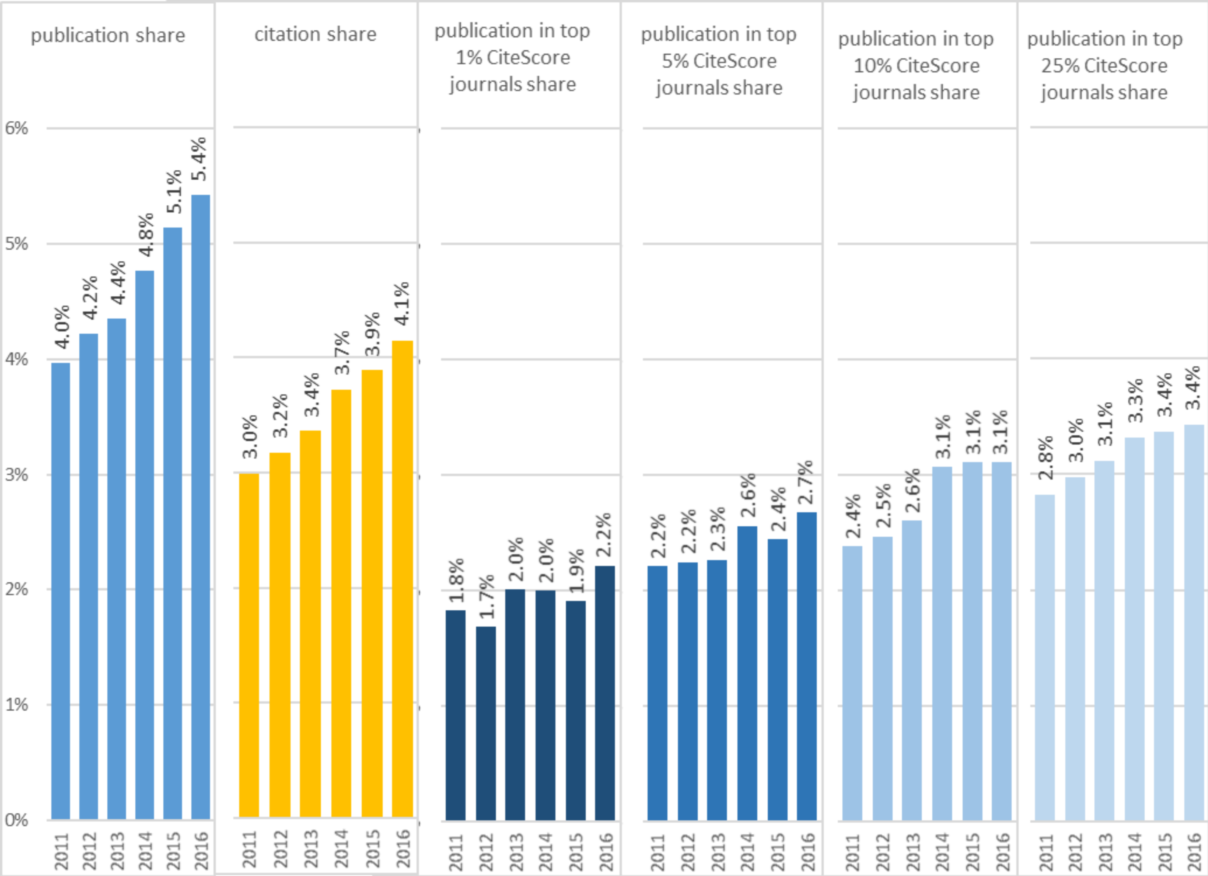

Figure D — *India's global share of scholarly publications, citations, and publications in top CiteScore journals, 2011-2016; Source: Scopus*

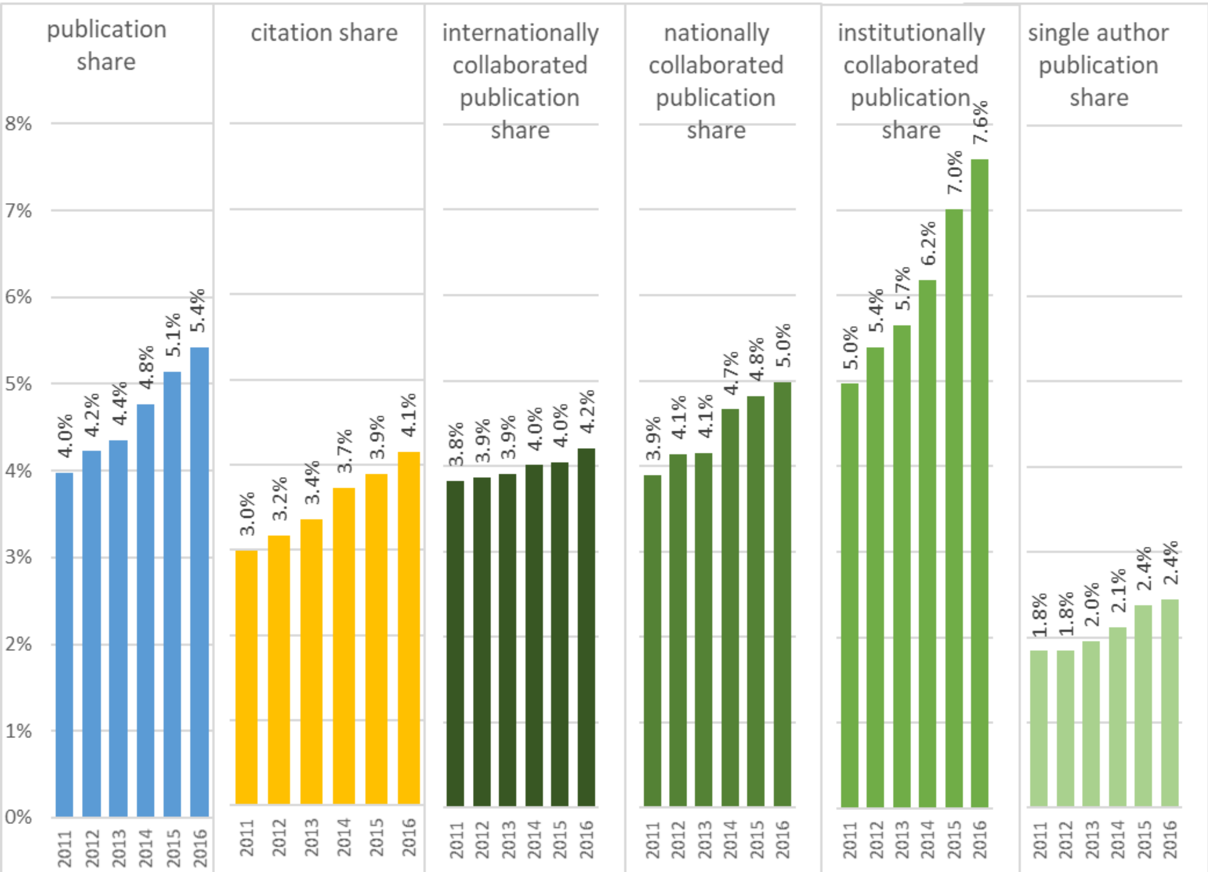

Figure E — *India's global share of scholarly publications, citations, international, national, institutional, and single author publications, 2011-2016; Source: Scopus*

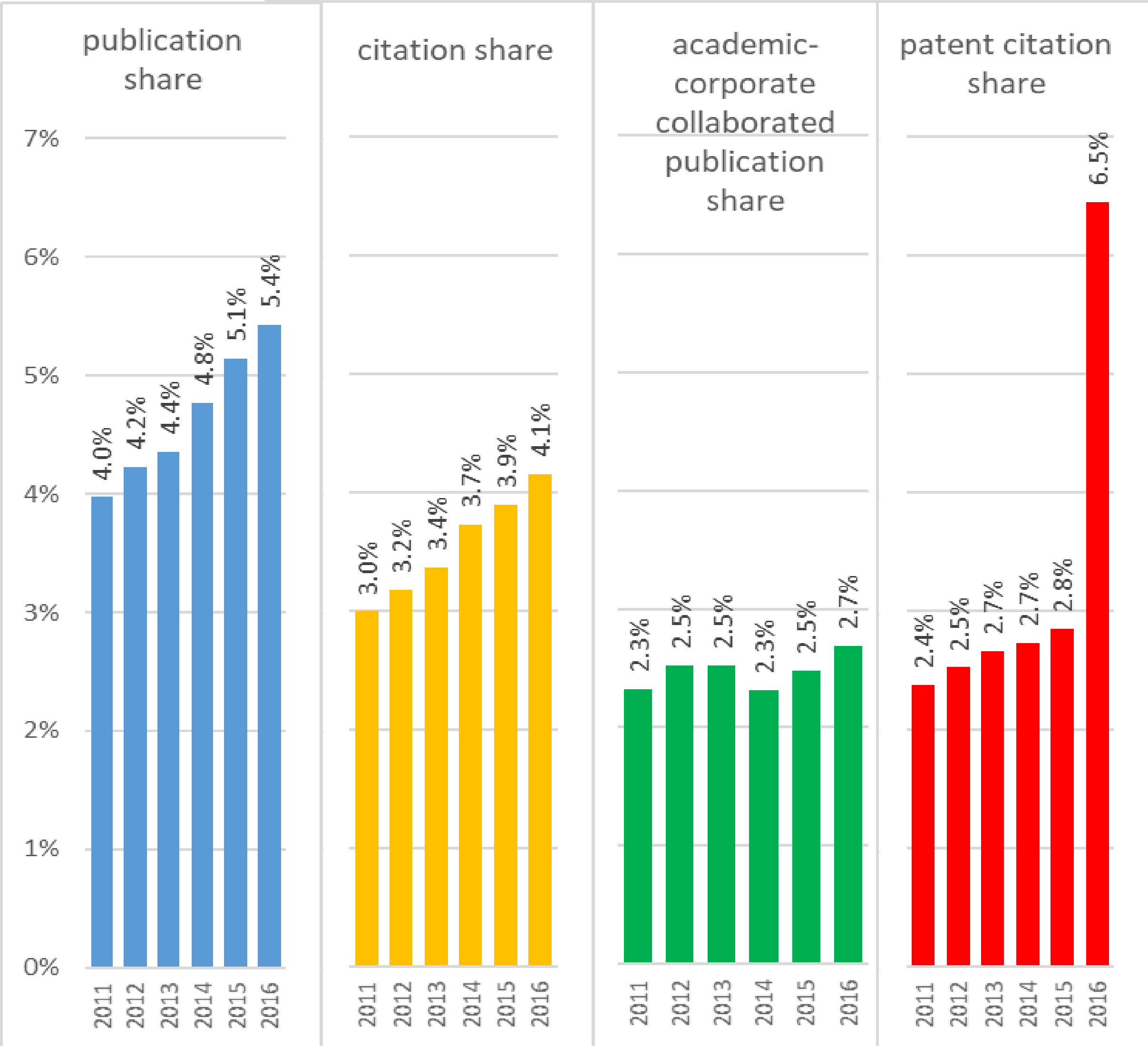

Figure F — *India's global share of world publications, citations, academic-corporate publications, and patent citations, 2011-2016; Source: Scopus.* ***India's 2016 patent citation share is unreliable due to too few occurrences.***

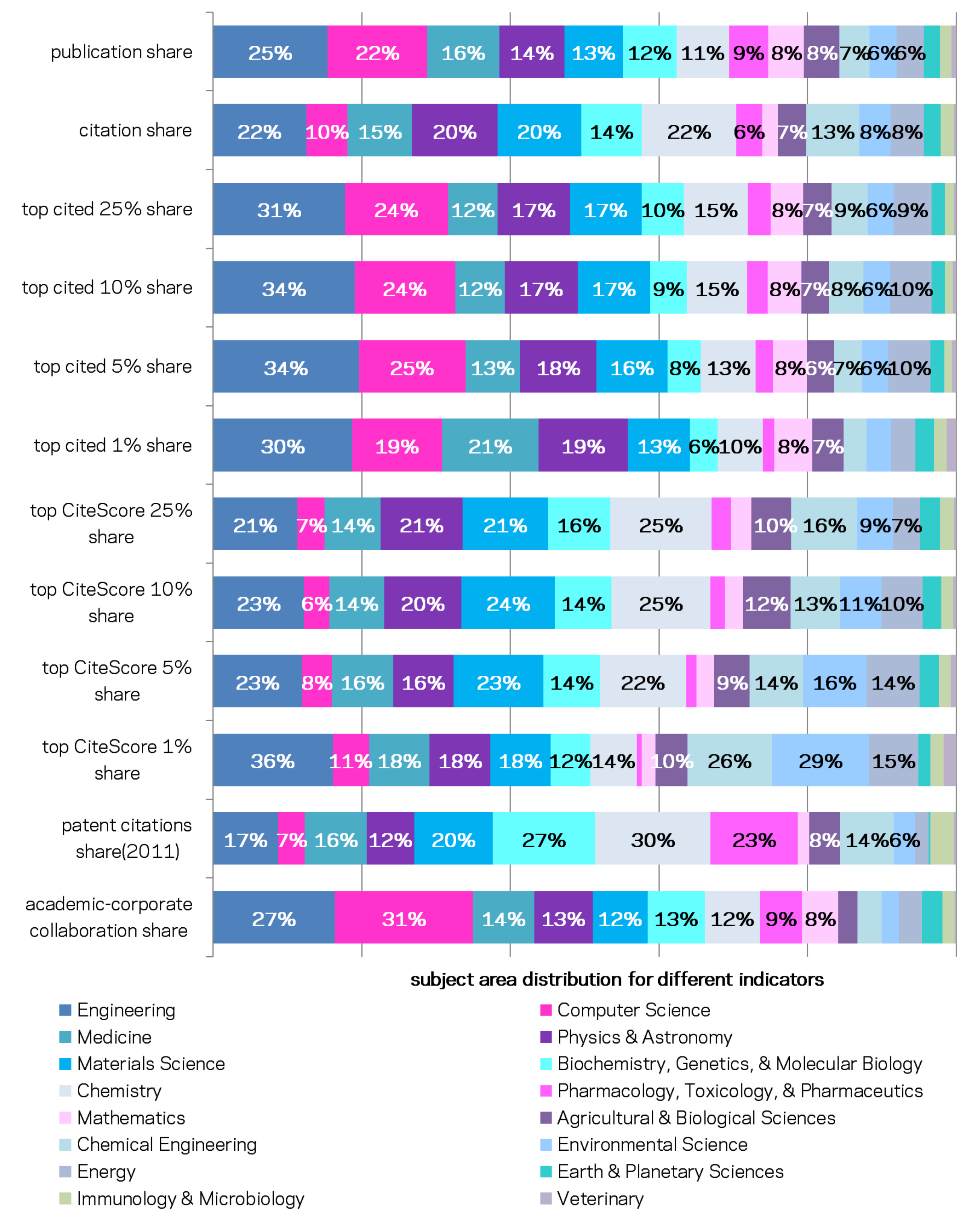

Figure G — *subject area breakdown for different indicators for India, 2016; Source: Scopus*

Key Facts at a Glance

INDIA'S SCHOLARLY OUTPUT IN 2016

136,238 publications

5.4% of the world's scholarly output

INDIA'S SCHOLARLY OUTPUT RANK IN 2016

1st among SAARC countries
2nd among BRICS countries
5th among G20 countries

INDIA'S SCHOLARLY OUTPUT GROWTH FROM 2011 TO 2016

8.4% CAGR

Compound Annual Growth Rate, compared to 1.9% for the world

INDIA'S SCHOLARLY CITATIONS IN 2016

262,677 citations

4.1% of the world's scholarly citations

INDIA'S SCHOLARLY CITATIONS RANK IN 2016

1st among SAARC countries
2nd among BRICS countries
10th among G20 countries

INDIA'S RESEARCH FOCUS IN 2016

Engineering, Medicine, and Computer Science

INDIA'S INTERNATIONAL COLLABORATION IN 2016

22,186 publications

16.4% of India's scholarly output

INDIA'S MOST PROLIFIC INTERNATIONAL COLLABORATION PARTNERS IN 2016

USA, UK, Germany, Korea, and Saudi Arabia

INDIA'S ACADEMIC-CORPORATE COLLABORATED OUTPUT IN 2016

1,768 publications

1.3% of India's scholarly output

Chapter 1

International comparative research performance

Between 2011 and 2016, India's scholarly output increased at a high 8.4% annual growth rate, reaching 5.4% of the global output in 2016 and ranking 5th among G20 countries. India's output attracted 4.1% of the world's citations in 2016, ranking 10th among G20 countries. India's research was cited 24% less than the world average.

1.1 Key Findings

INDIA'S SCHOLARLY OUTPUT

136,238

5.4% of the world's scholarly output in 2016

INDIA'S SCHOLARLY OUTPUT GROWTH

8.4%

2011-2016 Compound Annual Growth Rate (CAGR), compared to 1.9% for the world

INDIA'S CITATION SHARE

4.1%

of world citations in 2016

INDIA'S CITATION IMPACT

0.76

24% less than the world average in 2016

INDIA'S EXCELLENT OUTPUT TOP 25%

27,892

4.3% of the world's top 25% cited publications in 2016

INDIA'S EXCELLENT OUTPUT TOP 10%

9,027

3.6% of the world's top 10% cited publications in 2016

INDIA'S EXCELLENT OUTPUT TOP 5%

3,947

3.4% of the world's top 5% cited publications in 2016

INDIA'S EXCELLENT OUTPUT

606

2.8% of the world's top 1% cited publications in 2016

1.2 Output

Comparator group	India's ranking in 2011 publications	India's ranking in 2016 publications
SAARC	1	1
BRICS	2	2
G20	7	5
Top 20	7	5

Figure 1.1— *India's publication ranking in different benchmark groups; Source: Scopus*

In terms of scholarly publications, in 2016 India ranked 1st among SAARC countries, 2nd among BRICS countries, and 5th among G20 and Top 20 countries as mentioned in Figure 1.1. India accounted for nearly 4.0% of the world's total scholarly output in 2011 and 5.4% in 2016, and nearly the totality of SAARC's in 2011 and 2016 respectively (see Figure 1.2).

India published 136,238 scholarly publications in 2016. This accounted for 5.4% of the global scholarly output. India also published most of the SAARC region's output – without India, SAARC countries made up only 0.8% of the world's scholarly publications. Since 2015, India has been publishing more than 5% of the global scholarly output, thanks to its fast growth over the 2011- 2016 period. In the same period, BRICS countries caught up with the EU28 in terms of scholarly publications. Scholarly output grew globally in recent years at a rate of 8.4% CAGR (see Appendix for terms and acronyms definitions).

Figure 1.2 shows publication output in 2011 and 2016 for India and benchmarks SAARC, BRICS, EU28, G8, G20, WLD, revealing India's strong growth rate in publications. Comparatively, SAARC countries had a growth rate of 1.7%, while BRICS countries had a high annual growth rate of 5.1% compared to 0.1% for the EU and 1.3% for G8. To some extent, BRICS's and especially SAARC's fast growth can be attributed to India, which grew its scholarly output by an average 8.4% annually over that period.

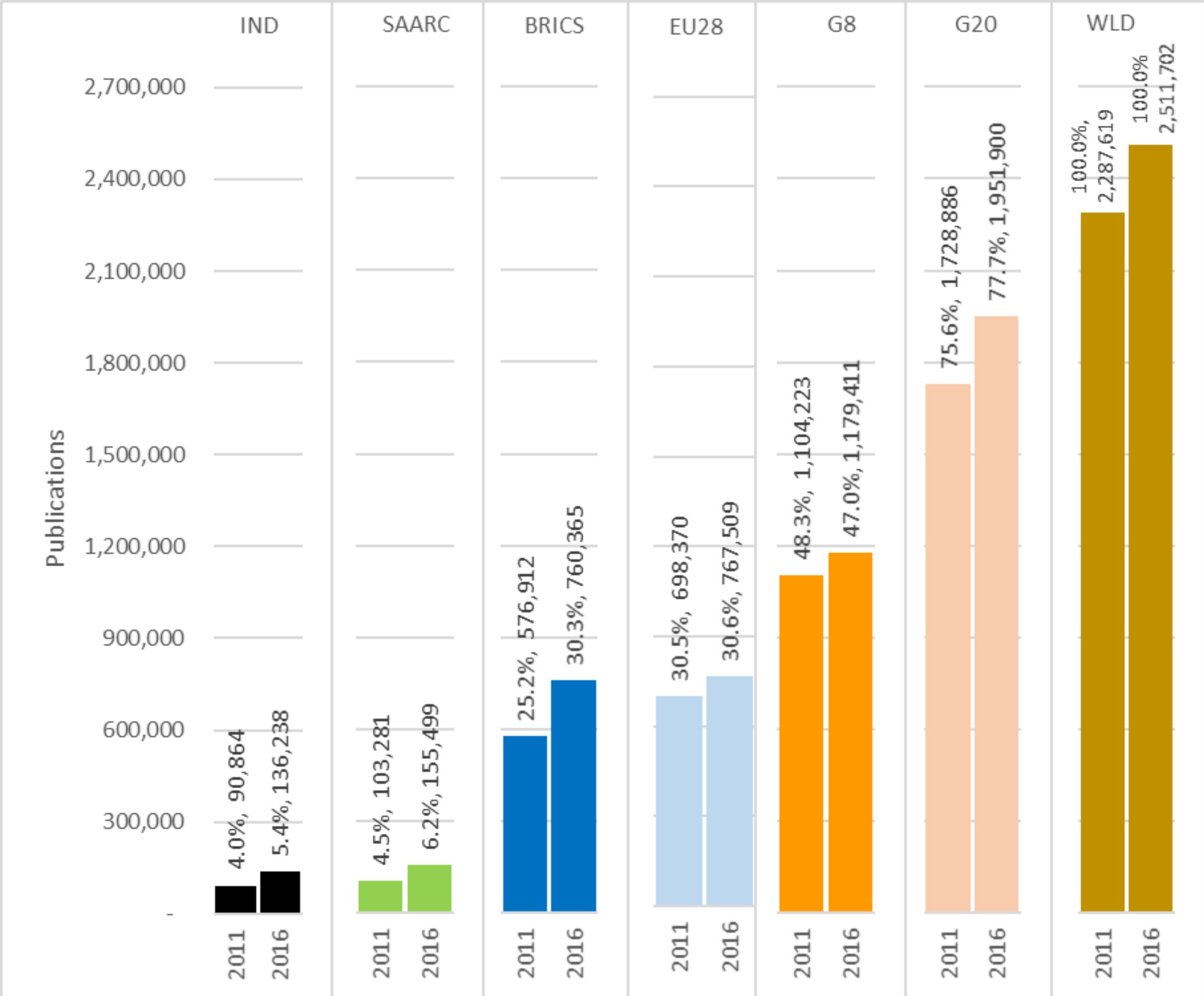

Figure 1.2 — *Scholarly publications for India and benchmarks in 2011 and 2016; Source: Scopus*

1.3 Citations

Comparator group	India's ranking in 2011 citations	India's ranking in 2016 citations
SAARC	1	1
BRICS	2	2
G20	11	10
Top 20	14	11

Figure 1.3— *India's citation ranking in different benchmark groups; Source: Scopus*

India received 880,733 scholarly citations in 2011 and 262,677 in 2016. This accounted for 3.0% and 4.1% of the world's total citations in 2011 and 2016, respectively, growing by 1.1 percentage point over the period. India also accounted for nearly all of citations to the SAARC region's scholarly output – without India, these would have accounted for only 0.4% of the world's scholarly citations.

Ranking 1st among SAARC countries, India received more scholarly citations than any other SAARC country, any other BRICS country except China, eight of the G20 countries, and ten of the top 20 countries (Figure 1.4). India ranked 11th among the Top 20 comparators. Since 2011, India grew its scholarly citation share by 1.1 percentage point to reach 4.1% of the global total in 2016.

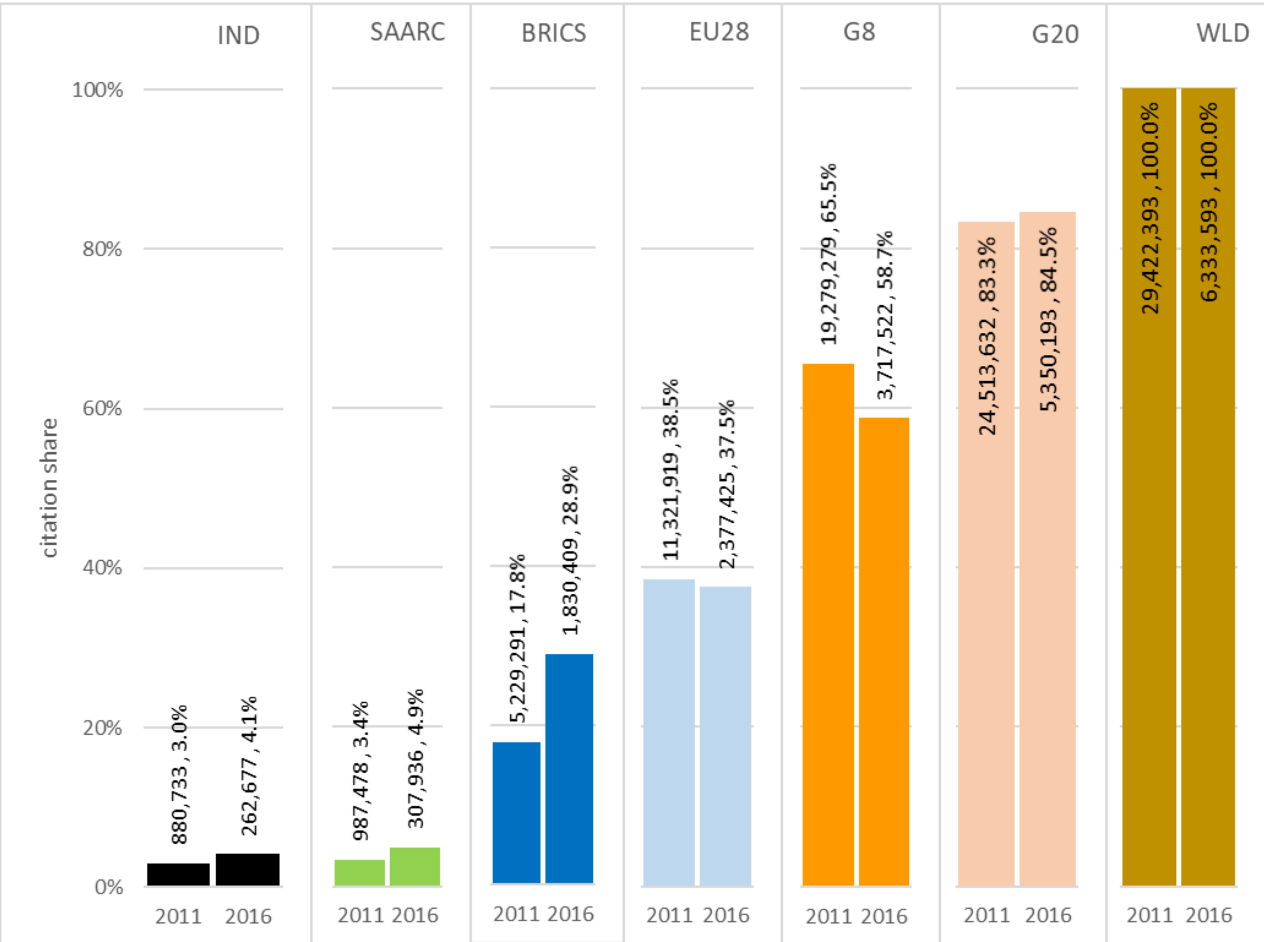

Figure 1.4 — *Scholarly citation for India and benchmarks in 2011 and 2016; Source: Scopus*

1.4 Field-Weighted Citation Impact

Field-Weighted Citation Impact (FWCI) is a sophisticated indicator that accounts for differences in publication age, publication type, and subject area; it is therefore well-suited to comparatively analyse the scholarly impact of different entities.

Figure 1.5 shows that India's FWCI was 0.76 in 2016, meaning that its research was cited 24% less than the global average when citations are normalized by number of scholarly publications, their age, their type, and their field.

The FWCI trend for India showed minor fluctuations, starting at 0.74 in 2011 to peak in 2013 at 0.79 and declining to 0.76 in 2016. BRICS's strong FWCI growth led it to overtake India and SAARC in 2014. SAARC countries' FWCI was 0.02 index point higher than India's, because SAARC's scholarly output was composed for the most part of Indian publications, which thereby strongly influenced the SAARC aggregate value.

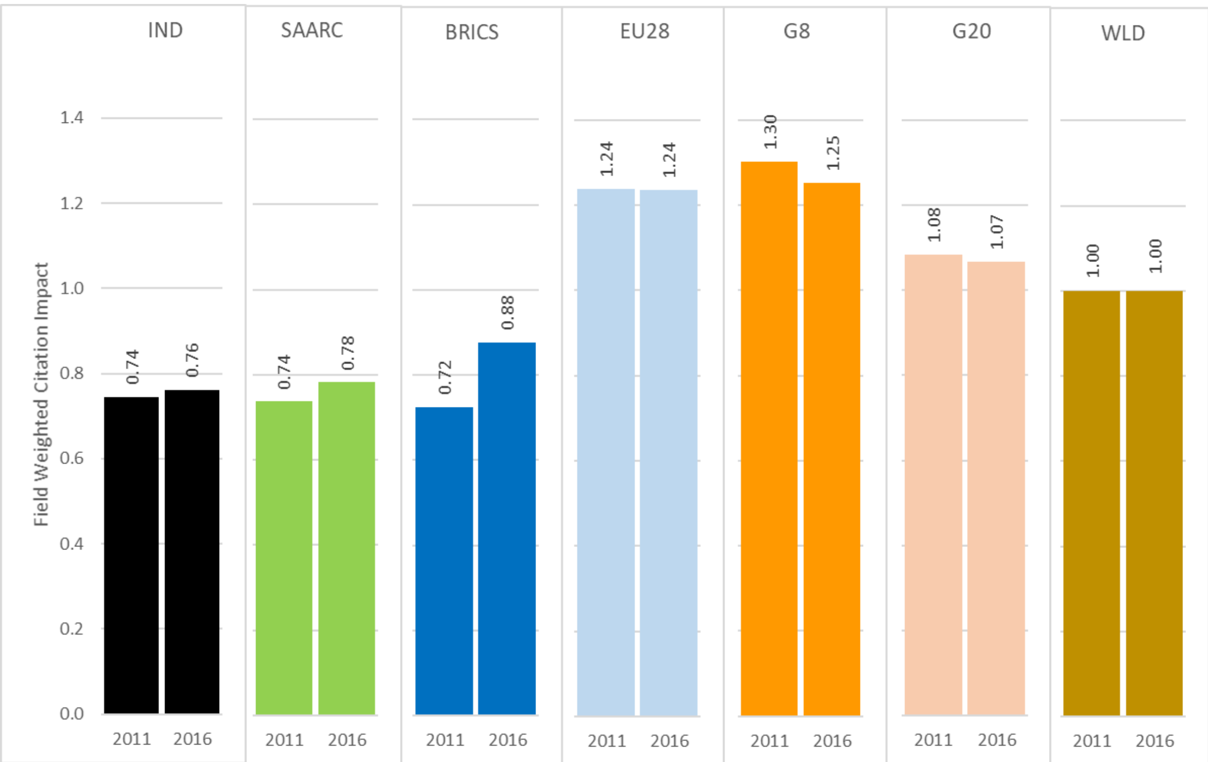

Figure 1.5 — *Field-Weighted Citation Impact of India and benchmarks, 2011 and 2016; Source: Scopus*

1.5 Excellence

Looking at share of the world's top-cited output (Figures 1.6, 1.7, 1.8, 1.9) and share of publications in top cited journals (Figures 1.10, 1.11, 1.12, 1.13) give an idea of how each comparator fares in terms of the excellence of its research at various levels (top 25%, 10%, 5%, and 1% of most cited publications and publications in top cited journals globally).

Across all percentile values, the shares of G8 were mostly stable and the shares of BRICS, SAARC, India, and most other benchmarks increased. India's share of top cited 1% of publications increased sharply 2011- 2014, then plateaued during 2014- 2016. For 5%, 10%, and 25%, India's share increased from 2011 to 2016. India's share of publications in top cited journals overall increased over the period with minor fluctuation for the highest percentiles.

Per Figure 1.6, India nearly doubled its number of top 1% cited publications between 2011 and 2016, from 372 to 606 publications, increasing in share by one percentage point from 1.8% to 2.8% of the world's top 1% cited publications.

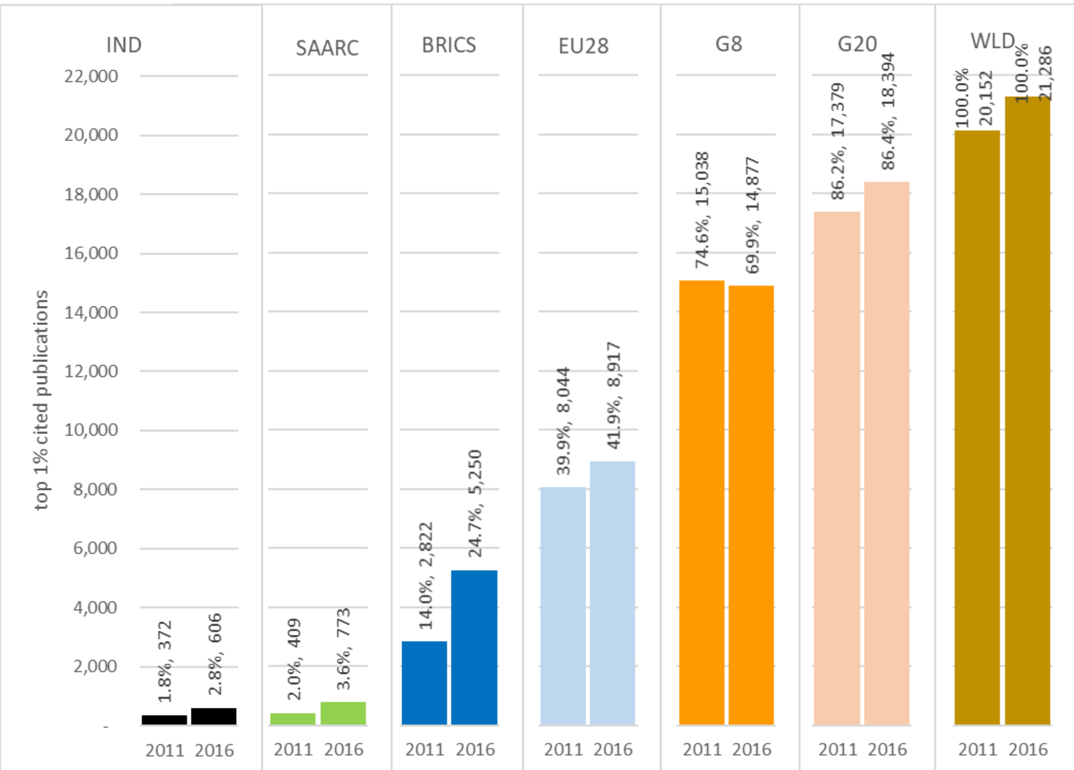

Figure 1.6 — *Share of world top 1% cited scholarly output for India and benchmarks, 2011 and 2016; Source: Scopus*

Per Figure 1.7, India increased its number of top 5% cited publications between 2011 and 2016, from 2,472 to 3,947 publications, increasing in share by 1.1 percentage point from 2.3% to 3.4% of the world's top 5% cited publications.

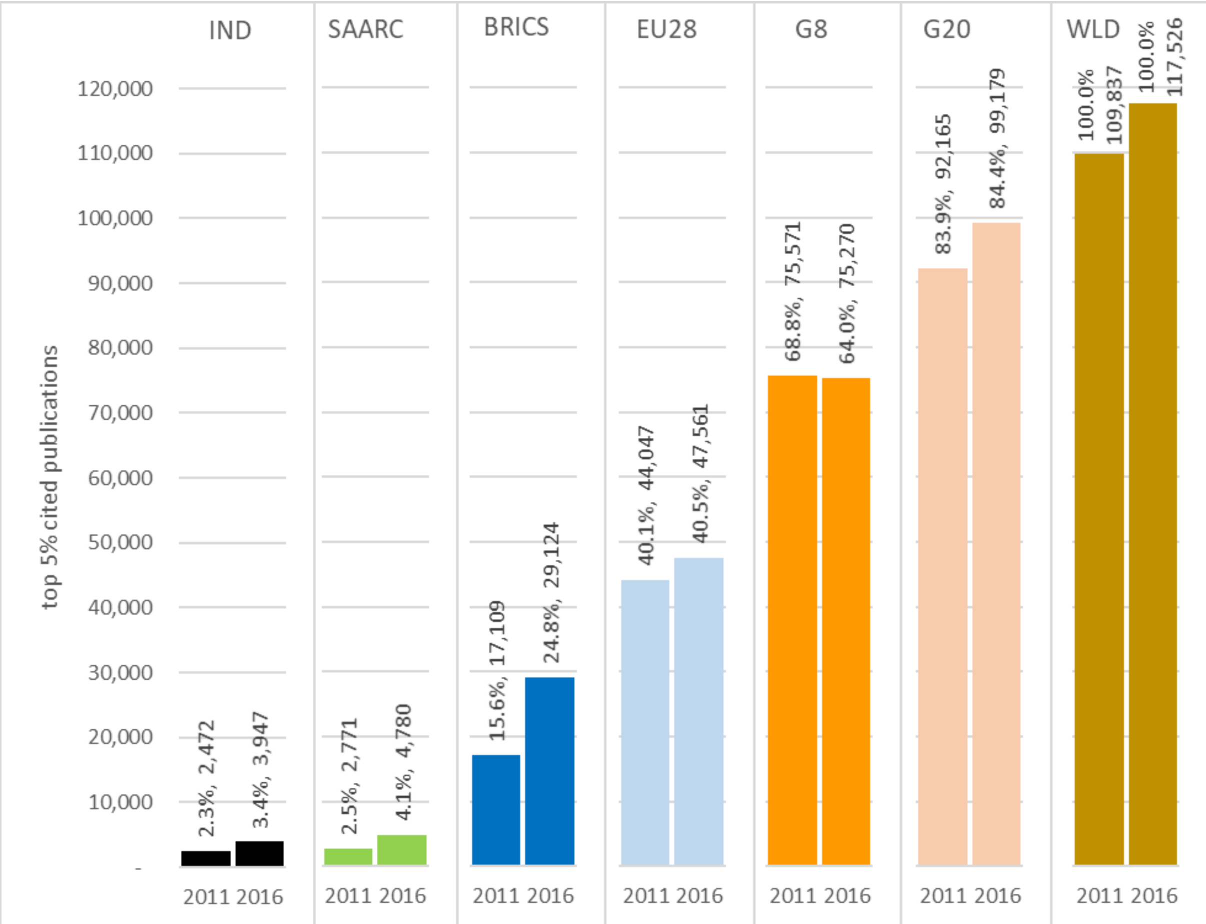

Figure 1.7 — *Share of world top 5% cited scholarly output for India and benchmarks, 2011 and 2016; Source: Scopus*

Per Figure 1.8, India increased its number of top 10% cited publications between 2011 and 2016, from 5,642 to 9,027 publications, increasing in share by 1.1 percentage point from 2.5% to 3.6% of the world's top 10% cited publications.

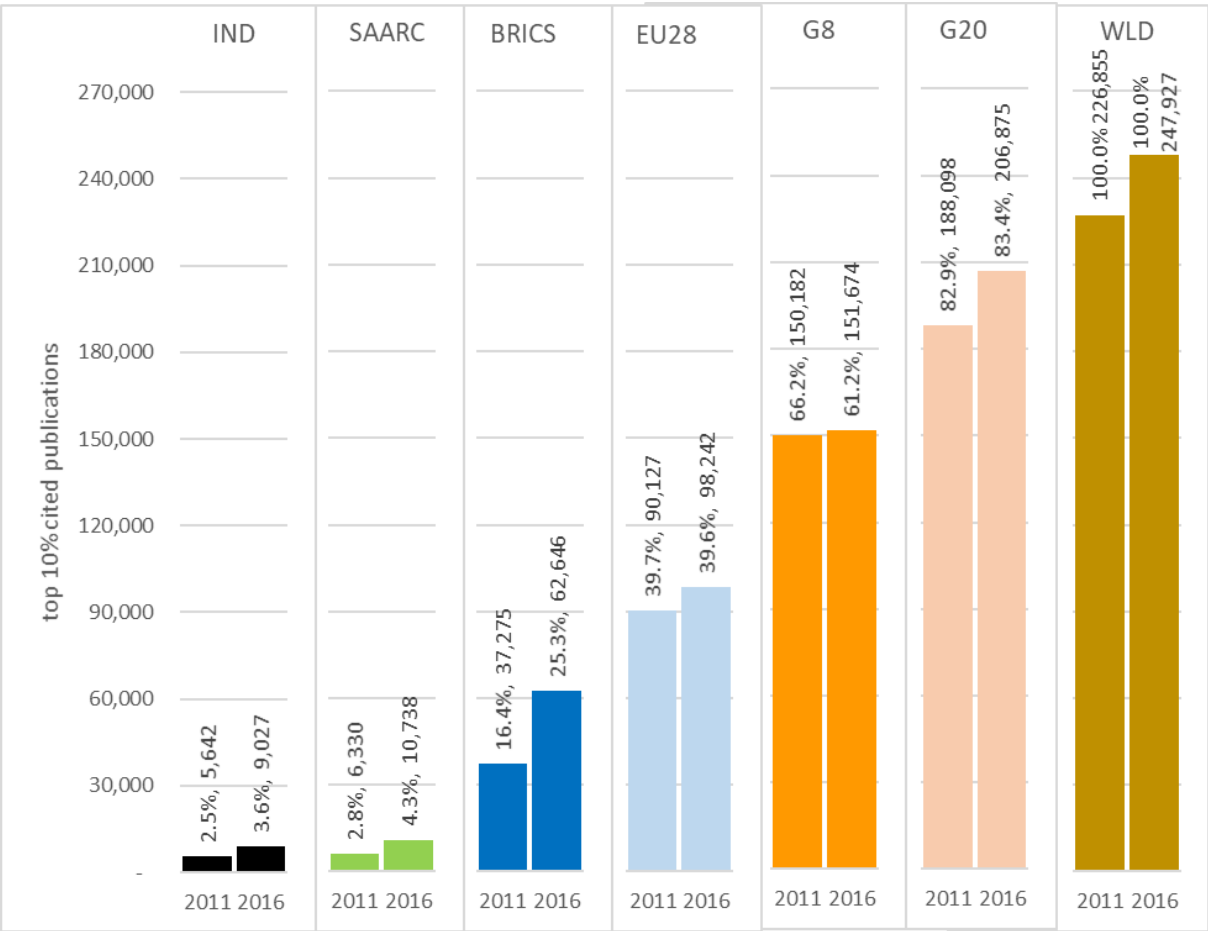

Figure 1.8— *Share of world top 10% cited scholarly output for India and benchmarks, 2011 and 2016; Source: Scopus*

Per Figure 1.9, India increased its number of top 25% cited publications between 2011 and 2016, from 17,141 to 27,982 publications, increasing in share by 1.4 percentage point from 2.9% to 4.3% of the world's top 25% cited publications.

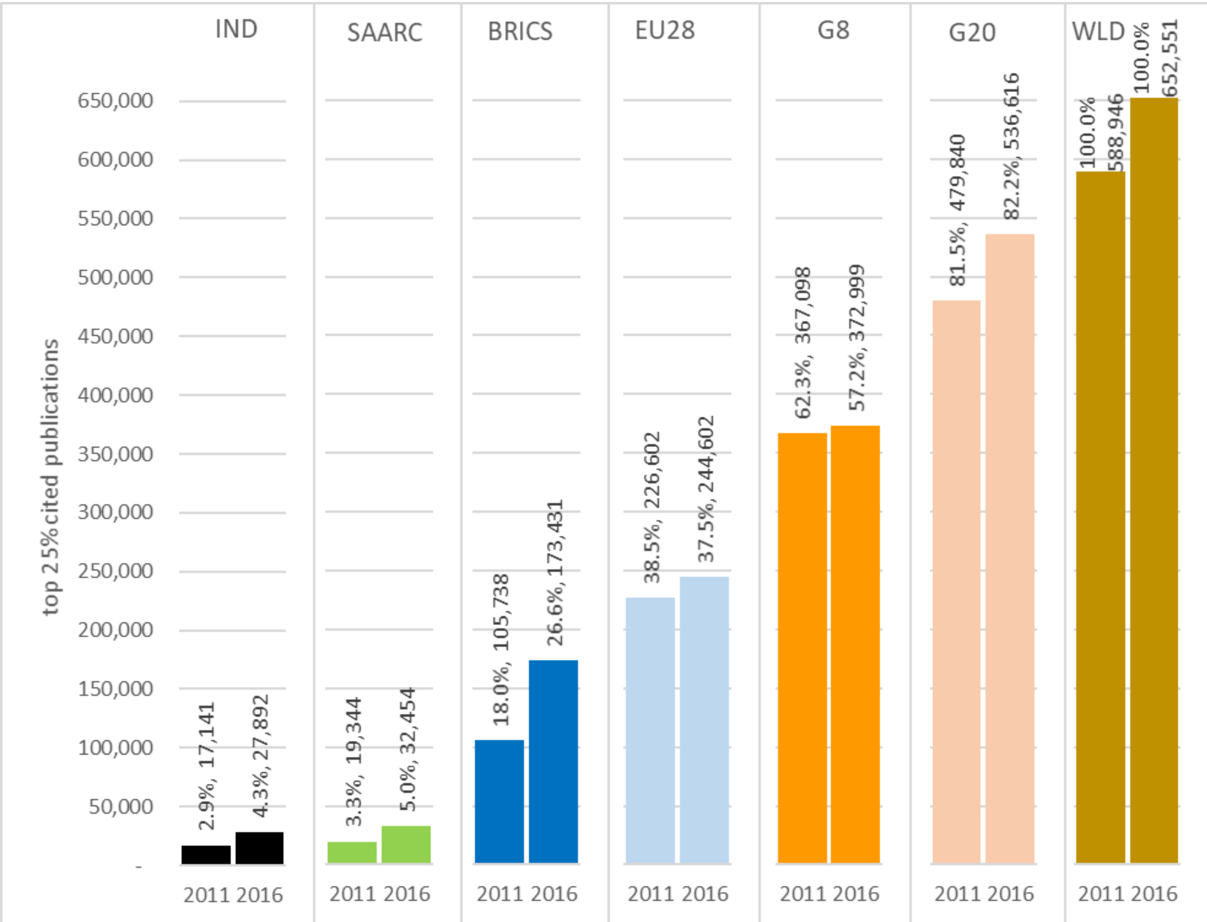

Figure 1.9 — *Share of world top 25% cited scholarly output for India and benchmarks, 2011 and 2016; Source: Scopus*

Per Figure 1.10, India's publication share in top 1% cited journals increased from 2011 to 2016 by 0.4% from 1,233 publications in 2011 to 1,666 in 2016. Publication share in top 1% cited journals increased for SAARC, BRICS and G20 benchmarks while for G8 and EU28 it slightly decreased from 2011 to 2016.

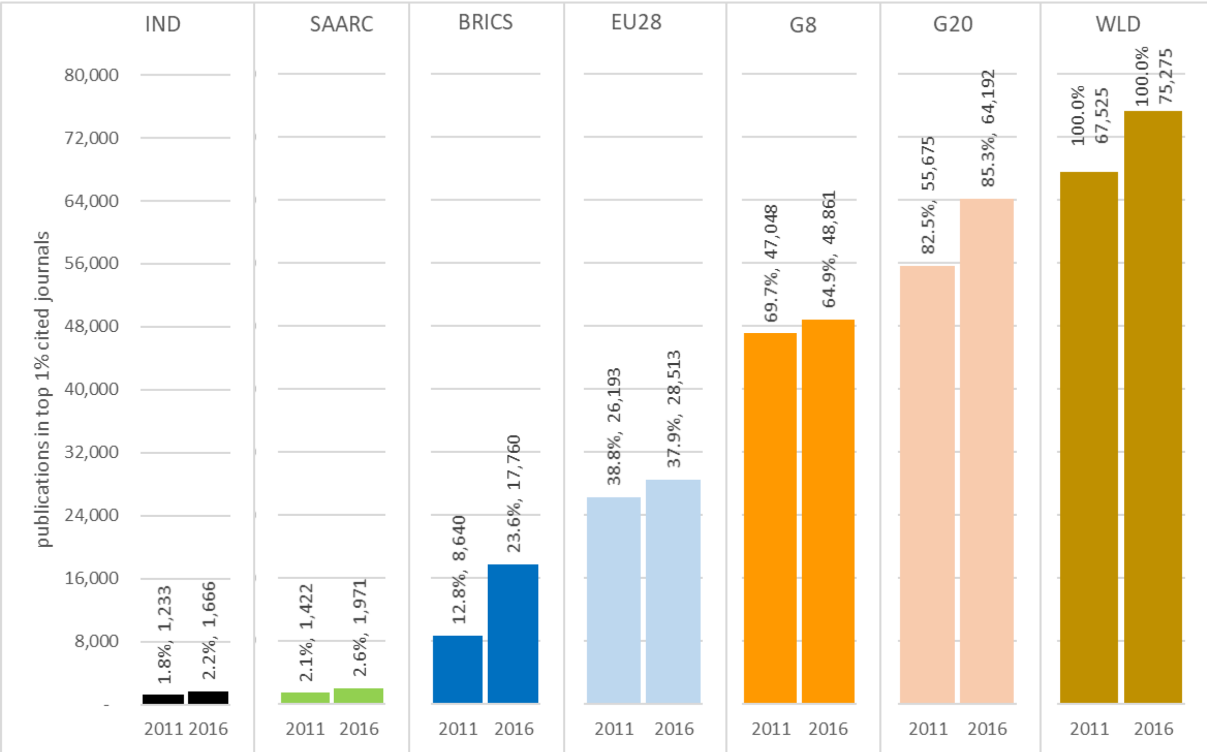

Figure 1.10 — *Share of global publications in top 1% cited journals for India and benchmarks, 2011-2016; Source: Scopus*

Per Figure 1.11, India's publications share in top 5% cited journals increased from 2011 to 2016 by 0.5% from 5,538 publications in 2011 to 8,646 in 2016. Publication share in top 5% cited journals increased for SAARC, BRICS and G20 benchmarks while for G8 it has slightly decreased and for EU28 remained stable from 2011 to 2016.

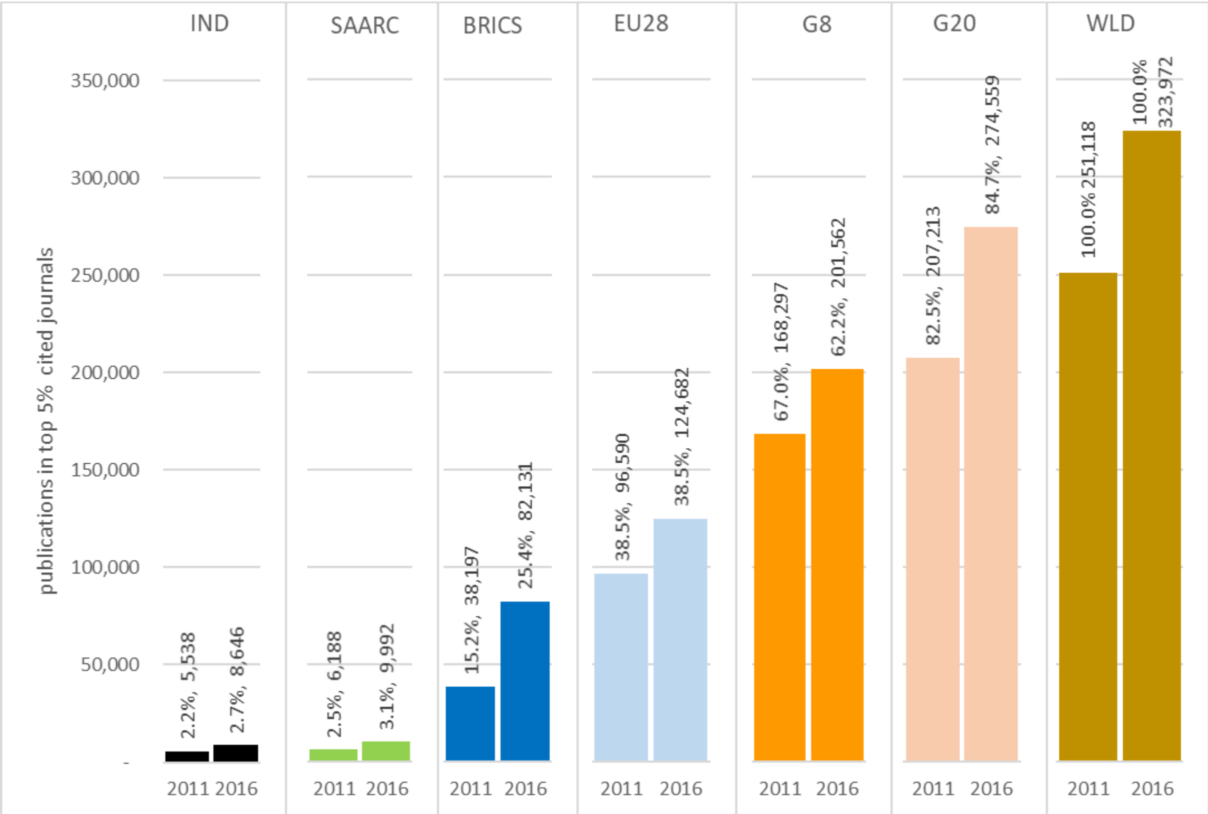

Figure 1.11— *Share of global publications in top 5% cited journals for India and benchmarks, 2011-2016; Source: Scopus*

Per Figure 1.12, India's publications share in top 10% cited journals increased from 2011 to 2016 by 0.7% from 10,936 publications in 2011 to 17,748 in 2016. Publication share in top 10% cited journals increased for SAARC, BRICS, and G20 benchmarks while for G8 and EU28 it slightly decreased from 2011 to 2016.

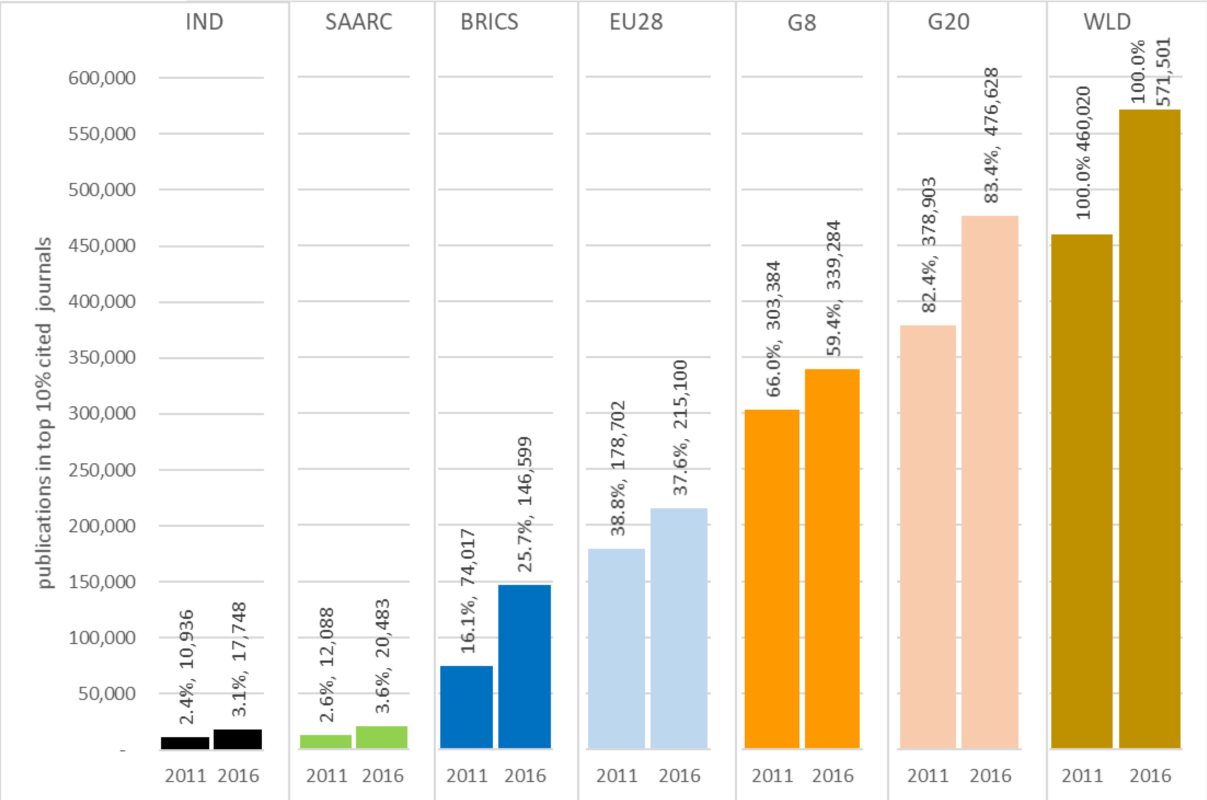

Figure 1.12 — *Share of global publications in top 10% cited journals for India and benchmarks, 2011-2016; Source: Scopus*

Per Figure 1.13, India's publications share in top 25% cited journals increased from 2011 to 2016 by 0.6% from 23,533 publications in 2011 to 35,333 in 2016. Publication share in top 25% cited journals increased for SAARC, BRICS, and G20 benchmarks while for G8 and EU28 it slightly decreased from 2011 to 2016.

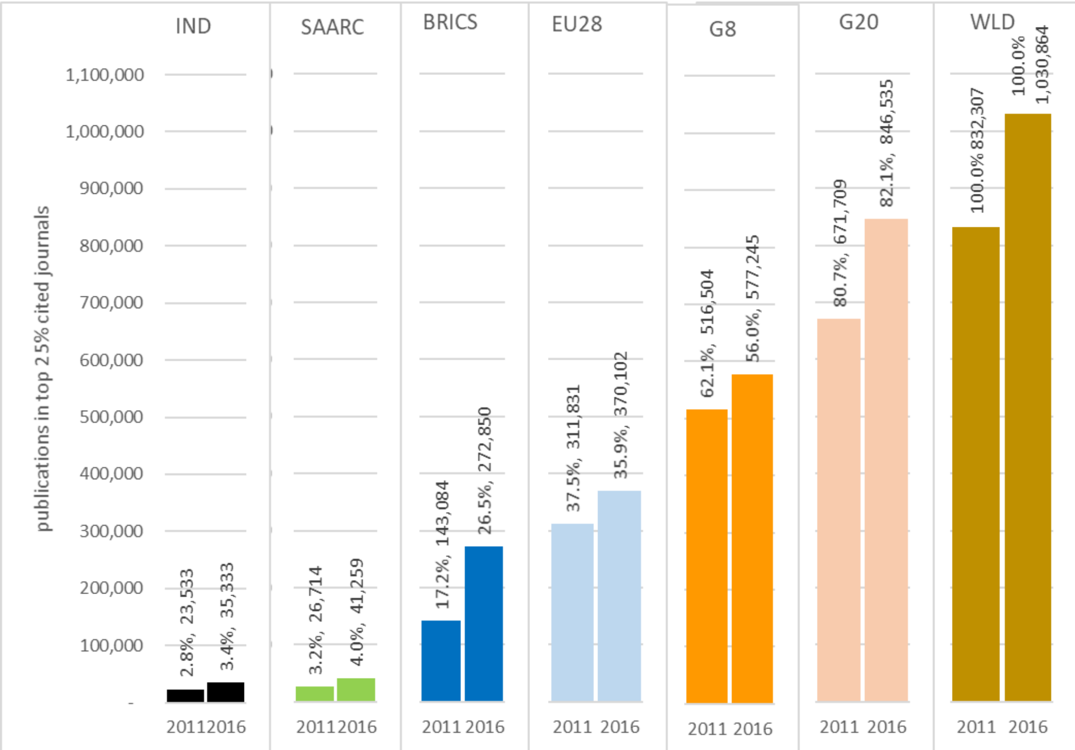

Figure 1.13 — *Share of global publications in top 25% cited journals for India and benchmarks, 2011-2016; Source: Scopus*

Chapter 2
Factors of success of India's research

In 2016, there were 426 Indian journals in Scopus. The most prolific research institution was Vellore Institute of Technology, with 2,737 publications, followed by the Indian Institute of Science Bangalore and the University of Delhi. 16.4% of India's scholarly output resulted from international collaboration. Publications with Brazil, Russia, Netherlands were highly cited. 1.3% of India's publications resulted from academic-corporate collaboration and India held 2.8% of patent citations to 2015 publications.

2.1 **Key Findings**

INDIAN JOURNALS IN SCOPUS IN 2016

426

representing 1.8% of all journals in Scopus

PUBLICATIONS IN 2016

2,737

by Vellore Institute of Technology

INDIA'S INTERNATIONAL COLLABORATION

16.4%

of India's output in 2016

INDIA'S NATIONAL COLLABORATION

31.9%

of India's output in 2016

MOST IMPACTFUL INTERNATIONAL COLLABORATORS IN 2016

Brazil, Russia, the Netherlands, Spain, Taiwan, South Africa, Switzerland, and Sweden

INDIA'S ACADEMIC-CORPORATE COLLABORATION

1.3%

of India's output in 2016

INDIA'S GLOBAL PATENT CITATION SHARE

2.8%

of globalpatent citations in 2015

2.2 Indian journals in Scopus

Figure 2.1 shows that the number and share of Indian journals in Scopus was stable from 2011 to 2016, with minor fluctuation from 432 titles in 2011 to 426 titles in 2016, corresponding to 1.8-1.9% of all journals in Scopus.

Figure 2.2 shows that the number of Indian journals was highest in Medicine (reflecting the global distribution of journals in Scopus). The highest share of Indian journals in Scopus was in Pharmacology, Toxicology, and Pharmaceutics, reflecting India's specialisation.

Research publications from researchers at Indian affiliations may occur in Indian or other journals.

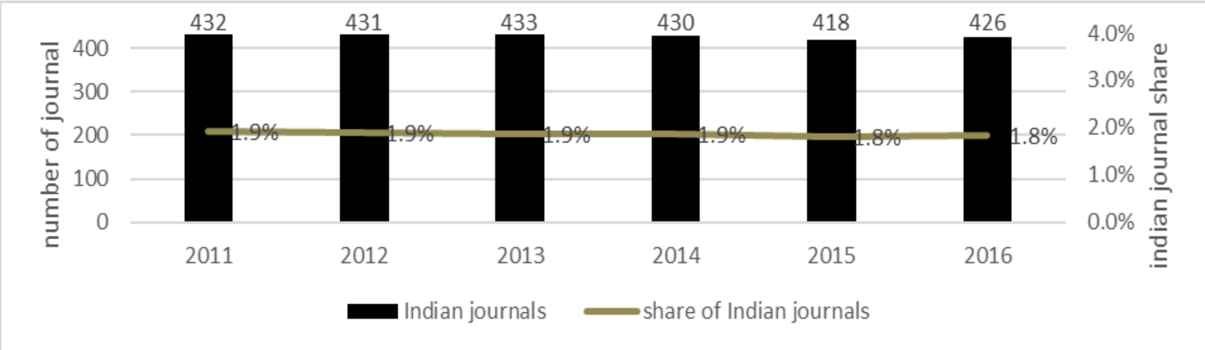

Figure 2.1 — *Number and share of Indian Journals in Scopus, 2011-2016; Source: Scopus*

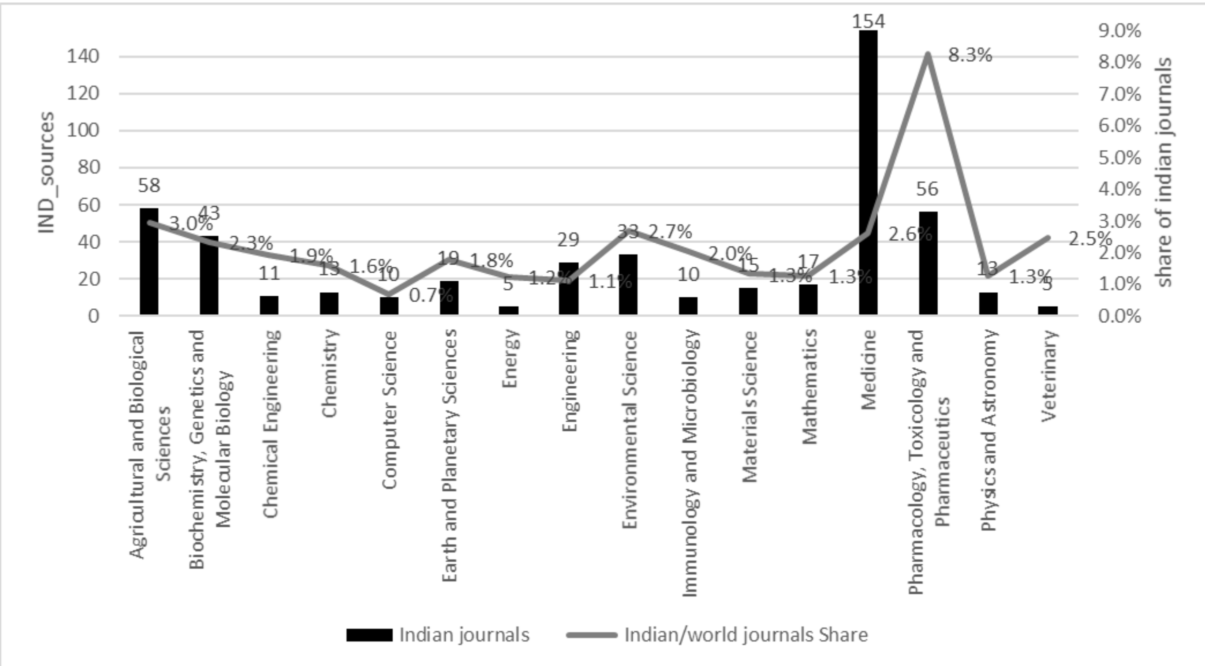

Figure 2.2 — *Subject breakdown of Indian journals in Scopus, 2016; Source: Scopus*

2.3 Prominent Indian institutions

The Indian academic landscape is complex, evolving, and growing. The most prolific institution in 2016 was the Vellore Institute of Technology, with 2,737 publications in 2016 (Figure 2.3). It also had by far the highest Compound Annual Growth Rate (CAGR) of publications with 36.3%, meaning that on average, its publication output grew by more than a third year on year. Of the top ten institutions by number of publications, five were Indian Institute of Technology locations.

Rank	Institution Name	Total 2011	Total 2016	CAGR
1	Vellore Institute of Technology	581	2,737	36.3%
2	Indian Institute of Science Bangalore	2,010	2,477	4.3%
3	University of Delhi	1,648	2,350	7.4%
4	Indian Institute of Technology, Bombay	1,459	2,200	8.6%
5	Indian Institute of Technology, Kharagpur	1,663	2,106	4.8%
6	Anna University	1,579	1,954	4.4%
7	Indian Institute of Technology, Madras	1,521	1,932	4.9%
8	Indian Institute of Technology, Delhi	1,648	2,350	7.4%
9	Banaras Hindu University	1,414	1,805	5.0%
10	Indian Institute of Technology Roorkee	1,115	1,748	9.4%

Figure 2.3 – *Top 10 prolific Indian academic institutions: rank and publication count in all subject areas, 2016. Source: Scopus.*

Scholarly citations can be considered a proxy for academic impact and are, to some extent, tied to output volume. Figure 2.4 shows the count of citations and citations per paper (CPP) for each of the top 10 institutions by 2016 number of citations. The Tata Institute of Fundamental Research had the highest total number of 2016 citations (8,279) as well as the highest average CPP at 8, higher than other top prolific India institutions by considerable difference. As a reference, the world average CPP was 11.71, and all top ten cited Indian institutions had a lower CPP.

Rank	Name	Citation count	Citations per publication (CPP)
1	Tata Institute of Fundamental Research	8,279	8.0
2	Indian Institute of Science Bangalore	7,540	3.0
3	University of Delhi	7,407	3.2
4	Indian Institute of Technology, Kharagpur	6,093	2.9
5	Banaras Hindu University	5,831	3.2
6	Indian Institute of Technology, Delhi	5,579	2.9
7	Indian Institute of Technology, Bombay	5,493	2.5
8	Indian Institute of Technology Roorkee	5,292	3.0
9	Vellore Institute of Technology	4,753	1.7
10	Indian Institute of Technology, Madras	4,713	2.4

Figure 2.4 - *Citations and citations per paper (CPP) overall of top 10 prolific Indian academic institutions, 2016. Source: Scopus.*

2.4 Collaboration types

Research collaborations increasingly extend beyond the walls of an institution or the boundaries of a country and can be evaluated through the proxy of co-authorship on scholarly publications. The various comparators in this study have different proportions of each collaboration type (Figure 2.5). India's, SAARC's, and BRICS's distributions were similar, with nearly half of their output the result of institutional collaboration, about a third the result of national collaboration, about 15-20% the result of international collaboration, and less than 10% written by single authors. Most comparators and especially established research nations tend to present a different distribution, with a rising majority of internationally collaborated output, followed by stable or declining proportions of institutionally, nationally, and single-authored publications. Notable exceptions include G8, for which "international collaborations" refer to collaborations with non-G8 countries, and national collaborations may be national or international collaborations within one or several G8 countries. A similar trend is observed for G20 and EU28 countries. The USA shows similar proportions of international, national, and institutional collaborations – due to its scale, international collaborations may be partly replaced by inter-state collaboration.

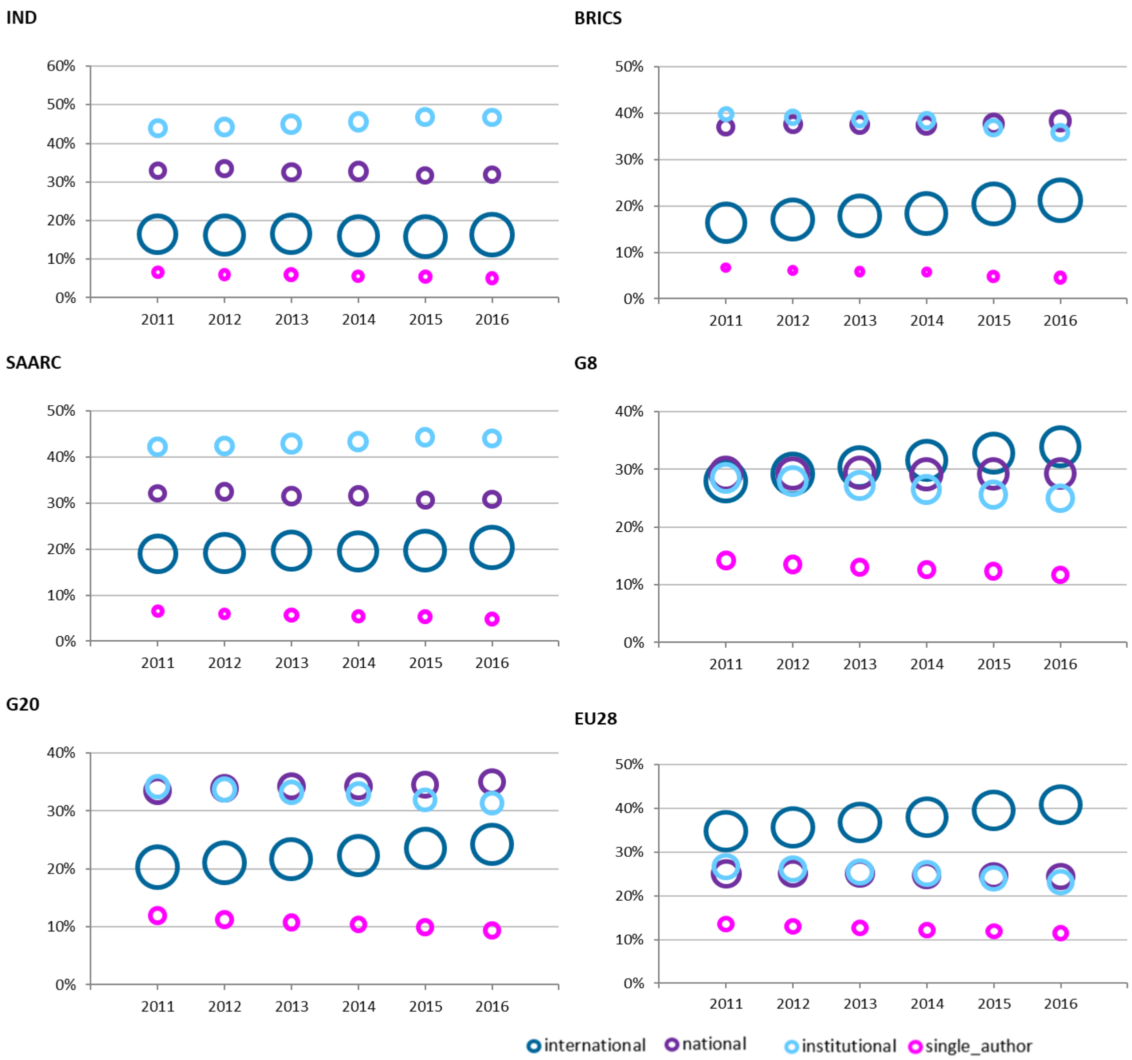

Figure 2.5 — *Proportion of collaboration of India and benchmarks with size of the circles representing FWCI, 2011-2016; Source: Scopus*

2.3 Collaboration partners

India's most prolific international collaborations tend to be advantageous to both India and the partner countries in terms of citation impact, as shown in Figure 2.6. Collaborations with the USA were the most prolific, but brought moderate citation impact benefit to both partners.

India's most impactful prolific collaborations were with Brazil; on average these publications were cited about four times more than India's and three and a half times more than Brazil's average for internationally co-authored publications.

Collaborations with Russia were also highly impactful for both collaborators, since they tended to be cited nearly 3.5 times the rate of both India's and Russia's internationally co-authored publications.

Collaborations with Netherlands, Spain, and Taiwan all tended to be cited at least three times more than India's internationally co-authored publications and two and half times more than their respective average internationally co-authored publications.

Also, Switzerland, China, Italy, Canada, Australia, Japan, and Malaysia all tended to have publications cited about at least two times more than India's internationally co-authored publications.

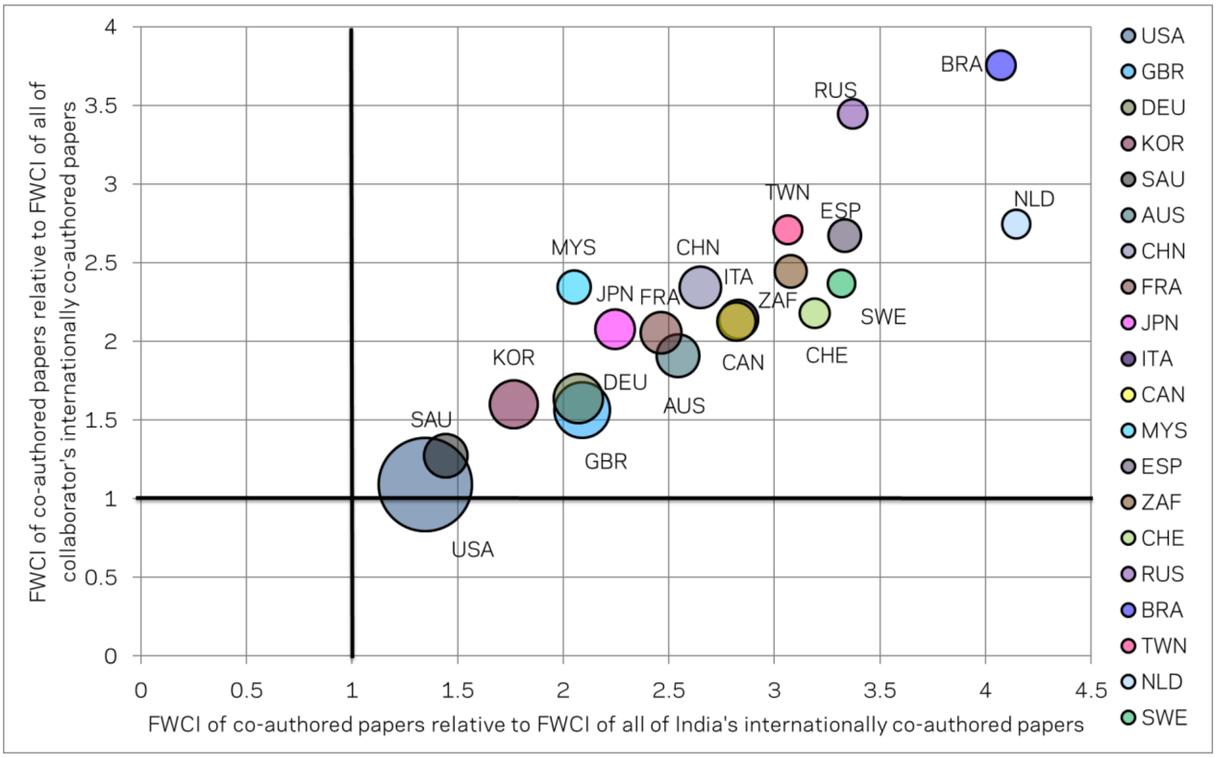

Figure 2.6— *India's collaboration matrix, 2016; source: Scopus. Node size is proportional to the number of co-authored publications. Thick black line represents average values.*

2.4 Academic-Corporate collaboration

Collaboration between academic and corporate sectors is another indicator of knowledge transfer and can be measured via the proxy of publications co-authored across sectors.

Figure 2.7 shows that India's proportion of academic corporate collaboration slightly decreased in recent years from 1.7% in 2011 to 1.3% in 2016. Its academic-corporate collaboration FWCI peaked in 2012 but was otherwise stable in recent years, cited twice as much as the overall global average.

Per Figure 2.8, SAARC was heavily influenced by India which represented the vast majority of its output, and therefore exhibited similar trends.

India had relatively less academic-corporate collaboration than all other benchmarks (BRICS, G8, G20, Top 20, EU28, world, in Figure 2.8 and Figure 2.9), but it yielded greater scholarly impact than BRICS or the world.

For most benchmarks, there was stability in proportion of academic-corporate publications and their scholarly impact, with the exception of slight declines for G20 (output from 3.4% in 2011 to 3.0% in 2016 and FWCI from 1.88 in 2011 to 1.69 in 2016), for EU28 (output from 3.7% in 2011 to 3.6% in 2016 and FWCI from 2.16 in 2011 to 2.03 in 2016). G8 also experienced a small decline in academic-corporate collaboration share from 4.4% to 4.0%. and impact from 2.09 to 1.92.

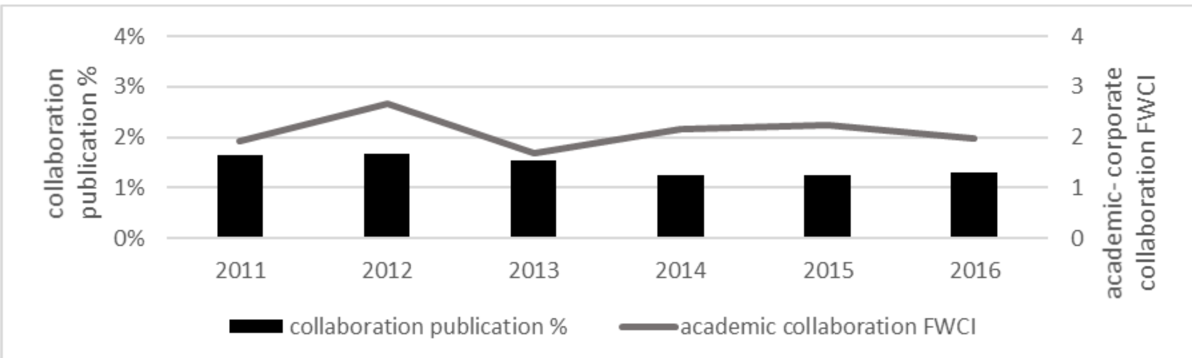

Figure 2.7 — *academic-corporate publication shares and their FWCI for India, 2011-2016; source: Scopus*

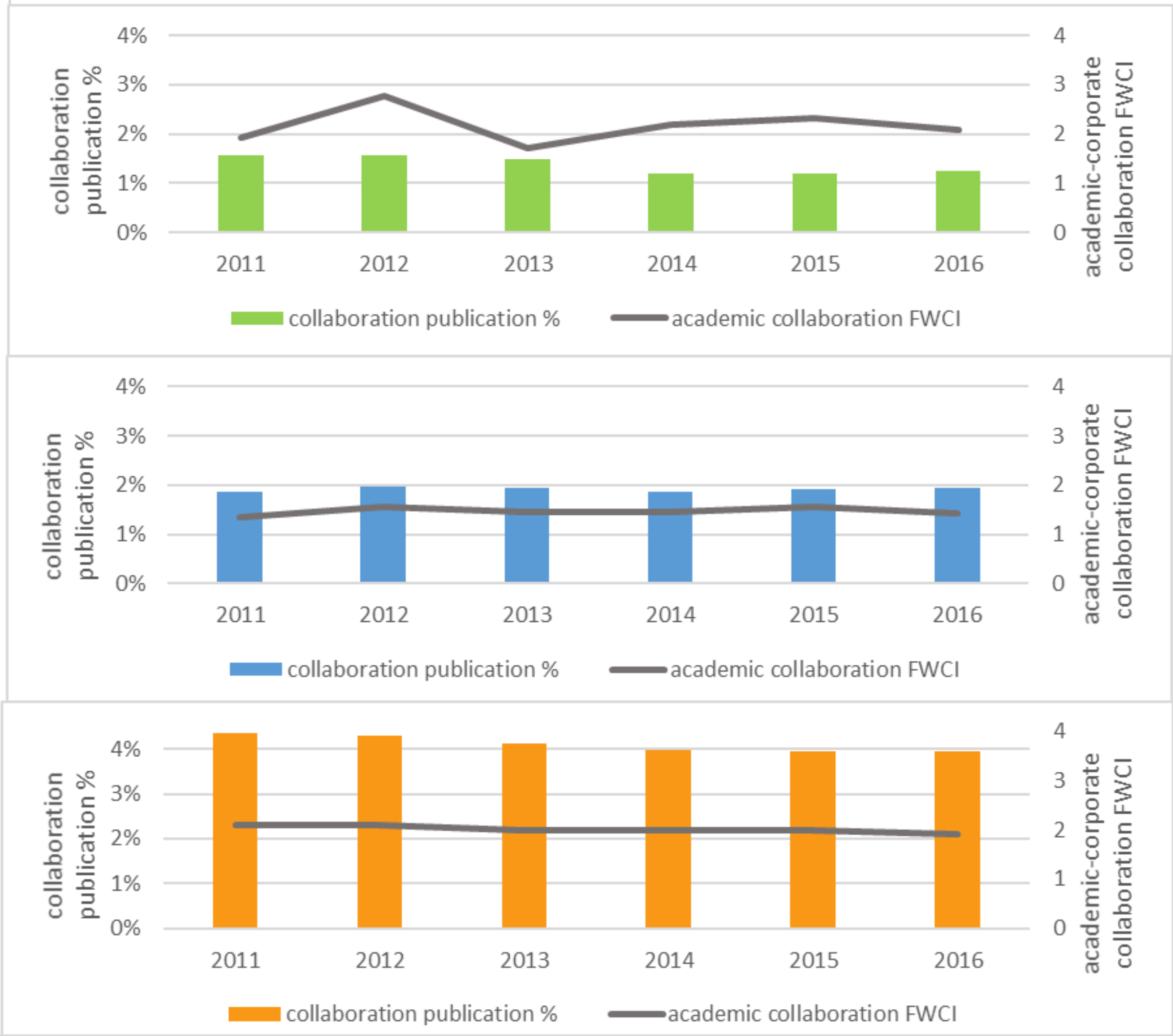

Figure 2.8 — *academic-corporate publication shares and their FWCI for SAARC (upper pane), BRICS (middle pane) and G8 (lower pane) benchmarks, 2011-2016; source: Scopus*

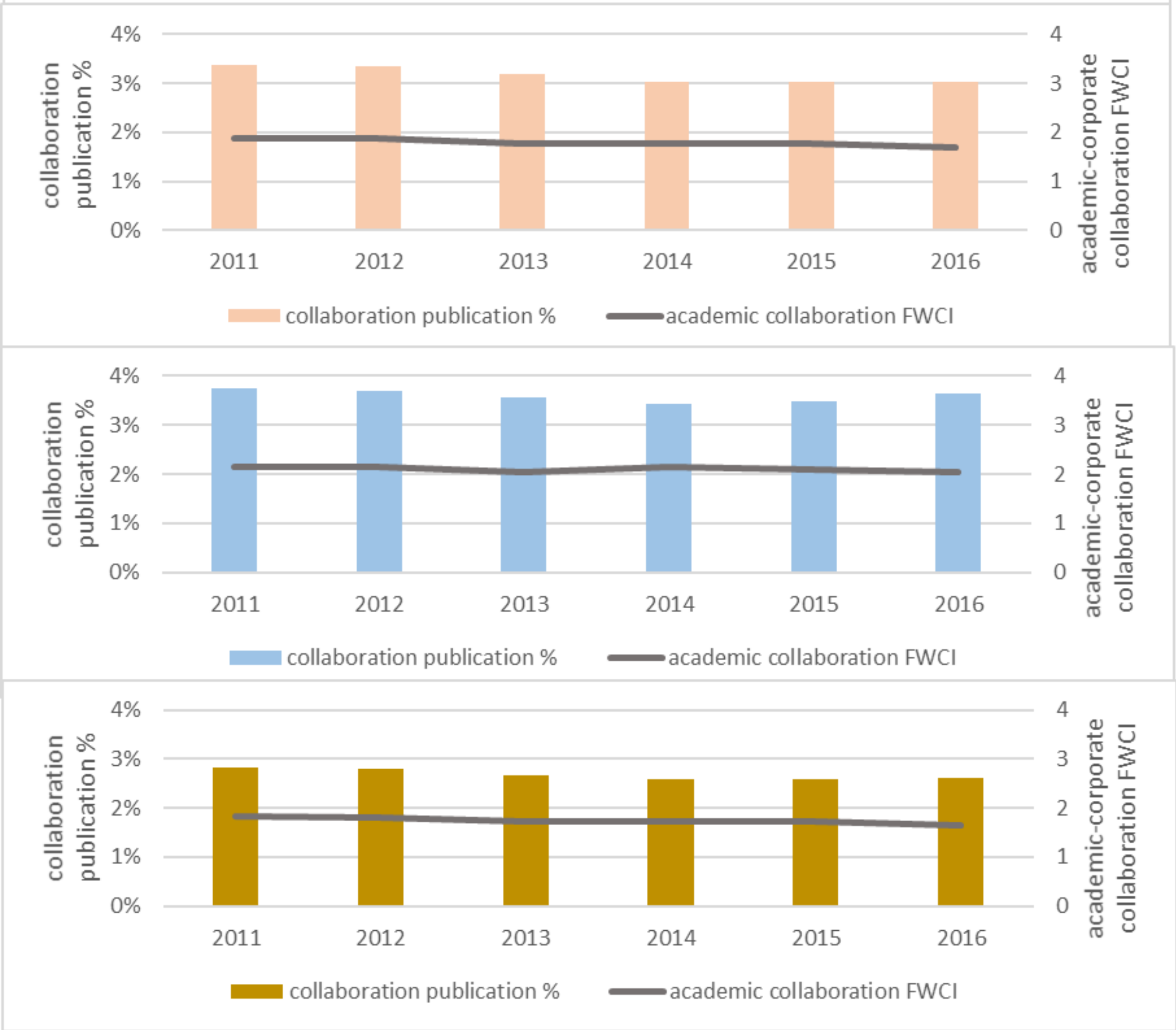

Figure 2.9 — *academic-corporate publication shares and their FWCI for G20 (upper pane), EU28 (middle pane) and world (lower pane) benchmarks, 2011-2016; source: Scopus*

2.5 Patent Citations

The referencing of scholarly literature in patents is an indication of the transfer of knowledge between the academic and corporate sectors and can be measured via patent citations. A patent citation occurs when a research publication is referenced in a patent.

Typically, patent citations take a long time to accrue, because inventors must first read relevant published research, decide to cite it in their patent drafts, and then the patent needs to be submitted and published, which can take several months. For this reason, patent citations typically show declining trends over time in absolute numbers, and so we use patent citation shares in this analysis.

In 2011, India's patent citation share was 2.4% whereas in 2015, it was 2.8%. India ranked 1st in SAARC countries, 2nd in BRICS where China ranks first, and 10th among G20 and top 20 countries. For BRICS and G20, patent citation shares increased between 2011 to 2015 while shares for EU28 and G20 decreased slightly from 2011 to 2015 (Figure 2.10).

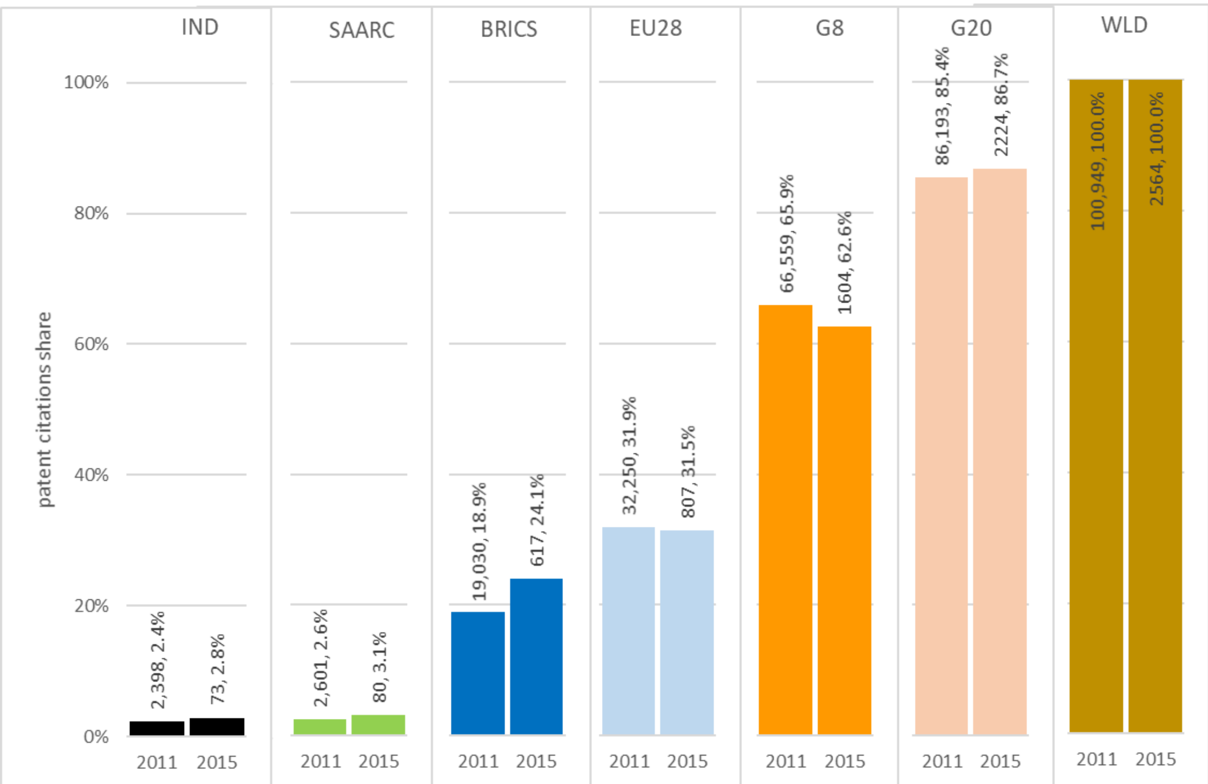

Figure 2.10 —*global patent citation shares of India and benchmarks, 2011 and 2015; source: Scopus*

Chapter 3
Mapping the Indian research landscape

Compared to the subject distribution of the world, India was particularly prolific and cited in Engineering and Computer Science, and most impactful in Chemistry. In knowledge transfer India showed a higher emphasis than the world in Computer Science, Materials Science, Chemistry, and Pharmacology, Toxicology & Pharmaceutics. India's top 10 cited publications for the 2014-2016 period belonged to the fields of Medicine or Physics & Astronomy.

3.1 Key Findings

INDIA'S RESEARCH FOCUS

Engineering and Computer Science

Higher relative emphasis compared to the world in 2016

INDIA'S MOST IMPACTFUL FIELD

Chemistry

Cited 1% less than the world average in 2016

SUBJECT AREAS OF TOP 10 MOST CITED 2014-2016 PUBLICATIONS

Medicine, Physics & Astronomy

INDIA'S KNOWLEDGE TRANSFER SUBJECT FOCUS

Computer Science, Materials Science, Chemistry, Pharmacology, Toxicology & Pharmaceutics

Higher relative emphasis compared to the world

3.2 India's research focus

As illustrated in Figure 3.1, while there were some similarities between comparators in terms of their outputs' subject breakdowns, there were also differences.

For instance, looking at the 16 selected subject areas, it is evident that Medicine, Engineering, Physics & Astronomy, Computer Science, and Biochemistry Genetics & Molecular Biology, tended to be relatively prolific areas in general and for India.

However, relative to the world, India published relatively more in Engineering, Biochemistry Genetics & Molecular Biology, and Pharmacology, Toxicology, & Pharmaceutics, and relatively less in Medicine.

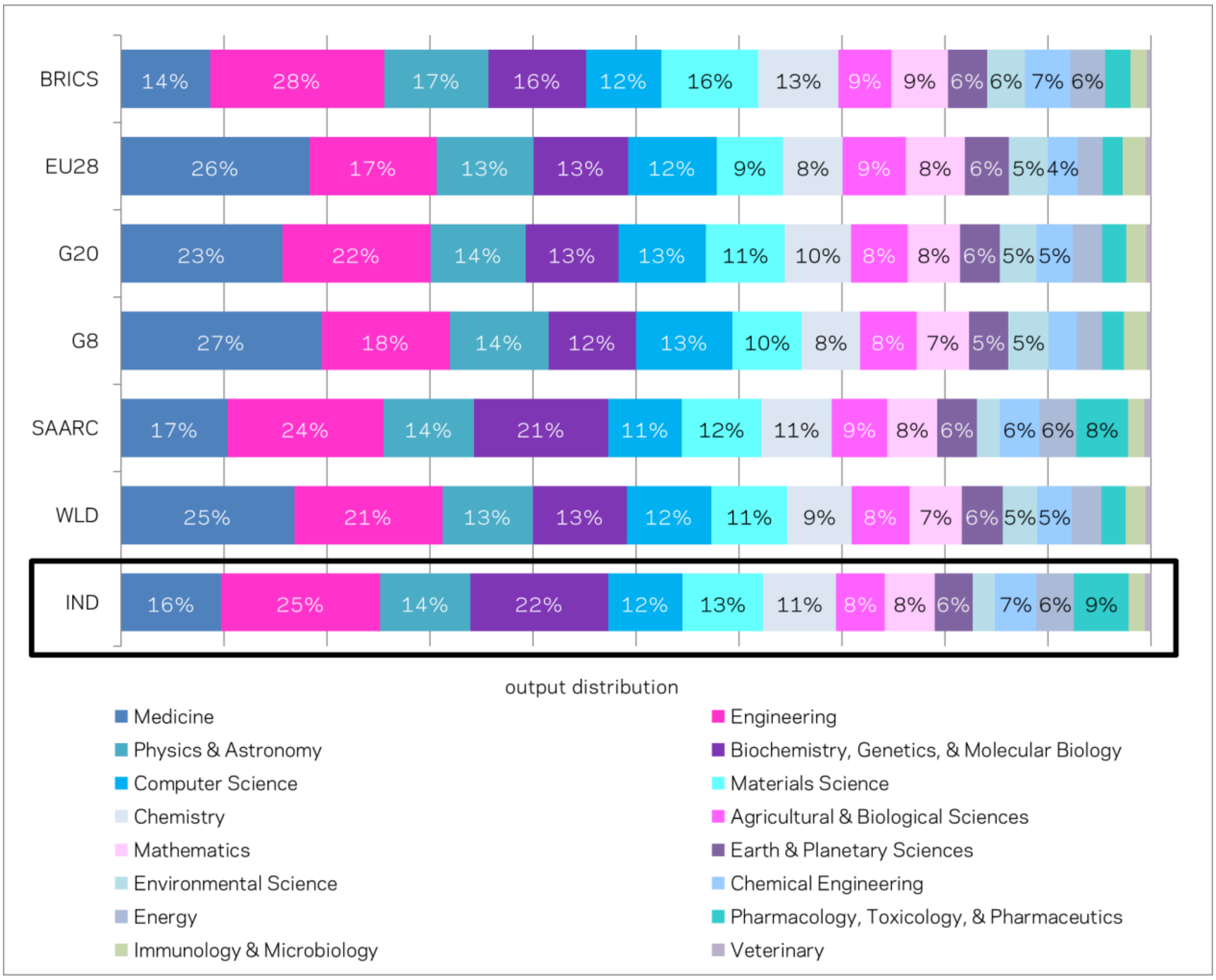

Figure 3.1 — *Subject area breakdown of scholarly output of India and benchmarks 2016; Source: Scopus*

3.3 India's citations per field

Across benchmarks and India, citation distribution by subject area tended to broadly mirror output distribution by subject area (see Figure 3.2). However, one trend that could be generally observed across benchmarks is that relative to output distribution, citation distribution appeared to be skewed towards the physical sciences and away from the life and medical sciences. Accordingly, India's citation distribution by subject area seems roughly similar to its output distribution by subject area. However, it had relatively larger proportions of citations in the physical sciences. Against the citation distribution of comparators in Figure 3.2, India tended to show even larger proportions of citations in Chemistry than it did in output. India's scholarly citation distribution differed from that of the world with less volume in the Health & Life Sciences (notably, Medicine and Biochemistry, Genetics, & Molecular Biology), and more volume in Physical Sciences (Chemistry, Engineering, Physics and Material Sciences).

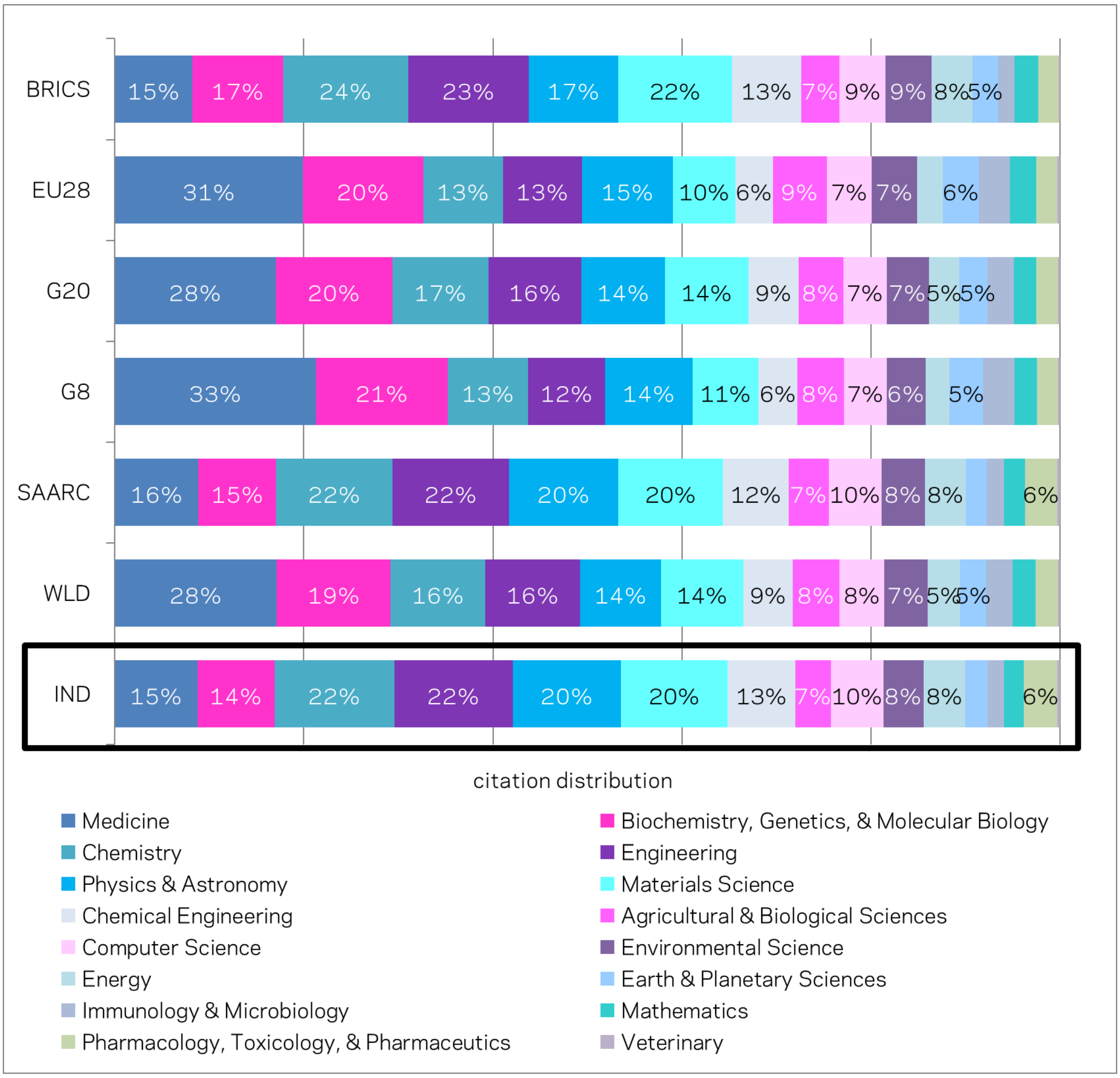

Figure 3.2 — *Subject area breakdown scholarly citations of India and benchmarks, 2016; source: Scopus*

3.4 India’s citation impact per field

As per Figure 3.3, when citations are normalised by number of scholarly publications, their age, their type, and their field, India’s citation average was lower than the world’s and nearly all benchmarks in all subject areas.

In all fields, India’s FWCI was close to SAARC’s, which it influenced heavily.

In Engineering, Physics & Astronomy, Energy and Computer Science, India’s FWCI was slightly higher than BRICS’s.

India’s output had the highest citation impact in Chemical Engineering, Chemistry, Materials Science, and Physics & Astronomy.

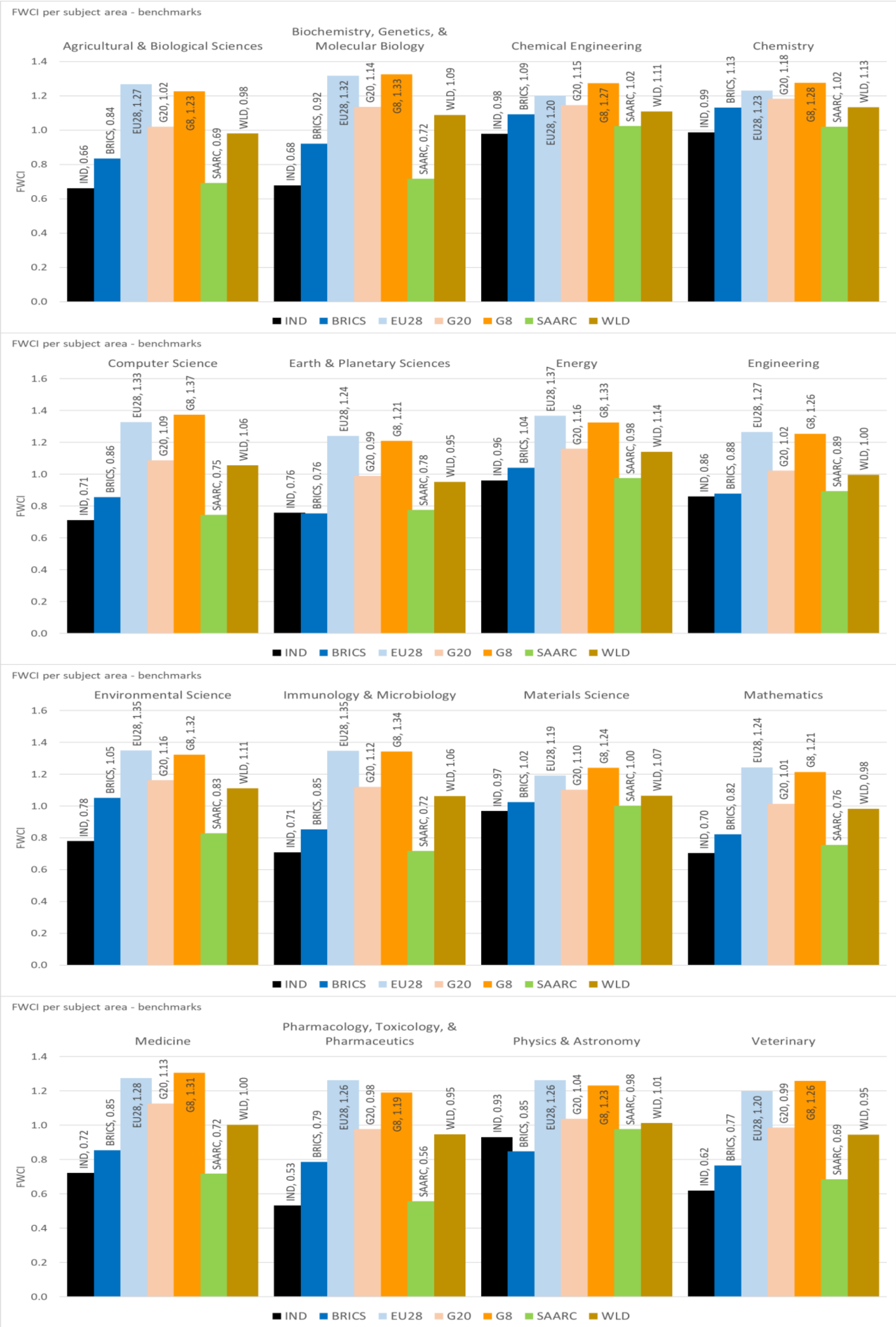

Figure 3.3 — *Field-Weighted Citation Impact subject area breakdown for India and benchmarks, 2016; Source: Scopus*

3.5 India's excellence per field

As per Figure 3.4, India had the highest share of top 1% cited publication in Engineering which was 5 percentage points higher than the world. This was followed by Physics and Astronomy which was 4 percentage points higher than the world.

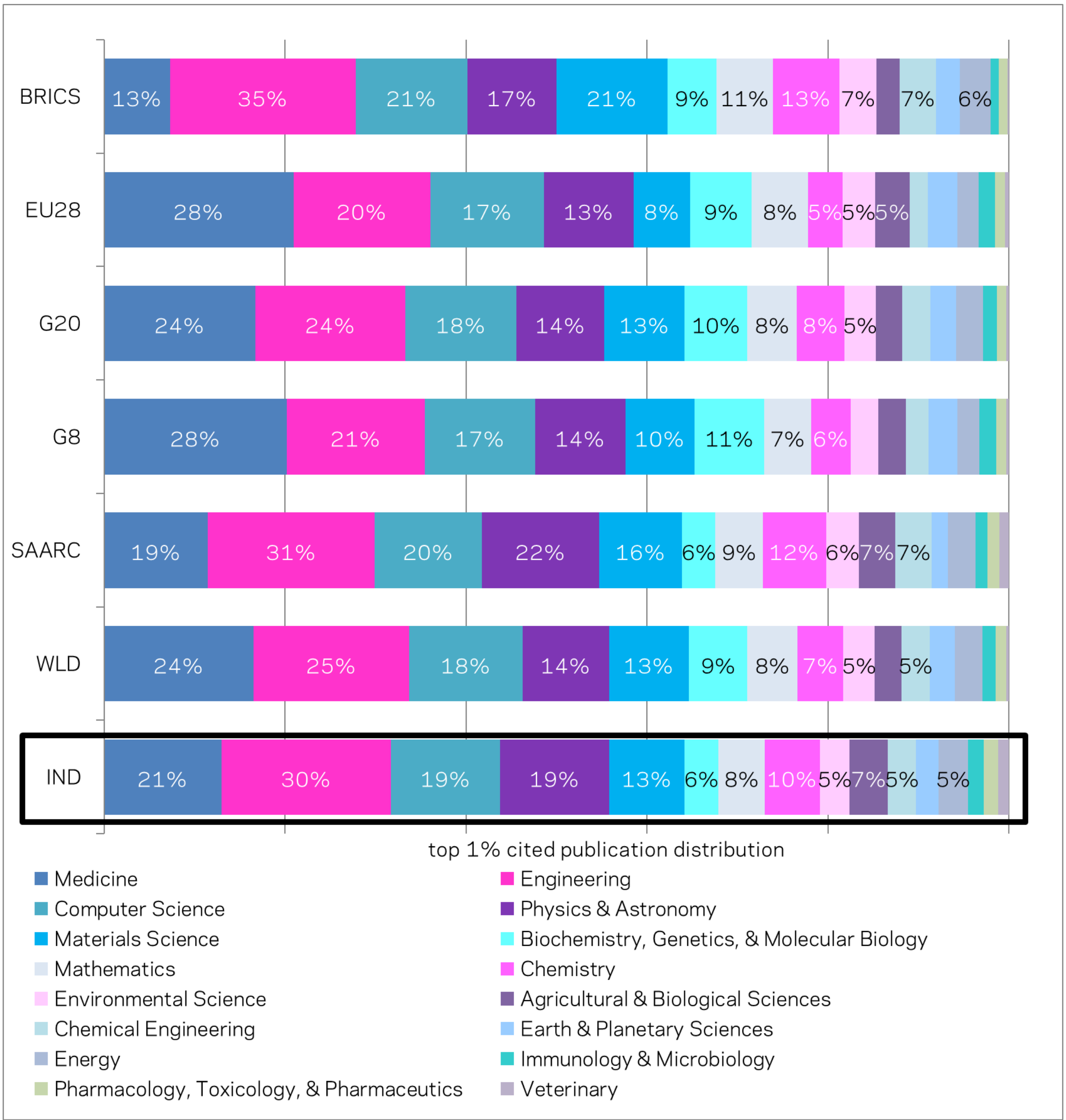

Figure 3.4 — *Subject area breakdown of publications in top 1% cited publication for India and benchmarks, 2016; Source: Scopus*

Per Figure 3.5 and Figure 3.6 in the top 5% and 10% cited publications, India had a similar share as SAARC in Engineering, which was 10 percentage points higher than the world share; India was similarly more specialised in Computer Science compared to the world. G8 and EU28 also specialised in Engineering, with 3-4 percentage points more than the world for share of top 5% cited publications. In top 5% cited publications, India had 25% share in Computer Science which was higher than other G20 countries.

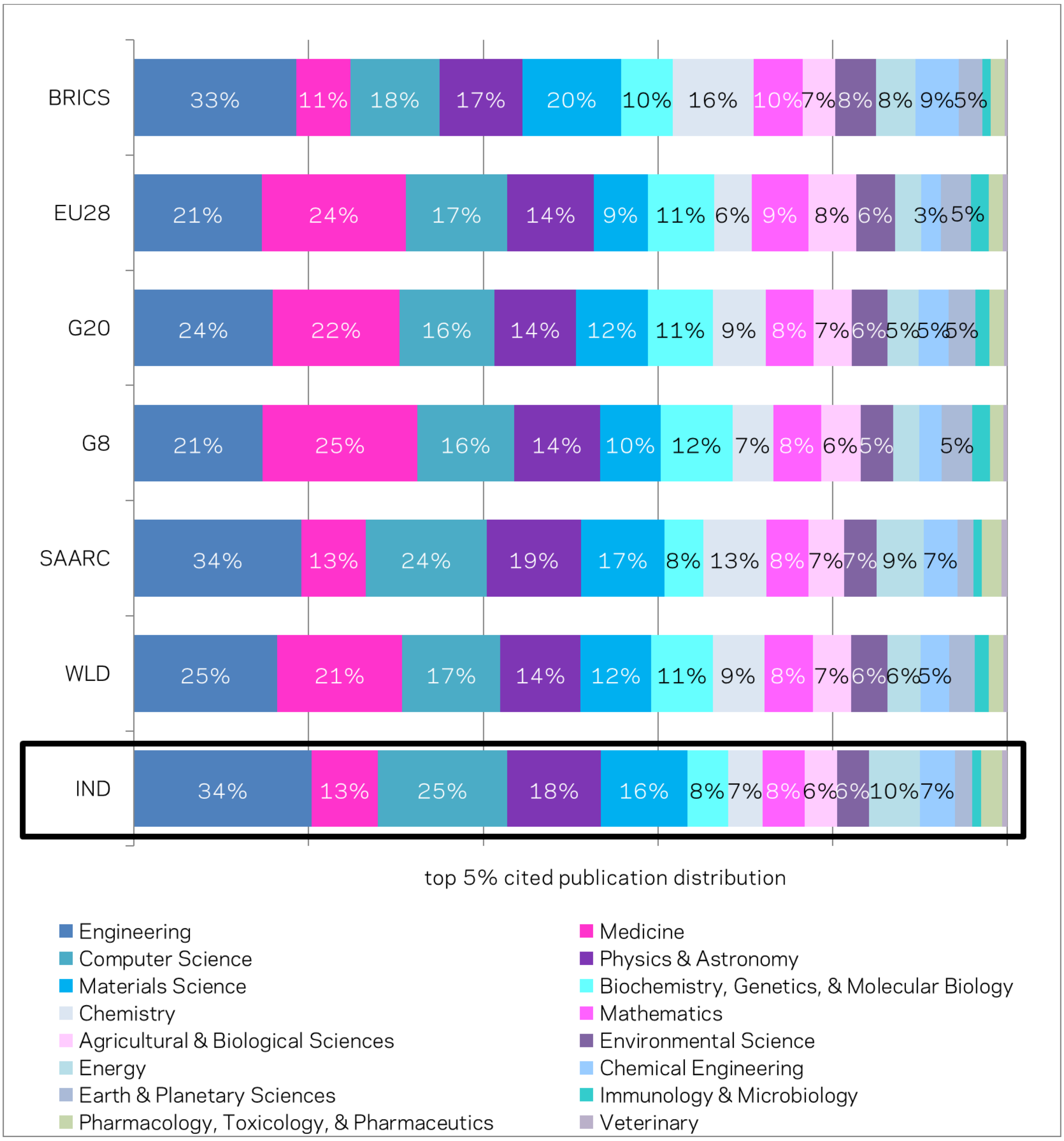

Figure 3.5 — *Subject area breakdown of publications in top 5% cited publication for India and benchmarks, 2016; Source: Scopus*

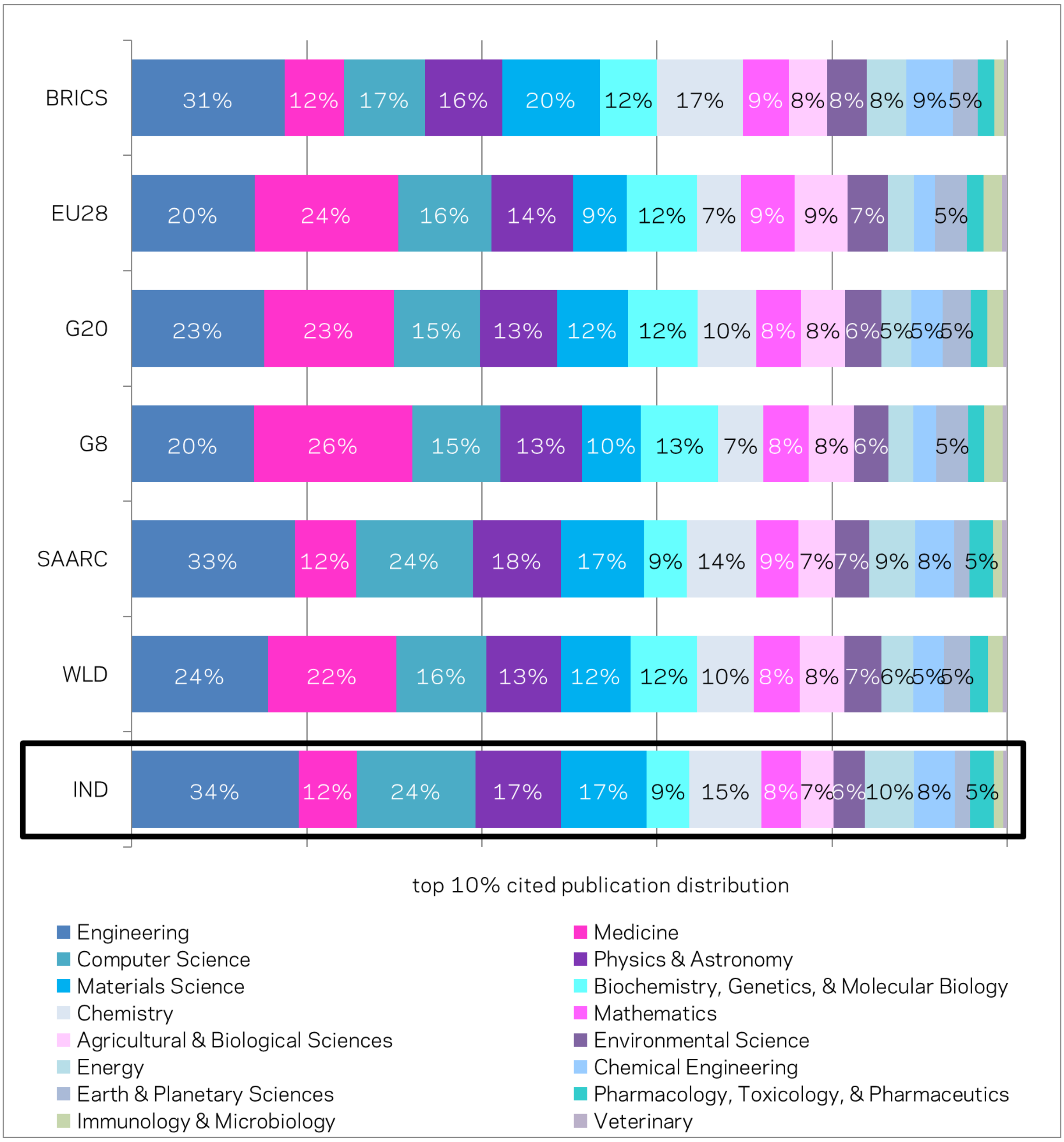

Figure 3.6 — *Subject area breakdown of publications in top 10% cited publication for India and benchmarks, 2016; Source: Scopus*

Per Figure 3.7, India's share of top 25% cited publication in Engineering, Computer Science, Physics and Astronomy and Material Science were higher than these subject areas' share for the world.

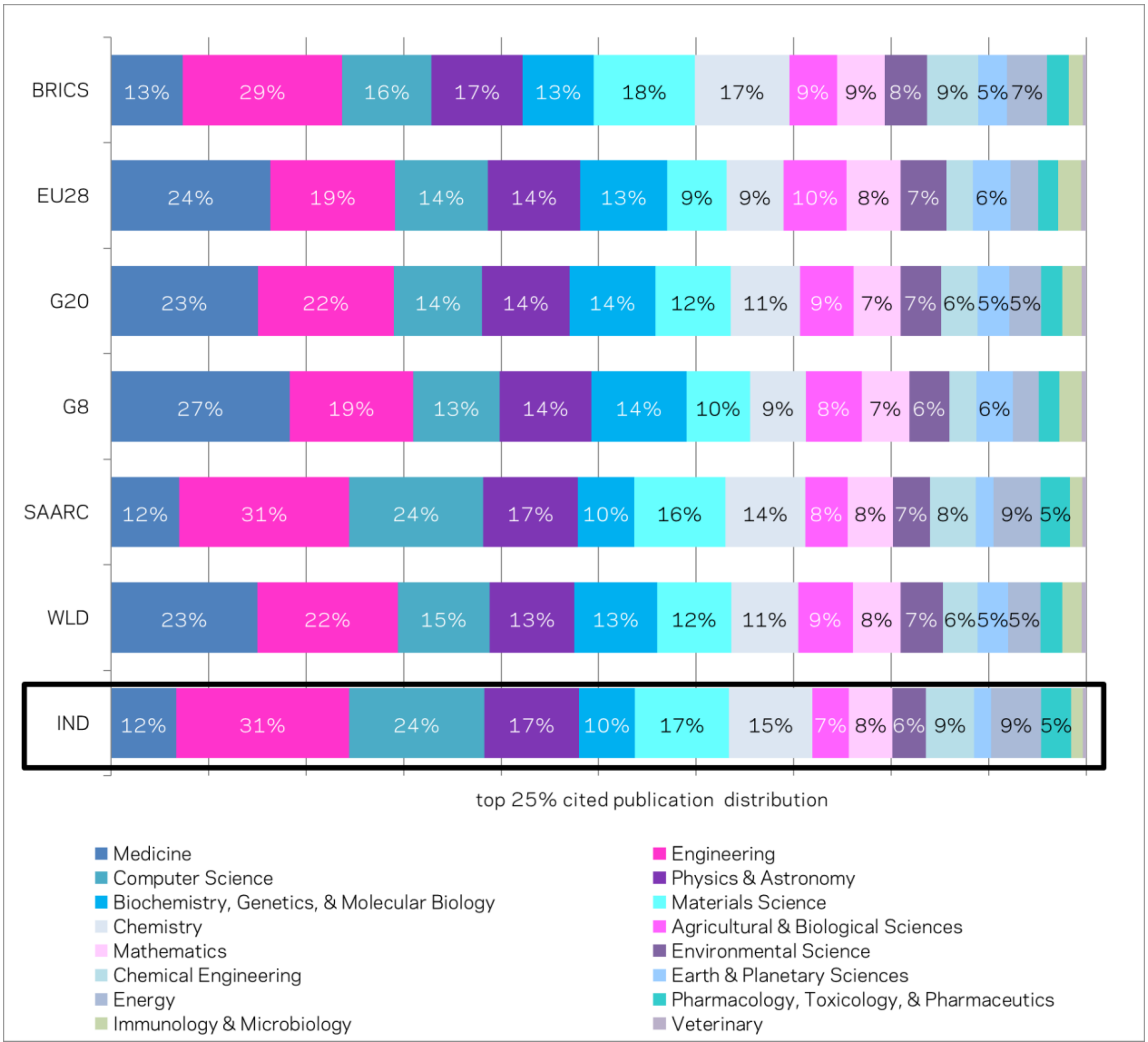

Figure 3.7 — *Subject area breakdown of publications in top 25% cited publication for India and benchmarks, 2016; Source: Scopus*

3.6 India's collaboration per field

As per Figure 3.8, India's subject wise output distributions had the highest proportion of institutional collaboration in Computer Science, Energy, and Engineering. Highest proportions of international collaboration were found in Earth and Planetary Sciences, but they were most impactful in Veterinary.

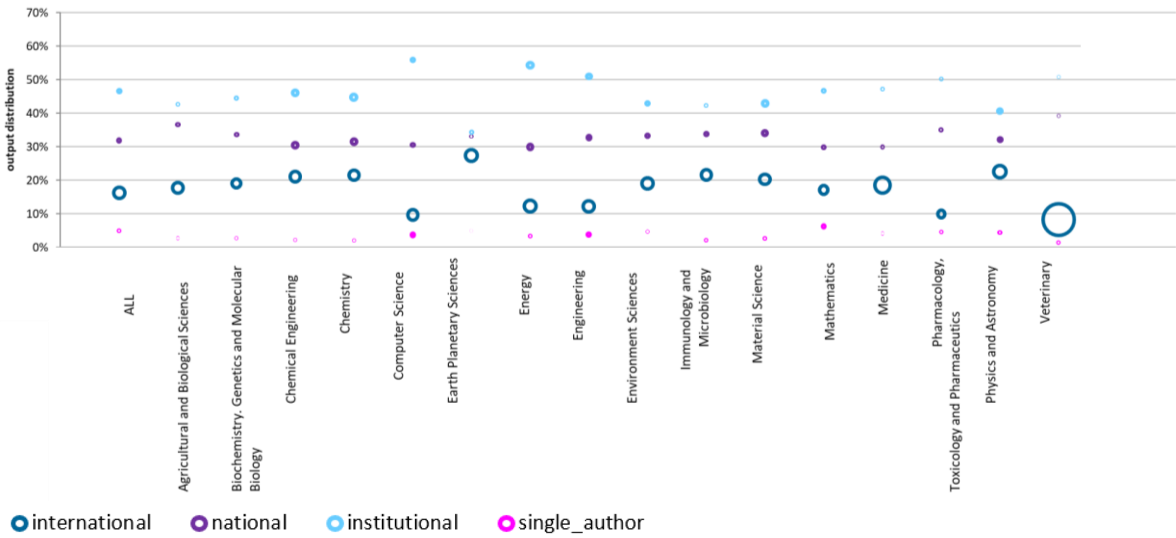

Figure 3.8 — *Collaboration output distribution per subject area for India and benchmark with size of the circles representing FWCI, 2016; Source: Scopus*

As per Figure 3.9, for India, Computer Science and Earth & Planetary Sciences were the fields with the largest proportion of academic-corporate collaboration, but the most impactful academic-corporate research for India was in Medicine. Earth & Planetary Sciences academic-corporate collaborations have high citation impact of more than twice the world average, followed by Environmental Science and Immunology & Microbiology.

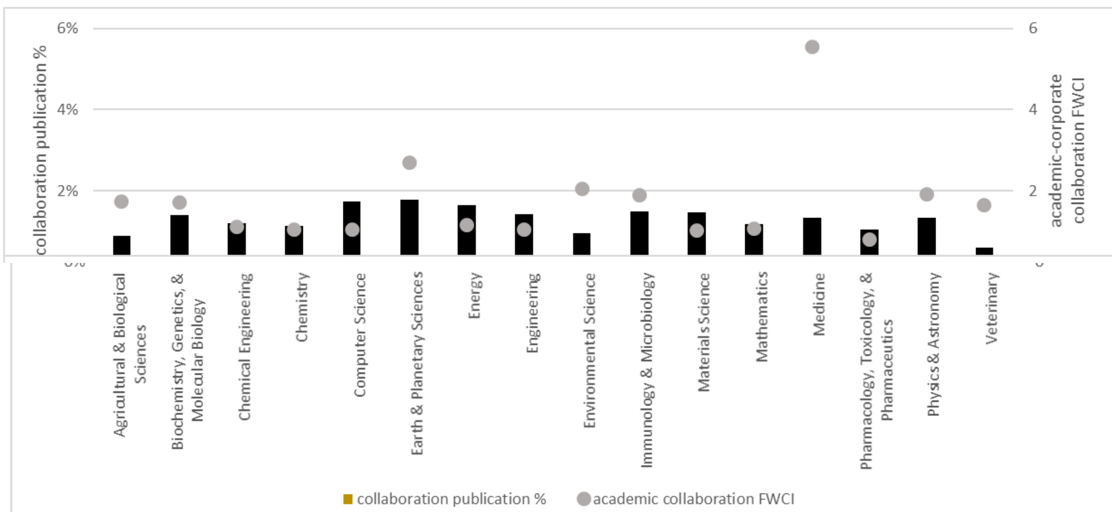

Figure 3.9 — *Subject breakdown of academic-corporate collaborations for India and benchmark 2016; Source: Scopus*

3.7 **India's patent citations per field**

The referencing of scholarly literature in patents is an indication of the transfer of knowledge between the academic and corporate sectors. Typically, patent citations take a long time to accrue, because inventors must first read relevant published research, decide to cite it in their patent drafts, and then the patent needs to be submitted and published, which can take several months. For this reason, patent citations typically show low numbers in recent years, and so we focus on data pertaining to the 2011 publication year.

Figure 3.10 presents breakdowns per subject area for India's patent citations, and patent-cited publications with and without overlap between patent offices. This reveals that the concentration of India's patent citations and patent-cited publications lies in Chemistry as well as Biochemistry, Genetics, & Molecular Biology, Pharmacology, Toxicology, & Pharmaceutics, Materials Science, Engineering, Medicine, Chemical Engineering, and Physics & Astronomy. Interestingly, this aligns to most of India's prolific subject areas (Medicine, Engineering, Physics & Astronomy, and Biochemistry Genetics & Molecular Biology), but omits Computer Science, indicating perhaps a gap in in the applicability of India's research to innovation. It also aligned to India's specialisation areas (Engineering, Biochemistry Genetics & Molecular Biology, and Pharmacology, Toxicology, & Pharmaceutics). Medicine appears to have relatively fewer patent-cited publications without overlap than overall, in line with India's lesser specialisation in that field.

subject area	patent citations	patents cited publications	patents cited publications (no overlap)
All	2,560	1,843	209
Chemistry	778	586	76
Biochemistry, Genetics, and Molecular Biology	724	489	56
Pharmacology, Toxicology, and Pharmaceutics	573	409	53
Materials Science	506	374	43
Engineering	415	305	33
Medicine	398	252	18
Chemical Engineering	367	272	41
Physics and Astronomy	298	238	31
Agricultural and Biological Sciences	235	168	12
Computer Science	164	116	13
Environmental Science	154	102	8
Immunology and Microbiology	152	105	10
Energy	75	64	6
Mathematics	66	45	10
Veterinary	16	12	2
Earth and Planetary Sciences	13	13	3

Figure 3.10 — *Subject area breakdown of patent citations of India, 2011; Source: Scopus*

APPENDICES

Appendix A
Lists of countries and benchmarks

	Country
AFG	Afghanistan
ARG	Argentina
AUS	Australia
AUT	Austria
BEL	Belgium
BGD	Bangladesh
BGR	Bulgaria
BRA	Brazil
BRICS	**BRICS countries (Brazil, Russia, India, China, South Africa)**
BTN	Bhutan
CAN	Canada
CHE	Switzerland
CHN	China
CYP	Cyprus
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
EU28	**European Union (28 member states)**
FIN	Finland
FRA	France
G20	**G20 countries (20 member states)**
G8	**G8 countries (France, Germany, Italy, United Kingdom, Japan, United States, Canada, Russia)**
GBR	United Kingdom
GRC	Greece
HRV	Croatia
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland
IRN	Iran
ITA	Italy
JPN	Japan
KOR	South Korea
LKA	Sri Lanka
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MDV	Maldives
MEX	Mexico
MLT	Malta

NLD	Netherlands
NPL	Nepal
PAK	Pakistan
POL	Poland
PRT	Portugal
ROU	Romania
RUS	Russia
SAARC	**SAARC countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka)**
SAU	Saudi Arabia
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
Top 20	**Top 20 countries publishing the most publications over the analytical period**
TUR	Turkey
TWN	Taiwan
USA	United States
ZAF	South Africa

Appendix B
Subject Classification

Journals in Scopus are classified under four broad subject clusters (life sciences, physical sciences, health sciences, and social sciences and humanities), which are further divided into 27 major subject areas, of which DST selected 16 (highlighted in bold in the table below) for further focus of this analysis. Journals may belong to more than one subject area.

Scopus Subject Classification	Broad Cluster	ASJC Code
General (multidisciplinary journals like Nature and Science)	All	1000
Agricultural and Biological Sciences	**Life Sciences**	**1100**
Arts and Humanities	Social Sciences	1200
Biochemistry, Genetics and Molecular Biology	**Life Sciences**	**1300**
Business, Management and Accounting	Social Sciences	1400
Chemical Engineering	**Physical Sciences**	**1500**
Chemistry	**Physical Sciences**	**1600**
Computer Science	**Physical Sciences**	**1700**
Decision Sciences	Social Sciences	1800
Earth and Planetary Sciences	**Physical Sciences**	**1900**
Economics, Econometrics and Finance	Social Sciences	2000
Energy	**Physical Sciences**	**2100**
Engineering	**Physical Sciences**	**2200**
Environmental Science	**Physical Sciences**	**2300**
Immunology and Microbiology	**Life Sciences**	**2400**
Materials Science	**Physical Sciences**	**2500**
Mathematics	**Physical Sciences**	**2600**
Medicine	**Health Sciences**	**2700**
Neuroscience	Life Sciences	2800
Nursing	Health Sciences	2900
Pharmacology, Toxicology and Pharmaceutics	**Life Sciences**	**3000**
Physics and Astronomy	**Physical Sciences**	**3100**
Psychology	Social Sciences	3200
Social Sciences	Social Sciences	3300
Veterinary	**Health Sciences**	**3400**
Dentistry	Health Sciences	3500
Health Professions	Health Sciences	3600

Appendix C
Methodology & Data Sources

C-1 Methodology and Rationale

Our methodology is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. The *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems* (Moed, Glänzel and Schmoch, 2004)[1] gives a good overview of this field and is based on the pioneering work of Derek de Solla Price (1978),[2] Eugene Garfield (1979)[3] and Francis Narin (1976)[4] in the USA, and Christopher Freeman, Ben Martin and John Irvine in the UK (1981, 1987)[5], and in several European institutions including the Centre for Science and Technology Studies at Leiden University, the Netherlands, and the Library of the Academy of Sciences in Budapest, Hungary. The analyses of bibliometric data in this report are based upon recognised advanced indicators (e.g., the concept of relative citation impact rates). Our base assumption is that such indicators are useful and valid, though imperfect and partial measures, in the sense that their numerical values are determined by research performance and related concepts, but also by other, influencing factors that may cause systematic biases. In the past decade, the field of indicators research has developed best practices which state how indicator results should be interpreted and which influencing factors should be taken into account. Our methodology builds on these practices.

Article Types

For all bibliometric analysis, only the following document types are considered: research articles, reviews, conference papers, focussing the corpus on scholarly communications.

Counting

All analyses make use of whole counting rather than fractional counting. For example, if a paper has been co-authored by one author from India and one author from Singapore, then that paper counts towards both the publication count of India, as well as the publication count of Singapore. Total counts for each country are the count of unique publications.

Measuring collaboration

Collaboration is defined as the set of publications with at least two co-authors (opposed to single-authored publications). There are three mutually exclusive collaboration types:

- International collaboration occurs if an article has at least two different countries listed in the authorship byline. If an article has only one author affiliated with institutions in two different countries, this article is not counted as an internationally collaborated article.
- National collaboration occurs if an article has at least two different institutions listed in the authorship byline, all of which are from the same country.
- Institutional collaboration occurs if an article has at least two authors listed in the authorship byline, all of which are affiliated with the same institution.

Cross-sector collaboration

Cross-sector collaboration is defined as the set of publications whose authors have affiliations in different sectors (e.g., academic, corporate, government, medical). The cross-sector collaboration analysed in this report is the academic-corporate collaboration type.

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C-2 Data Sources

LexisNexis

LexisNexis is a leader in comprehensive and authoritative legal, news and business information and tailored applications. LexisNexis® is a member of Reed Elsevier Group plc. Patents are obtained via a partnership with LexisNexis and include those from the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO), the Japanese Patent Office (JPO), the Patent Cooperation Treaty (PCT) of the world Intellectual Property Organization (WIPO) and the UK Intellectual Property Office (UKIPO).

Scopus

Scopus is Elsevier's abstract and citation database of peer-reviewed literature, covering 75 million documents published in over 22,000 journals, book series and conference proceedings by some 5,000 publishers.

Scopus coverage is multi-lingual and global: approximately 21% of titles in Scopus are published in languages other than English (or published in both English and another language). In addition, more than half of Scopus content originates from outside North America (>6,000 titles), representing many countries in Europe (>12,400 titles), Latin America (>700 titles), the Middle East & Africa (>750 titles) and the Asia Pacific region (>2,300).

Scopus coverage is also inclusive across all major research fields, with 6,900 titles in the Physical Sciences, 6,400 in the Health Sciences, 4,150 in the Life Sciences, and 6,800 in the Social Sciences (the latter including some 4,000 Arts & Humanities related titles). Titles which are covered are predominantly serial publications (journals, trade journals, book series and conference material), but considerable numbers of conference publications are also covered from stand-alone proceedings volumes (a major dissemination mechanism, particularly in the computer sciences). Acknowledging that a great deal of important literature in all fields (but especially in the Social Sciences and Arts & Humanities) is published in books, Scopus has begun to increase book coverage in 2013 (89,000 books in June 2015).

For this report, a static version of the Scopus database covering the period 1996-2016 inclusive was aggregated by country, region, and subject. Subjects were defined by ASJC subject areas (see Appendix B for more details). When aggregating article and citation counts, an integer counting method was employed where, for example, a paper with one author from an Indian address and one from a United Kingdom address would be counted as one article for each country (i.e. 1 for India and 1 for the United Kingdom). This method was favoured over fractional counting, in which the above paper would count as 0.67 for India and 0.33 for the United Kingdom, to maintain consistency with other reports (both public and private) we have conducted on the topic.

A body of literature is available on the limitations and caveats in the use of such 'bibliometric' data, such as the accumulation of citations over time, the skewed distribution of citations across articles, and differences in publication and citation practices between fields of research, different languages, and applicability to social sciences and humanities research.

Appendix D
Glossary of terms

CAGR (Compound Annual Growth Rate) is defined as the year-over-year constant growth rate over a specified period of time. Starting with the first value in any series and applying this rate for each of the time intervals yields the amount in the final value of the series:

$$\mathrm{CAGR}(t_0, t_n) = \left(V(t_n)/V(t_0)\right)^{\frac{1}{t_n - t_0}} - 1$$

Here, $V(t_0)$ is the starting value, $V(t_n)$ is the finishing value, and $t_n - t_0$ is the number of years in the period.

Citation is a formal reference to earlier work made in an article or patent, frequently to other journal articles. A citation is used to credit the originator of an idea or finding and is usually used to indicate that the earlier work supports the claims of the work citing it. The number of citations received by an article from subsequently published articles is a proxy of the quality or importance of the reported research.

CiteScore is a journal-based metric that measures the average number of citations received per document published in a particular journal. It is calculated by taking the total number of citations received in a given year (e.g. citations received in 2017) by publications published in that journal during the three preceding years (e.g. publications in the journal from 2014-16) divided by the total number of publications from that journal during that three-year period. For example, if the *Journal of ABC* has published 300 publications during the three years ranging from 2014-2016 and these 300 publications were cited a total of 6,000 times by Scopus indexed publications published in 2017, then the CiteScore for the *Journal of ABC* is calculated as 6,000/300=20. (Note: The calendar year to which a serial title's issues are assigned is determined by their cover dates and not the dates at which the documents were made available online first.)

Citations per Publication (CPP) is defined as the average number of citations a paper in a certain publication set has received within a certain period.

FWCI (Field-Weighted Citation Impact) is an indicator of mean citation impact, and compares the actual number of citations received by an article with the expected number of citations for articles of the same document type (article, review or conference proceeding paper), publication year and subject field. Where the article is classified in two or more subject areas, the harmonic mean of the actual and expected citation rates is used. The indicator is therefore always defined with reference to a global baseline of 1.0 and intrinsically accounts for differences in citation accrual over time, differences in citation rates for different document types (reviews typically attract more citations than research articles, for example) as well as subject-specific differences in citation frequencies overall and over time and document types. It is one of the most sophisticated indicators in the modern bibliometric toolkit.
In general, the Field-Weighted Citation Impact (FWCI) is defined as:

$$FWCI = \frac{C_i}{E_i}$$

with
Ci= citations received by publication i
Ei= expected number of citations received by all similar publications in the publication year plus following 3 years
To calculate mean FWCI for a publication set, we use the formula:

$$\overline{FWCI} = \frac{1}{N}\sum_{i=1}^{N}\frac{C_i}{E_i}$$

With N = the number of Scopus-indexed publications in the publication set.

Highly cited publications are those in the top-cited X% of all articles published and cited in a given period. We report on highly cited articles in the top 1%, top 5%, top 10%, top 25%.

H-index (Hirsch-index) is an indicator of the cumulative citation impact of a researcher throughout their career. A researcher has an h-index of *n* if *n* of their publications have each received at least *n* citations.

Patent citations occur when a research publication is referenced in a patent. It is important to remember that patents are published and can only become available for use in research metrics around eighteen months after the application date; hence patent citations take time to accrue. Citation of scholarly output in patents indicates a connection between academia and industry, indicative of the transfer of knowledge between sectors.

Publication output is the number of publications per country, which have at least one author affiliated to an institution in that country (according to the authorship byline). All analyses make use of 'whole' rather than 'fractional' counting: an article representing international collaboration (with at least two different countries listed in the authorship byline) is counted once each for every country listed. Same logic applies for institutions.

Sectors in this report are used to classify organisations and institutions that publish research. The main sectors are Corporate, Higher Education, Government, and Medical sectors.

Appendix E
Advanced trends for India 2017 & 2018

Publications:

- **2017 (partial data):** 154,306; India ranks 5th worldwide after the United States (681,318), China (536,970), the United Kingdom (209,849), and Germany (179,230). Next in the top 10 are Japan (131,385), France (123,044), Italy (118,173), Canada (108,304), and Australia (101,758).

- **2018 (partial data):** 171,879; India ranks 5th worldwide after the United States (685,639), China (605,797), the United Kingdom (212,696), and Germany (179,914). Next in the top 10 are Japan (132,135), France (121,265), Italy (120,507), Canada (111,640), and Australia (106,044).

Citations (citations per publications):

- **2017:** 464,052 (3.0); India ranks 10th in citations worldwide after the United States (3,437,753 (5.0)), China (2,495,705 (4.6)), the United Kingdom (1,157,559 (5.5)), Germany (952,1740 (5.3)), Italy (630,377 (5.3)), France (621,869 (5.1)), Australia (599,693 (5.9)), Canada (598,860 (5.5)), Japan (501,675 (3.8)).

- **2018 (partial data):** 193,625 (1.1); India ranks 9th in citations worldwide after the United States (1,300,786 (1.9)), China (1,100,856 (1.8)), the United Kingdom (446,204 (2.1)), Germany (361,198 (2.0)), Italy (250,230 (2.1)), Australia (245,222 (2.3)), France (237,480 (2.0)), Canada (229,722 (2.1)), and before Japan (193,625 (1.4)).

Top 10 Research Areas by 2017 and 2018 publications:

2017		2018	
Subject area	**Publications**	**Subject area**	**Publications**
Engineering	43,302	Engineering	54,008
Computer Science	32,496	Computer Science	44,175
Medicine	26,973	Medicine	27,364
Physics & Astronomy	22,569	Physics & Astronomy	27,161
Materials Science	21,921	Materials Science	25,475
Chemistry	16,622	Biochemistry, Genetics, & Molecular Biology	18,757
Biochemistry, Genetics, & Molecular Biology	16,269	Mathematics	18,115
Mathematics	13,507	Chemistry	17,191
Agricultural & Biological Sciences	13,118	Chemical Engineering	13,536
Environmental Science	9,811	Environmental Science	13,153

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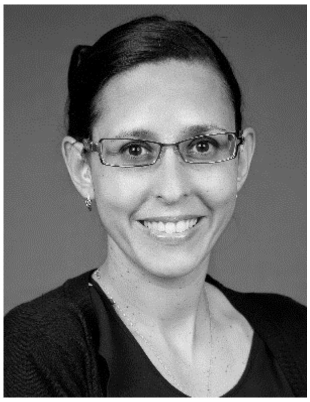

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