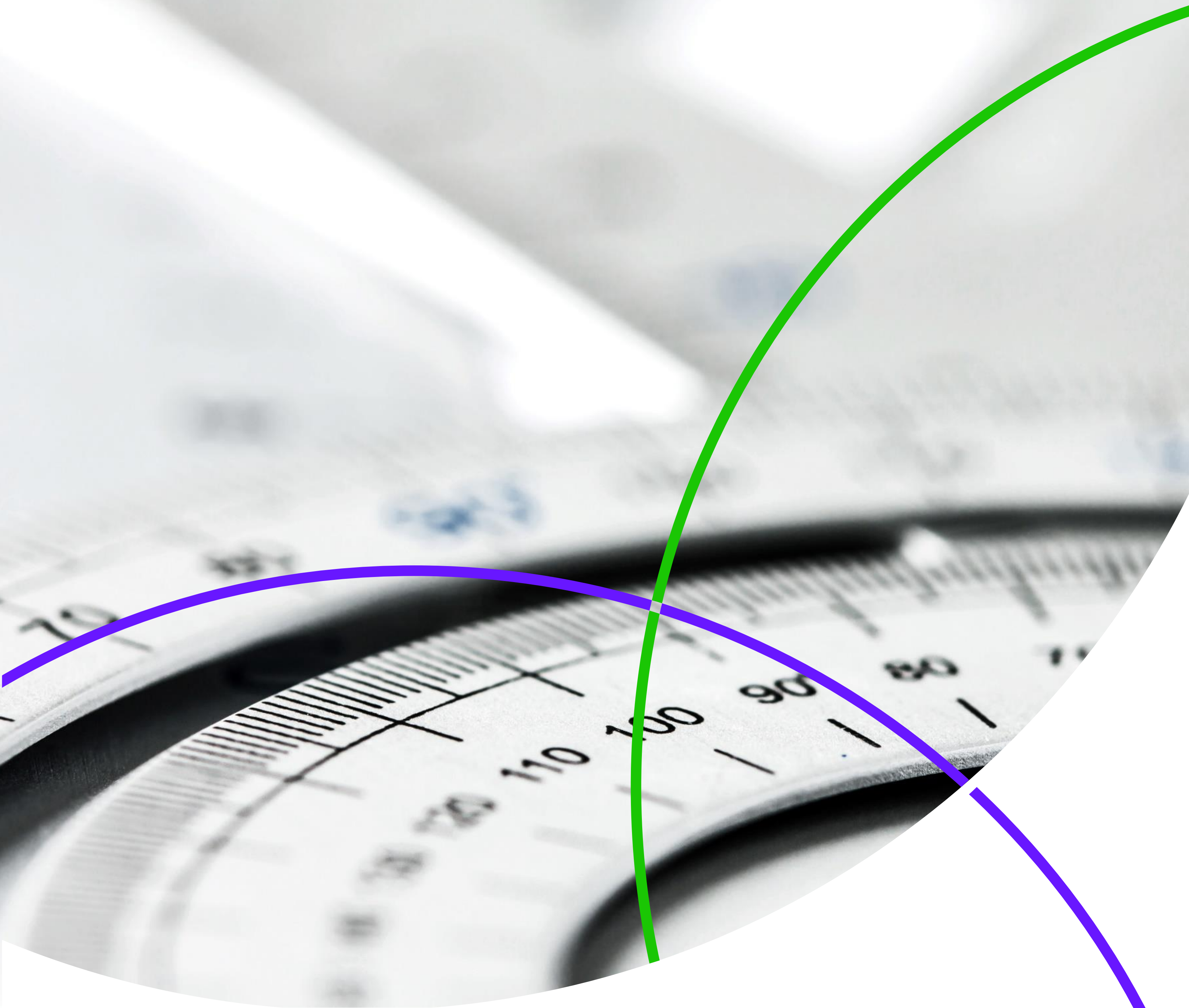

Bibliometric study of India's Research Output and Collaboration (2011-2016)

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DEPARTMENT OF
SCIENCE & TECHNOLOGY

Clarivate Analytics

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Clarivate Analytics was commissioned to prepare this report for the Department of Science and Technology, Government of India.

This report provides a comprehensive overview of India's research performance in a global context across all research fields. Seeks to answer questions about the current state of Indian research and how it has changed in recent years. Using bibliometrics to analyze Indian research papers published between 2011 and 2016 we have identified strengths and opportunities for Indian research.

In this report, all the publication data between 2011 and 2016 was collected with citation data up to the end of 2016, by using country name searches of the address affiliation data provided by authors and indexed in SCI-EXPANDED, SSCI and A&HCI of Web of Science Core Collection. Unlike other databases, the Web of Science Core Collection databases are selective, that is: the journals abstracted are selected using rigorous editorial and quality criteria. The authoritative, multidisciplinary content covers over 18,000 of the highest impact journals worldwide, including Open Access journals, and over 180,000 conference proceedings. The abstracted journals encompass the majority of significant, frequently cited scientific reports and, more importantly, an even greater proportion of the scientific research output which is cited. This selective process ensures that the citation counts remain relatively stable in given research fields and do not fluctuate unduly from year to year, which increases the usability of such data for performance evaluation.

More specifically, only the publications with document types of articles and reviews are included in the analyses, and editorials, meeting abstracts or other types of publications are not included. Articles and reviews are the subset of publications for which citation data are most informative and which are used in the calculation of citation impact. Furthermore, articles and reviews tend to be those that report research findings and they are peer-reviewed, whereas other publication types often cover other materials and are not reviewed in the same way, which also explains why they are most often used in research evaluations as an internationally accepted best practice.

The key findings of this report are:

Productivity of Indian research

• **India' rank in number of publications**: India ranked 10th in number of papers globally in the year 2016. During the time period of analysis (2011-2016) India's rank was highest as 9th in 2014. (Table 5.1.3, page. 77, Vol 2)

• **India's research output growth**: India's research output increased by 36.5% between 2011 (47,081) and 2016 (64,267) – faster than most countries analysed in this study – and it grew by 6.4% (CAGR) as compared to 3.7% (CAGR) for the world. (Table 5.1.1, page 74, Vol 2)

• **India's global share**: India's global share in scientific research publications increased from 3.6% in 2011 to 4.1% in 2016. During the time period of analysis (2011-2016) India's global share in scientific research publications was highest in 2016. (Table 5.1.2, page 76, Vol 2)

• **India's position compared to emerging countries**: Among the emerging research countries, India's research output rank improved from 3rd in 2011 to 2nd in 2016. China consistently maintained its 1st rank in the time period 2011-2016. (Emerging countries included Argentina, Brazil, China, Indonesia, Mexico, Russia Saudi Arabia, South Africa, South Korea, Spain, Taiwan and Turkey). (Table 5.1.3, page. 77, Vol 2)

• **India's position compared to established countries**: Among the established research countries, India's research output ranked dropped from 8th in 2011 to 9th in 2016. During the period of 2011-2016, Switzerland, Sweden, and Netherlands published fewer papers than India but are much smaller in terms of their populations. Australia is the only established country with a similar publication output to India, and between 2011 and 2016 the two countries had a comparable growth (India's CAGR - 6.4%, Australia's CAGR - 7.3%) in output of papers. (Established countries included Australia, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, United Kingdom and United States of America). (Table 5.1.3, page. 77, Vol 2)

(Theme 1, Section 5)

Research areas and national output

• **India's Top Research Areas**: Among all the research fields analysed, India's research papers tend to be focused on the technology and the physical and applied sciences - fields that support the domestic economic agenda. During the time period 2011-2016, chemistry (71,493) alone accounts for more than a fifth (21.2%) of all Indian papers, followed by engineering (34,092 or 10.1%), physics (32,942 or 9.8%), clinical medicine (32,251 or 9.6%) and materials science (29,677 or 8.8%). Consistent strengths are chemistry, physics, and materials science, as they all have a higher share of output compared to the world average, and the impact is also stable and above the Indian average. For the recent year 2016 of the analysis, India's top 3 research areas were Chemistry (12,779 or 19.9%) followed by Engineering (8,056 or 12.5%) and Physics (6,154 or 9.6%). (Figure 2.5a & Figure 2.5b, page. 23, Vol 1 and Table 2.6 page 24, Vol 1)

• **India's Fastest Growing Research Areas**: There has been massive growth in India's output of computer science (CAGR = 22.0%), psychiatry/psychology (CAGR=19.6%) and engineering (CAGR = 14.4%) papers during this study period.

• **India's least productive research fields**: During the time period of 2011-2016, India's least productive fields were related to social sciences. Psychiatry/psychology (1,431 or 0.4%) had the fewest papers, followed by economics & business (1,529 or 0.5%) and space science (3,969 or 1.2%). For the recent year 2016 of the analysis, India's least productive fields were Psychiatry/psychology (320 or 0.5%) followed by economics & business (320 or 0.5%) and space science (741 or 1.2%). (Figure 2.5, page. 23, Vol 1)

• **Emerging countries research focus**: The emerging countries (including India) tend to focus on the physical sciences and fields with the technological application, whereas the established countries have a greater bio-medical focus i.e. USA and UK had 21.6% and 19.7% of papers published in clinical medicine for the time period of 2011-2016. The pattern remained the same in 2016. (Figure 2.8a, page 30 & Figure 2.8b, page 31, Vol 1)

(Themes 3 and 4, Sections 5, 6 and 7)

• **Top funders for India's top 100 highly cited papers**: Out of 25 most frequent funding organisations that appeared in the acknowledgment of the top 100 most cited Indian papers, only two were domestic funders - the Council of Scientific & Industrial Research and the Department of Science and Technology – each funded around 10% of India's 100 most cited papers. The USA's National Science Foundation (NSF) has been the most frequent funder of high-impact Indian research papers, having funded the research behind a quarter of India's 100 most cited papers. (Table 8.2, page 559, Vol 2)

(Theme 2, Section 8)

• **Journal Analysis**: In the year 2011, 13,547 or 29.0% of all Indian papers were published in the top quartile of journals by JIF, by 2016 this number of papers had increased to 21,038 or 32.0% of all Indian papers. New England Journal of Medicine (59), Chemical Reviews (52) and Lancet (137) are the top 3 highest impact journals in which Indian research was published during the time period of 2011-2016. (Table 10.2.1-a, page 610, Vol 2). In the year 2011, 11.9% of India's total publications were in Indian-originated journals, by 2016 this number decreased to 9.6%. The number of Indian journals covered in Web of Science Core Collection in 2011 and 2016 was 153 and 143 respectively.

(Theme 2, Section 10)

Collaboration

• **India's International Collaboration**: Increasingly Indian researchers were collaborating internationally; in 2016, a quarter of Indian papers (26.0% or 16,728) had one or more international co-authors as compared to 22.4% (10,532) in 2011. In 2016, India's share of international collaboration in globally internationally collaborative papers was 4%.

India collaborated less frequently than other countries with 23.6% of papers resulting from the international collaboration during the time period of 2011-2016. Among all countries included in this study, smaller countries appear to be more collaborative than larger ones – China has the third lowest rates of international co-authorship (25.1%) of all the countries. Potentially, larger countries like India and China can maintain all the required research infrastructure domestically. (Table 9.1.1-a, page 562, Vol 2)

• **India's top internationally collaborative research areas**: Indian researchers were most internationally collaborative in fields where the output is relatively smaller (i.e. economics & business, space science). Over half of Indian papers in economics & business (53.3%) have at one or more international co-authors during the period of 2011-2016, followed by space science (50.3%) and psychiatry/psychology (46.4%).
(Table 5.21.9, page 468, Vol 2; Table 5.20.9, page 449, Vol 2; Table 5.22.9, page 487, Vol 2)

• **India's least internationally collaborative research areas**: India was least internationally collaborative in the high-output field with application to sectors significant to the Indian economy, such as food production (agricultural sciences). Only a tenth of Indian agricultural sciences papers (11.7%) results from the international co-authorship during the period of 2011-2016, followed by pharmacology & toxicology (17.9%) and Engineering (18.3%).
(Table 5.8.9, page 222, Vol 2; Table 5.10.9, page 260, Vol 2; Table 5.3.9, page 127, Vol 2)

• **India's top internationally collaborating countries:** India collaborated with countries in all regions of the globe, most frequently with the USA (25,584) and established countries (UK – 9,641, Germany – 9,030 and France – 6,387), economic peers and neighboring Asian countries (South Korea – 7,785, China – 5,853 and Japan – 5,630) in the study period 2011-2016. (Table 9.1.1-a, Page 562, Vol 2)

India collaborated most frequently with other Asian countries/regions, like Japan, Taiwan, China, and Singapore, in material science, computer science and chemistry, suggesting these fields are of regional focus.

The Indian-Saudi Arabian collaboration was the fastest growing for the timer period of 2011-2016. From a total of 360 collaborative papers in 2011, it increased to 1,300 in 2016 and outpaced all the other collaborating countries with 261% increase. This is the result of a series of bilateral agreements between the governments to support closer partnerships in research and education.

(Themes 2 and 4, Sections 5 and 9)

Impact of Indian research

• **India's citation impact**: India's citation impact as indicated by the Normalised Citation Impact - NCI (0.75) was higher than that of Russia (0.60) and Turkey (0.63) among all countries included in this study during the time period of 2011-2016. The Normalised citation impact for the world is 1.

Encouragingly, the average NCI of Indian research has increased steadily by 17.4 % from 0.69 in 2011 to 0.81 in 2016, with nearly 3.3% increase each year. This is approaching the BRICS average of 0.83 in the year 2016. (Table 5.1.6, Page 82, Vol 2). In the year 2016, Indian papers (NCI = 0.81) had a higher average NCI than Mexico (0.75), Russia (0.69), Turkey (0.63) and South Korea (0.80) by a narrow margin.

In 2016, India's global citation share was 4%. Space sciences was the research area with highest Citation per paper in 2016 (2.75) as well as for the time period of the analysis 2011-2016 (9.79).

• **India's total citations**: The total citations of Indian research (1,780,492) were 3.0% of world total citations (59,254,444) for the time period of 2011-2016. The total citations of India research (37,709) were 4% of world total citations (938,294) in the year 2016. (Table 5.1.4, Page 79, Vol 2)

• **India's research areas by citation impact:** The citation impact of India's clinical medicine research (0.83 on average) is consistently higher than in other fields during the time period of 2011-2016. However, in 2011, space science has had a very high average citation impact (1.48) due to a handful of very highly-cited papers resulting from larger international collaborations. (Table 5.20.4, Page 440, Vol 2)

Agricultural sciences research had the lowest citation impact (0.51) even though India publishes many papers in the field. This likely reflects that Indian research in this field has a local application rather than international citation impact, as the results are relevant to the local environment and food production.

• **Percentage of highly-cited papers**: India's ranking by the percentage of top 10% highly-cited papers improved from 21st (2011) to 16th (2016) among all countries included in this study. (Table 5.1.8, page 87, Vol 2)

Among all ESI fields of Indian research, space science had the highest percentage of papers assigned as top 1% highly-cited papers (1.8%), computer science had the highest percentage of papers assigned as top 5% highly-cited papers (4.6%), and materials science had the highest percentage of papers assigned as top 10% and top 25% highly-cited papers (8.9% and 22.7% respectively).
(Table 5.20.7, page 444, Vol 2; Table 5.13.7, page 311, Vol 2; Table 5.6.7, page 178, Vol 2)

(Themes 1 and 4, Section 5)

During the time period of 2011-2016, Indian researchers authored some very highly-cited papers (with 0.7% and 3.5% of papers assigned as top 1% and top 5% highly-cited papers respectively) and are approaching world average percentages of papers in the top 1% and 5% of most highly-cited papers worldwide. Meanwhile, 6.8% and 17.7% of Indian papers are assigned as the global top 10% and 25% highly-cited papers, respectively.

National Institutions

• **Top 3 national institutions in number of research publications**: Universities and government research institutions are among the most productive research active organisations. The most productive Indian research organisations are the Indian Institute of Technology system (IIT, 46,747), Council of Scientific & Industrial Research (CSIR, 34,664) and Indian Council of Agricultural Research (ICAR, 13,245). (Table 2.2, Page 15, Vol 1)

• **Institution with highest citation impact**: The institution with the highest citation impact (NCI) is the National Institute of Science Education and Research (NISER), which published 887 papers with an average NCI of 2.17 during the time period of 2011 - 2016. (Table 2.3, Page 16, Vol 1)

• **Focus areas of top 100 institutions**: The 100 Indian organisations with the highest output of papers tend to focus on chemistry, physics and clinical medicine as defined by ESI categories. And the percentage of paper with an international co-author is generally higher than that of India overall. (Table 11.3, Page 734, Vol 2)

• **Collaboration**: Around 90.0% of the papers published by the 100 most productive Indian organisations were co-authored by two or more Indian institutions. (Table 11.3, Page 734, Vol 2)

(Theme 2, Section 11)

Industry - Academia Collaboration

• **India's industrial co-authors** from multinational corporations mostly came from the pharmaceutical sector (e.g. Novartis and Dr. Reddy's Laboratories) and the information technology sector (e.g. IBM). (Table 12.2, Page 764, Vol 2)

• **Citation impact**: In 2016, academic-corporate collaboration accounted for 1 percent of India's total scientific output. The citation impact (NCI) of industry-academia collaborative papers (1.5) was significantly higher than the overall India's citation impact (0.75) during the time period 2011-2016. (Table 12.1, Page 763, Vol 2)

• **Top Indian corporate entities**: Top Indian corporate entities that collaborated with academic institutions included Dr. Reddy's Laboratories (India), Tata Steel Ltd, Biocon Ltd, Reliance Industries Ltd., General Electric, IBM, Tata Consultancy Services, Piramal Enterprises Ltd and GlaxoSmithKline.

• **Top academic institutions**: Top academic institutions that collaborated with industry included IIT system, CSIR, IISc Bangalore, Jawaharlal Nehru Technological University Hyderabad, Vellore Institute of Technology, University of Hyderabad, University of Delhi, AIIMS, National Institute of Technology, Tiruchirappalli and Osmania University. (Table 12.3, Page 765, Vol 2)

(Theme 2, Section 12)

Patent Citation Analysis

• **Total WIPO patents**: Total WIPO patents published in the time period 2011-2016 increased consistently except for year 2015. (Table 14.1, Page 789, Vol 2)

• **Non-patent citations**: About 50% of the total WIPO patents had non-patent citations in each of the first four years of the analysis period and there is a declining trend in 2015 and 2016. (Table 14.1, Page 789, Vol 2)

The PCT application also showcases non-patent references cited in its priority application. The count of PCT application with non-patent cited references has been decreasing in the recent years. One explanation could be the time lag in publication of the priority application by the patent office from its filing date, and the resulting delay in reflection of non-patent cited references in PCT data.

Number of Indian publications cited in WIPO patents published during 2011-2016 increased from 2011 to 2016. For the time period 2011 to 2016, 0.63% of publications received citation in WIPO patents during 2011-2016. The percentage could be slightly lesser than the actual number because the recent publications had limited chance to get cited in WIPO patents considered for this analysis. Also, DOI/Title matching was used to match scientific literature with non-patent citations of WIPO patents. There is a possibility that some Indian publications even though cited in WIPO, may not be matched/identified through DOI/Title matching.

(Theme 2, Section 14)

2 KEY FINDINGS

This report presents the results of a bibliometric analysis of papers published by researchers affiliated to organisations in India between 2011 and 2016. The purpose of this analysis is to describe the current state of research in India.

The analysis relates to four main themes, which cover different components of the research system:

- **Theme 1** India's published research in the six years from 2011 to 2016, compared to 23 other countries.
- **Theme 2** The domestic and international organisations that are important to India's research landscape.
- **Theme 3** Comparing Indian research fields and India's research strengths, weaknesses, opportunities and threats in a global context.
- **Theme 4** Indian research performance in each of 21 individual research fields.

2.1 Theme 1: India's research landscape and how it compares to other countries.

In this theme, we focus on the comparative analysis of bibliometric indicators for the overall research papers Indian scientists published in the six years from 2011 to 2016, with those for 23 other countries. From this, we can assess how Indian research compares in terms of the number of papers published, overall citation impact (as indicated by normalised citation impact) and the production of excellent research (as indicated by highly-cited papers).

Theme 1 relates to regional benchmarking analysis in **Section 5.1.**

Comparator countries

Clarivate Analytics aligns with the idea of forming a basis for outcome-based performance, by comparing Indian research to both established and emerging research economies, as listed in **Table 2.1** below.

Table 2.1 Countries covered in the report

Code	Country	Report Group	Aggregation Group
IND	India		G20, BRICS
AUS	Australia	Established research economies	G20
CAN	Canada	Established research economies	G8, G20
FRA	France	Established research economies	G8, G20
DEU	Germany	Established research economies	G8, G20
ITA	Italy	Established research economies	G8, G20
JPN	Japan	Established research economies	G8, G20
NLD	Netherlands	Established research economies	
SWE	Sweden	Established research economies	
CHE	Switzerland	Established research economies	
GBR	United Kingdom	Established research economies	G8, G20
USA	United States of America	Established research economies	G8, G20
ARG	Argentina	Emerging research economies	G20
BRA	Brazil	Emerging research economies	G20, BRICS
CHN	China	Emerging research economies	G20, BRICS
IDN	Indonesia	Emerging research economies	G20
MEX	Mexico	Emerging research economies	G20
RUS	Russia	Emerging research economies	G8, G20, BRICS
SAU	Saudi Arabia	Emerging research economies	G20
ZAF	South Africa	Emerging research economies	G20, BRICS
KOR	South Korea	Emerging research economies	G20

Code	Country	Report Group	Aggregation Group
ESP	Spain	Emerging research economies	
TWN	Taiwan	Emerging research economies	
TUR	Turkey	Emerging research economies	G20

The twelve emerging countries selected for this analysis includes Brazil, Russia, China and South Africa which are often referred to, together with India, as the BRICS nations. These five countries are similar in having rapidly growing economies resulting from recent industrialization, with large populations and regional influence. When comparing research landscapes, the BRICS are good comparators for India as they are they have similar resources, challenges and potential to become world leaders in scientific research. China can be a difficult comparator because it does an enormous quantity of research and development, resulting in orders of magnitude more papers than the other BRICS countries.

The established research economies included in the analysis are world leaders in scientific research, with excellence derived from decades of sustained higher-education, research funding, and infrastructure. These countries set the standards to which the Indian research community (and that of other emerging research economies) are working towards.

India is also compared to three aggregated groups of countries, the BRICS, the G20 countries and the G8. India is a member of both the BRICS and G20 but not the G8. The G8 consists of Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States. These eight industrialised countries have historically been the wealthiest nations with the largest-GPD, although China now has a higher GDP than any of these countries except for the USA.

2.1.1 How many papers does India publish relative to the rest of the world?

India

In year 2016, India has the tenth highest output of scientific papers in the world, having experienced rapid growth in the number of papers it publishes in recent years (**Table 5.1.3**). Publication output has increased by more than a quarter (36.5%), from 47,081 in 2011 to 64,267 in 2016. This represents a 0.3% increase in the share of world output of papers and, as of 2016, 4.1% of all papers worldwide have at least one author based in India (**Table 5.1.2**).

The rest of the world

In 2014, India overtook Spain in terms of the numbers of research publications it produced annually. By 2016, among the emerging research countries, India's research output was second only to China, which each year published around four times more papers than India.

Worldwide, China's research publication output is second only to the USA (**Figure 5.1.1**). It took to 2014 for the publishing output of the BRICS countries combined to equal and then exceeded the number of papers that the USA produces annually. BRICS growth is driven primarily by the increase in Chinese publication output.

By 2016 most of the established countries still published more papers than India. Switzerland, Sweden, and Netherlands published fewer papers than India but are much smaller in terms of their populations. Australia is the only established country with a similar publication output to India, and between 2011 and 2016 the two countries had a comparable growth in publication output (**Table 5.1.1**).

India and the other emerging countries have shown consistent growth in the number of papers they published and have an increasing share of world research output. Only Taiwan has shown a very modest decrease in output, (**Figure**

5.1.1). For BRICS countries, share of world output increased significantly between the two time periods 2011-2013 and 2014-2016 (from 22.9% to 28.1%).

Established countries did not experience such growth. This can be seen by comparing the change in the numbers of papers published by the G8 and the G20 for the two time periods 2011-2013 and 2014-2016. The G8's total output of research papers increased by 9.8% but fell as a percentage of world output (from 56.2% to 53.5%; Table 5.1.2), while the G20's output increased by 18.9% and increased as a share of global research output (from 80.8% to 83.2%, see **Table 5.1.2**)

2.1.2 How does the impact of Indian research compare to other countries?

The number of citations a paper receives reflects the impact it has had on later research. Papers cite earlier papers to reflect an intellectual contribution. Therefore, a paper (or a collection of papers) with a higher citation count can be said to have had a higher impact on the field to which it relates. However, citation rates also depend on the research field and the age of a paper (older papers have had more time to accumulate citations compared with more recent ones). To account for these factors, we normalize the citation count for a paper to the world average for the field and year of publication.

In this report, the term "normalised citation impact" (NCI) is used to refer to the average field normalised citation impact for a paper or group of papers. This means that a paper or collection of papers, with an NCI of 1.00 has a world average impact. An NCI above 1.00 indicates a higher than average impact and an NCI below 1.00 indicates below average impact. This approach is described in more detail in **Section 4.3** and **Section 15**.

India

Between 2011 and 2016 the citation impact of Indian research, with an NCI of 0.75, has remained below both the world average (1.00) and the BRICS average (0.82) (**Table 5.1.6**). Encouragingly, the NCI of Indian research has increased steadily by 17.3% between 2011 and 2016 to 0.81 (**Figure 5.1.6**). This is approaching the 2016 BRICS average of 0.83, and if growth continues at 2.9% a year Indian research will achieve world average impact (1.00) within seven years.

The rest of the world

Generally, the established countries had an NCI above the world average (1.00) and the emerging countries research had an NCI below this level. The exceptions among the emerging countries were Spain, Saudi Arabia and South Africa which year-on-year maintain an NCI well above 1.00. Switzerland had the highest NCI (1.67) in 2016 (**Table 5.1.6**).

All the established comparators and most of the other emerging ones have a higher NCI than India (**Table 5.1.6**). Looking beyond 2016 this is likely to change. As in year 2016, Indian papers had a higher citation impact than Mexico, Russia, Turkey and (by a narrow margin) South Korea. India has the potential to surpass other emerging countries in terms of citation impact if it can maintain an annual 2.9% increase in NCI as few other countries have experienced such large and sustained advances in impact.

There is also a difference between the established and emerging research economies in how citation impact changes year-on-year. Established countries usually have small, consistent yearly increases in NCI (**Figure 5.1.6-b**). In contrast, emerging countries often display far more erratic trends (**Figure 5.1.6-a**). The most extreme example of this is Indonesia with an NCI of 1.26 in 2015 falling to 0.96 in the following year, 2016. This observation is likely to be because of the relatively small annual output of papers by the emerging countries; Indonesia only publishes a few thousand papers a year. This means that the average NCI can be easily inflated a handful of papers have a high citation count. As we have seen, the emerging countries tend to publish less than the established countries, so are more susceptible to fluctuations in impact. India and China, which publish as many papers as established countries, have a steadier increase in NCI.

2.1.3 Do Indian researchers produce excellent research, and how does India compare to other countries in this respect?

Highly-cited work is recognised as having a greater citation impact than less cited work, and Clarivate Analytics has shown that high citation rates are correlated with other qualitative evaluations of research performance, such as peer review. In the previous section, NCI has been used to ascertain a country's citation impact. However, as a measure of research excellence, average NCI has some limitations. For countries like Indonesia, which publish a small number of papers, the average NCI be skewed by a few very highly-cited papers and does not reflect the impact of published outputs of the broader research community.

In this Section research excellence is indicated by the percentage of a country's papers that are in the world's top 1%, 5%, 10% and 25% of most highly-cited papers, taking year of publication and field into account.

Clarivate Analytics has traditionally used the world's top 1% of most highly-cited papers as its definition of highly-cited research. While this threshold certainly does indicate world-leading research, it may not be useful for more general research evaluation purposes. Such papers are very rare and therefore a difference of only a few papers between two entities may indicate a very substantial difference in their respective research performance. We therefore often use a more relaxed definition of what constitutes highly-cited research, or (as in this report) we consider multiple thresholds to give a broader perspective. For example, if a country has a relatively high percentage of papers in the world's top 1% but a relatively low percentage of top 25% papers this could indicate a small pocket of excellence but otherwise relatively poor performance.

These indicators also allow performance to be assessed against the world average. A country with 1% of its papers in the world's top 1% of most highly-cited papers would have the same relative distribution of highly-cited research as the world average. A higher percentage of such papers would indicate above average performance, and a lower percentage below average performance.

This approach is described more fully in **Section 15.**

India

Encouragingly, there are indications that sections of the Indian research community are publishing an increasing number of very highly-cited papers. By 2016, 0.7% and 3.3% of Indian papers were among the top 1% and 5% of most highly-cited papers, respectively. When compared for the two time-periods 2011-2013 and 2014-2016, the percentage of papers in top 1% increased from 0.7% to 0.8%. Similar increase of 0.1% was observed for % of papers in top 5% in the two time-periods (from 3.4% to 3.5%).

In contrast, the percentage of Indian of papers in the world's top 10% and 25% of most highly-cited papers have not shown consistent increases. The proportion of highly-cited papers in the top 10% reached a peak in 2014 at 7.2% and in the top 25% reached a peaked in 2013 at 18.9%, in the following years the percentages of papers fell. When compared for the two time-periods 2011-2013 and 2014-2016, the percentage of papers in top 10% decreased from 6.9% to 6.8%. Similar decrease was observed for % of papers in top 25% in the two time-periods (from 18.5% to 17.1%).

The data show that India researchers have successfully increased the number of very highly-cited papers published annual – as seen in the top 1% and 5% of highly-cited papers (**Table 5.1.7**). This suggests that a small but increasing number of India researchers are conducting very high impact research – which is reflected in its increasing NCI.

The rest of the world

The percentage of highly-cited papers tends to fall for all countries in the most recent year analysed. For example, until 2015 all the established countries (except Japan) had a higher than average percentage of papers in the world's top 25%, yet in 2016 all the established comparators failed to meet the 25% threshold (**Table 5.1.7**). This is because papers published more recently have had less time to accumulate citations than older papers - a paper from last year will, on average, have fewer citations than one published five years previously. This means that a smaller number of citations would be needed for a 2016 paper to be in the world's top 10% than for an older paper. It is, therefore, more difficult to distinguish between highly-cited papers and non-highly-cited ones in more recent years and few papers appear to be highly cited.

The percentages of highly-cited papers (i.e. that ranked in world top 1%, 5% 10% and 25% in terms of citations) for the established countries is generally higher than the world average. While the emerging countries tend to have a lower than average percentage of highly-cited papers. The exceptions are Japanese (established) papers which are below and Spanish (emerging) papers which exceeds world averages in proportions of highly-cited papers.

Comparing different thresholds, established countries tend to publish an above world average percentage of highly-cited papers for the 1%, 5%, 10% and 25% thresholds. Emerging countries less frequently reach the 25% of highly-papers threshold compared to the 1%, 5%, and 10%. Suggesting that emerging countries alongside with India's research landscapes have isolated pockets of excellence that produce exceedingly highly-cited papers that are in the top 1% and 5% of highly-cited papers but the research output of the country is below world averages, reflected in relevant low percentages of papers in the top 10% and 25% of highly-cited papers.

Top 1% of highly-cited papers

By 2016, 0.7% of Indian papers were included in the top 1% of highly-cited papers. For the period 2011-2016, India had highest percentage of its publications in top 1% in the year 2014 and 2015 i.e. 0.8%, From the year 2013 to 2015, the BRICS average reached the world average of 1% of highly-cited papers mostly due to strong performance in China. In the year 2016, BIRCS' average dropped to 0.8% due to drop in China's performance (0.8% in 2016 for China). Emerging countries that met the top 1% of highly-cited papers threshold in 2016 were Spain, South Africa and Saudi Arabia.

The established countries consistently publish more papers in the world's top 1% of most highly-cited papers than the world average. Switzerland had nearly three-times the globally expected percentage of highly-cited papers in the top 1% of papers.

Top 5% of highly-cited papers

3.3% of Indian publications were in top 5% of highly cited papers in 2016. Like the top 1% of highly-cited papers, China, South Africa, Spain and Saudi Arabia publish a relatively high proportion of papers in the world's top 5% of mostly highly-cited papers.

The established countries had an above average percentage of papers in the world's top 5% of most highly-cited papers. Switzerland has at least 10 percent of its papers in the world's top 5%, the highest of the countries analysed.

Top 10% of highly-cited papers

India had 6.2% of its total papers in (**Table 5.1.7**) in the world's top 10% of most highly-cited papers in the year 2016. Of the emerging countries, only Mexico (6.4%), Brazil (5.9%), Russia (4.6%) and Turkey (5.3%) publish a lower percentage of highly-cited papers at the 10% threshold than India (6.8%) for the time period of the analysis 2011-2016. In contrast, China, Saudi Arabia, Spain, and in some years South Africa, have an above average percentage of papers in the world's top 10% of most highly-cited papers. The established countries, except for Japan publish an above average percentage of papers in the world's top 10% of most highly-cited papers. Again, Switzerland has the highest percentage of papers; consistently more than 17% of its papers exceed the 10% threshold.

It was encouraging to see that as compared to overall time period of analysis (2011-2016), India's position improved compared to that of emerging countries in the recent year 2016 (ranked higher than Argentina, Brazil, Indonesia, Mexico, Russia, South Korea, Taiwan and Turkey in terms of the top 10% highly-cited papers).

To 25% of highly-cited papers

Between 2011 and 2016, around 18% of India's papers were in the world's top 25% of most highly-cited papers. The percentage of India's paper in world's top 25% of most highly-cited papers for year 2016 was 14.8%. None of the emerging countries exceeded the world average of top 25% of most highly-cited papers in the year 2016.

2.2 Theme 2: Stakeholders in India's research landscape

This theme identifies the key participants that contribute to domestic Indian research. Describing the Indian institutions where research takes place; the international and industrial organisations that collaborate with these institutions; the funders who support Indian research; the journals in which Indian research is published and the patents that use Indian research.

Theme 2 relates to:

Section 5 Comparative bibliometrics - 5.1 All fields.

Section 8 Funding Analysis

Section 9 International collaboration

Section 10 Journals Analysis

Section 11 Institution analysis

Section 12 Industry collaboration analysis

Section 14 Patent citation analysis

2.2.1 Indian research organisation

India was the tenth largest producer of research publications globally in the year 2016; having published a total of 64,267 papers in 2016 (**Table 5.1.3**). To produce such a massive body of work requires a research and development workforce numbering over half a million spread across many research active organisations. [1] Most of these organisations were universities, which in 2014 numbered 677, but this has increased and there are now probably closer to 800.[2]

Table 2.2 shows the top 10 most productive Indian research organisations by the number of papers published between 2011 and 2016. For more granular data of India's 100 most productive organisations see **Section 11**.

Which organisations publish the most papers?

Table 2.2 Top 10 Indian research organisations by number of papers published between 2011 and 2016

	Organisation	Number of papers	Average NCI
1	Indian Institute of Technology system[3] (IIT) (includes all IITs)	46,747	0.86
2	Council of Scientific & Industrial Research (CSIR) - India	34,664	0.87
3	Indian Council of Agricultural Research (ICAR)	13,245	0.48
4	Indian Institute of Science (IISC) - Bangalore	9,788	0.88
5	Bhabha Atomic Research Center	8,222	0.99
6	University of Delhi	6,895	1.02
7	Banaras Hindu University	6,393	0.80
8	Jadavpur University	5,078	0.81
9	Anna University	4,806	0.64
10	All India Institute of Medical Sciences	4,734	1.17

The Indian Institute of Technology system (IIT), Council of Scientific & Industrial Research (CSIR) and Indian Council of Agricultural Research (ICAR) published the highest numbers of papers between 2011 and 2016. They are the only organisations to publish more than 10,000 papers, which is significantly more than any of the other institutions listed (**Section 11**).

Remarkably, three of the ten most productive Indian research organisations (**Table 2.2**), are government research institutions: CSIR, the Indian Council of Agricultural Research (ICAR) and the Bhabha Atomic Research Center. This is an unusual attribute of the Indian research landscape, that a large proportion of domestic research is concentrated in government research institutions rather than academic institutions[4].

[1] UNESCO data. Available at: UIS statistics data.uis.unesco.org

[2] http://mhrd.gov.in/university-and-higher-education - accessed 31 May 2018

[3] IIT System includes: IIT (ISM) Dhanbad; IIT Bhilai; IIT BHU; IIT Bhubaneswar; IIT Bombay; IIT Delhi; IIT Dharwad; IIT Gandhinagar; IIT Goa; IIT Guwahati; IIT Hyderabad; IIT Indore; IIT Jammu; IIT Jodhpur; IIT Kanpur; IIT Kharagpur; IIT Madras; IIT Mandi; IIT Palakkad; IIT Patna; IIT Roorkee; and IIT Ropar.

[4] UNESCO data. Available at: UIS statistics data.uis.unesco.org

Which organisations have with the highest citation impact?

Table 2.3 Top 10 most productive Indian research institutions with the highest NCI between 2011 and 2016

	Organisation	Number of papers	Average NCI
1	National Institute of Science Education and Research(NISER)	887	2.17
2	Institute for Plasma Research (IPR)	895	1.90
3	Visva Bharati University	1,654	1.54
4	Tata Institute of Fundamental Research	4,645	1.45
5	Saha Institute of Nuclear Physics	2,393	1.39
6	IISER*	4,186	1.38
7	Institute of Physics Bhubaneswar (IOPB)	813	1.35
8	International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT)	1,071	1.32
9	Tata Memorial Hospital	1,131	1.28
10	Panjab University	4,130	1.27

**It includes all IISERs*

A quarter of India's 100 most productive research institutions have a citation impact above world average NCI (**Section 11**). The institution with the highest NCI is the National Institute of Science Education and Research(NISER), which between 2011 and 2016 published 887 papers with an average NCI of 2.17 (**Table 2.3**).

IPR is a government research institute. Many organisations with the highest citation impact are government research institutions and not universities (**Table 2.2**). These research organisations have usually been set up and supported by regional or national government funding, but there are also examples of research being set up or supported by private enterprise.

What is the research focus of the most productive organisations?

The 100 Indian organisations with the highest output of papers tend to focus on chemistry, physics and clinical medicine as defined by ESI categories. These are the same fields in which the whole Indian research community publishes the most papers (**Theme 3**).

The organisations with the highest impact conduct research in a range of different areas, from atomic physics to plant genetics. It is encouraging to see that that Indian researchers can maintain world standards of excellence across a diverse range of research fields. Many of the top research institutions have a narrow research focus such as clinical medicine at Tata Memorial Hospital, and nuclear physics at Saha Institute of Nuclear Physics and agriculture at International Crops Research Institute for the Semi-Arid-Tropics, as such they are centres of excellence for a field of research.

Who do Indian institutions collaborate with?

Rates of domestic collaboration between Indian organisations are high; around 90.0% of the papers published by the 100 most productive Indian organisations were co-authored by two or more Indian institutions (**Section 11**). International collaboration is less common. In 2016, around a quarter (26.0%) of India's papers had co-authors from other countries (**Figure 5.1.9**). However, for the top 100 most productive Indian institutions the percentage of paper with an international co-author is generally higher. Among them, 38 institutions of them have higher than 26% papers that are internationally collaborative in 2016, with the highest being National Institute of Science Education and Research(NISER) which has 71.8% internationally collaborative papers. .

The exception seems to be the organisations with a focus on clinical medicine, for example, the All India Institute of Medical Sciences, with 20.5% of papers resulting from international collaboration (**Section 11**). Potentially these organisations, often hospitals, will be researching diseases that are particularly prevalent in India and surrounding countries, affecting the local population. Accordingly, researchers studying these diseases are likely to receive direct funding from the Indian government to conduct their work domestically, Nevertheless, across all of India, clinical medicine rates of international co-authorship are generally higher (29.2% in 2016) than the Indian average (26.0% in 2016) (**Theme 4**, and **Figure 5.5.9**).

2.2.2 Which countries does India collaborate with?

Is it common for Indian researchers to engage in international collaboration?

About a quarter of Indian papers results from international collaboration. India increasingly collaborates with scientists working in other countries. In 2011 22.4% of papers had one of more international co-authors, this increased by 3.6% to 26.0% in 2016 (**Figure 5.1.9**).

Which countries does India collaborate with?

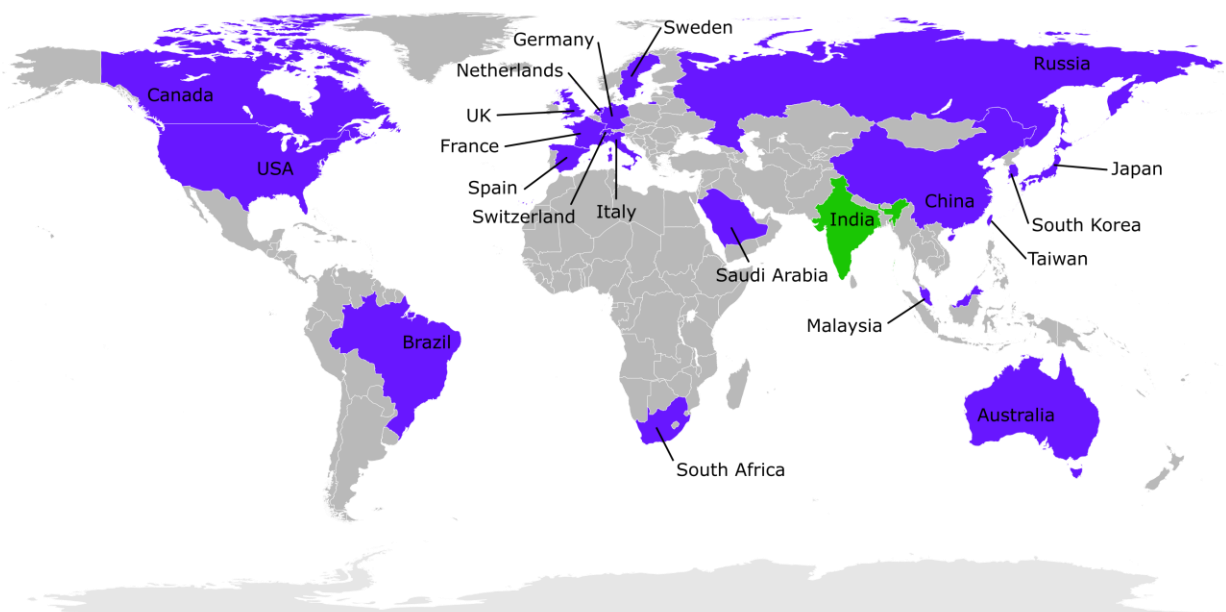

Figure 2.4 Twenty countries Indian most frequently collaborates

India collaborates with countries from all regions of the globe (**Figure 2.4**). The top 20 most productive international collaborations in terms of the number of papers are broadly made up of established countries, BRICS nations, and geographically close emerging countries.

The most productive collaboration is with the USA, accounting for 7.6% of internationally co-authored papers between 2011 and 2016, followed by the UK (2.9%) and Germany(2.7%). South Korea is the leading emerging country collaborator, closely followed by other Asian countries China and Japan which, as we see in **Section 6** and **Theme 3** have a broadly similar focus on the physical sciences. In the year 2016, India's top collaboration was with USA (8.4%), UK (3.2%), and Germany (2.7%).

Rates of collaboration between Saudi Arabia and India have increased five-fold, from 360 papers in 2011 to 1,300 in 2016, see **Section 9**. Rapid growth in collaboration between the two nations is probably due to the deliberate action of both national governments, who signed a series of bilateral agreements and memoranda of understanding to work together in scientific research. The first agreement that was formative in the modern Indian-Saudi Arabian relationship took place in 2006 when the ruler of Saudi-Arabia, King Abdullah, visited India and signed the Delhi Declaration agreeing to "Cooperation in the field of technology, in the field of information and communication technology, agriculture, biotechnology, and non-conventional energy technologies"[5].

Do Indian researchers collaborate internationally more-or-less than researchers in other countries?

Across the globe, international collaboration is increasing. Of the 23 comparator countries, only Indonesia has seen a decline in international collaboration since 2011. Even though India is becoming increasingly collaborative, by 2016 it still had the lowest rates of international collaboration, except for Turkey. However in 2016, with 26.0% of papers with an international co-author, India was approaching the BRICS average of 28.3% and the G20 average of 29.4% (**Figure 5.1.9**).

Generally, established research countries have higher rates of international collaboration. For example, during the period of 2011-2016, 35.1% of G8 papers involved international collaboration compared to 27.0% of G20 papers (**Figure 5.1.9**).

Collaboration seems correlated to a country's citation impact. It has been shown that the Normalised Citation Impact (NCI) of internationally co-authored papers is higher than those papers with authors from only one country.[6] We can see something akin to this by comparing the average NCI of all papers published by the comparator countries. For example, Japan has the lowest rates of international collaboration among the established countries, 33.4% papers have an international co-author, and it is also the only established country with an average NCI below the world average of 1.00. The benefit of international collaboration can be observed for South Africa which has the highest NCI of any emerging country and nearly 60% of its papers have an international co-author – well above the BRICS average.

China appears to be an outlier, maintaining a citation impact above many other emerging countries (**Figure 5.1.6**), including India, but engaging in relatively few international collaborations. In 2016, only 26.4% of Chinese papers had an international co-author, a similar value to India and below the BRICS average. Among established countries, the USA has some of the lowest rates of international collaborations and still maintains an NCI well above the world average of 1.00. These larger countries, China, USA and possibly India, may have a larger capacity for domestic research collaboration. Their research infrastructure has reached a critical mass such that researcher in these countries need not go abroad to fill gaps in expertise or access research facilities. Such an approach is not an option for small European countries which must join forces to match the research workforce and science facilities of larger countries.

2.2.3 Do Indian academics collaborate with multinational industries?

The analysis of Indian inter-sector collaboration concentrates on papers co-authored by researcher at Indian universities and multinational corporations because the corporations currently unified within Web of Science are

[5]Delhi Declaration, (2006). Available at: http://mea.gov.in/bilateral-documents.htm?dtl/5969/Delhi+Declaration+Signed+by+King+Abdullah+bin+Abdulaziz+Al+Saud+of+the+Kingdom+of+Saudi+Arabia+and+Prime+Minister+Dr+Manmohan+Singh+of+India – accessed 20 June 2018

[6] Adams J., (2013), Collaborations: The fourth age of research, Nature, 497: 557-560, https://doi.org/10.1038/497557a

primarily large multinationals. Hence the analysis presented here does not show collaborations between Indian universities and smaller domestic companies.

Compared to the vast number of collaborations between universities whether domestic or international, our analysis has uncovered few examples of inter-sectoral collaborations between academic and industrial researchers. Two examples of substantial inter-sector, international collaborations have been between Indian researchers and the USA firms Novartis and IBM. Between 2011 and 2016, Novartis researchers, co-authored 48 papers with Indian researchers in pharmacology & toxicology field (**Table 9.10.2**) and IBM researchers co-authored 32 papers with Indian researchers in computer science field (**Table 9.13.2**).

Currently, Indian corporations collaborate with universities and research institutions on a small, but growing, number of papers. Since 2011, the number of papers arising from such collaborations has increased by 44% to a peak of 737 papers in 2016 (**Table 12.1**). The citation impact of these papers is constantly high; papers published in 2016 have an NCI of 1.46, well above the world average of 1.00 and nearly double the 2016 Indian averages of 0.81. It appears that inter-sector collaboration is a strength of the Indian research base.

Some of the industrial partners involved in these collaborations come originally from India such as Dr. Reddy's Laboratories and Tata Steel, while those from other countries usually have a significant presence in India, including household names like Microsoft. Most of these companies are involved in the pharmaceutical and computer industries.

The most productive Indian universities (**Section 11**) are generally the same universities that collaborate most frequently with industry (**Table 12.3**). The leading inter-sector collaborator is IIT system (all IITs combined) and it is worth noting that many of the other academic institutions have a technology or medical focus such as National Institute of Technology, Tiruchirappalli – Bangalore and All India Institute of Medical Sciences. It seems that research fields such as clinical medicine with obvious technological application to an industrial sector, like pharmaceuticals, have the highest rates of inter-sector-collaboration.

Supporting closer working between the academic and industry sectors has been the stated objective of a series of Indian governments, particularly where the industrial partners are small and medium-sized enterprises (SMEs). Translating expertise in basic science into innovative technology and new commodities is a pillar of India's modern science and national policy, and is viewed as essential for sustainable and inclusive growth; directly improving the lives of the Indian population and perpetuating economic growth.[7] There have been a huge number of policy interventions and laws passed by the government to drive closer inter-sector collaboration by pursuing projects with a potential for industrial technology transfer or which align with wider national priorities.[8]

However, as this analysis is insensitive to increases in industrial R&D conducted by SMEs and domestic university-industry collaboration (the type of activity and organisations the government is trying to encourage) it cannot be used to assess R&D trends in domestic collaboration with industry and the impact of the governmental policy.

2.2.4 Research funders with a stake in Indian research

The range of funding organisations appear in the acknowledgment of high-impact Indian papers, demonstrates that Indian research is conducted in close association with and supported by the global scientific community. Of the 25

[7] Planning Commission (Government of India), (2013). *Twelfth Five Year Plan (2012–2017) Faster, More Inclusive and Sustainable Growth Volume I*. New Delhi: SAGE Publications India Pvt Ltd.
[8] Dehradun Declaration for CSIR Labs, (2015) available at: pib.nic.in/newsite/PrintRelease.aspx?relid=122489 – accessed 1 July 2018

funders most frequently acknowledged by the top 100 most cited Indian papers the clear majority are foreign (**Table 8.2**).

From this list, the amount of funding provided to the researchers, or what the funding was used for cannot be ascertained. There are many ways in which research funding is dispersed and it is likely that when funding comes from an organisation outside India, it is not going directly to Indian researcher or their institutions but to their international collaborators. As described in earlier sections, internationally collaborative papers tend to produce more highly cited papers, so it is probable that the top 100 most cited India papers have a higher number of international co-authors than the average for Indian research.

Out of 25 organisations, only two are domestic funders - the Council of Scientific & Industrial Research and the Department of Science and Technology. The most frequent international funders appear in the acknowledgment of the top 100 most cited Indian papers are European funders; including both national funders and European-wide funders. The next most prominent funders are USA-based government agencies, such as the US Department of Energy. The European funders are more numerous, while the USA organisation tend to support the most highly-cited papers. The USA's National Science Foundation (NSF) has been the most frequent funder of high-impact Indian research papers, having funding the research behind a quarter of India's 100 most cited papers.

Generally, foreign funding tends to come from national funders that are backed by public funds. These funders tend to be based in wealthy countries and regions. There are only three examples of funders from other BRICS, Brazil's National Council for Scientific and Technological Development and Sao Paulo Research Foundation and the National Natural Science Foundation of China. Again, these funders are supported by the government.

Only three non-governmental funders are listed, the Bill and Melinda Gates Foundation and the Wellcome Trust (both charities) and the pharmaceutical firm Pfizer.

2.2.5 Journals in which Indian research appears

India's domestic academic publishing sector

The number of papers published by Indian researchers in Indian journals increases annually. However, rates of Indian publication across all journals has increased at a similar rate, so the percentage has remained relatively stable at around 11.0% of all Indian papers (**Table 10.1.1**).

Indian papers appearing in the high impact journals

Publication in leading, high-impact journals is very competitive, and such journals tend to only accept papers that represent significant advances in human knowledge.

A journal's prestige can be assessed using the Journal Impact Factor (JIF). A journal's JIF is the number of citations received in a year by articles published in that journal during the two preceding years, divided by the total number of articles published in that journal during the two preceding years. For more specifics on how the JIF is calculated see the Methodology Section.

In 2013 DST made ambitious targets to quadruple in the number of Indian papers appearing in the "top impact making journals" by 2020.[9] Indian researchers are progressing towards this target, in 2011 13,547 or 29.0% of all

[14] Ministry of Science and Technology, (2013). *Science, Technology and Innovation Policy 2013*. New Delhi.

Indian papers were published in the top quartile of journals by JIF, by 2016 this number of papers had increased to 21,038 or 32.0% of all Indian papers.

The 10 journals listed in **Table 10.2.1** are the highest impact journals, by JIF in which Indian papers have appeared in the years between 2011 and 2016 regardless of the research field. Each year only a small number of Indian publications are published in these journals, typically between 50-70 papers annually, totaling 350 papers between 2011 and 2016. Indian papers in these journals tend to have an NCI substantially higher than the world average (1.00).

Six out of the top 10 journals are published by Springer Nature, which is based in the UK. Springer Nature titles also feature prominently among the most high-impact journals for individual research fields as described in **Theme 4**. The *Lancet* journal is frequently used by Indian researchers in biological and medical related fields.

The fields to which the 10 top journals are assigned tend to be those in which India conducts a lot of research and publishes extensively – chemistry, clinical medicine, and materials science. Three medical journals – the *New England Journal of Medicine*, *Lancet* and *JAMA Journal of the American Medical Association* – account for 211 out of the 350 papers.

Notably, there are no physics or engineering journals included in the list, despite India publishing many papers in these fields. Conversely, *Nature Reviews Immunology* (an immunology journal) and *Nature Reviews Molecular Cell Biology* (a molecular biology & genetics journal) appear in the list even though overall India published relatively few papers in these fields. This is because citation behaviour varies by field. Overall, journals in clinical medicine and other biomedical related fields have higher JIFs as papers in these fields receive more citations than papers in other fields, such as physics. Thus, the lack of physics journal titles in the top 10 high-impact journals is not because Indian physicists perform inferior research.

2.2.6 Patents that cite Indian research

How Indian research is used in international patents

The total number of World Intelligence Property Organisation (WIPO) patents published between 2011 and 2016 has increased each year, except for in 2015 (**Figure 14.1**). From 2011 to 2014 about 50.0% of all WIPO patents had non-patent citations including references to academic papers. Though this proportion declining in 2015 and 2016 (**Figure 14.1**).

The International Patent System (PCT) application also showcases non-patent citations in patent applications made before 2011. The count of PCT application with non-patent cited references has been decreasing in the recent years. One explanation could be the time lag in publication of the priority application by the patent office from its filing date, and the resulting delay in the reflection of non-patent cited references in PCT data.

The number and percentage of Indian publications cited in WIPO patents published from 2011 to 2016 decreased from 2011 to 2016. This could be because the recent published Indian papers have had less time to be cited by the WIPO patents considered for this analysis. Also, DOI/Title matching was used to match scientific literature with non-patent citations of WIPO patents there is a possibility that some Indian publications even though cited in WIPO, may not be matched/identified through DOI/Title matching.

2.3 Theme 3: Mapping the Indian Research Landscape.

In this theme, we summarize the different disciplines that comprise India's research landscape. By combining Research Footprint analyses and Strength, Weakness, Opportunity, and Threat (SWOT) analyses we can construct a full picture of India's research priorities and strengths. We also compare India's research landscape to that of other countries.

Theme 3 relates to:

Section 6 Research Footprint and

Section 7 SWOT analysis.

2.3.1 In which scientific fields is Indian research focused?

A Research Footprint analysis provides a distinct view of the country’s research activities based on the number of papers published in each research field. Sharp peaks indicate a field with a high output of papers, while valleys indicate research fields with little research activity.

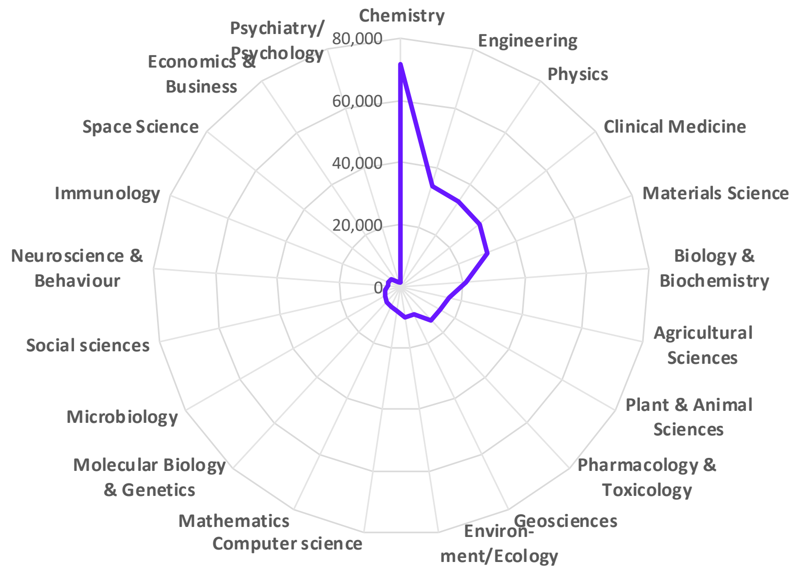

Figure 2.5a Research Footprint for India 2011 to 2016.

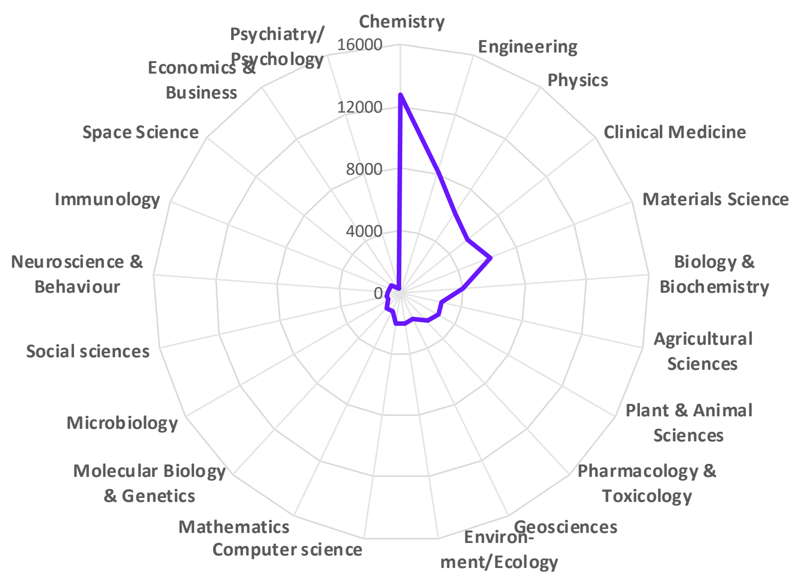

Figure 2.5b Research Footprint for India 2016.

The Research Footprint diagrams show the 22 ESI research fields around the circumference. The ESI fields are ordered by the number of papers published by India between 2011 and 2016, with the most productive field, chemistry at the top of the circle, in the 12 o'clock position, and ordered in decreasing number of papers clockwise around the plot (**Figure 2.5a and 2.5b**).

Table 2.6 Papers published in each research field by Indian researchers between 2011 and 2016

Field code	Research field	Rank	2011-2016 Number of papers	2011-2016 % of all Indian papers	2016 Number of papers	2016 % of all Indian papers
ALL	All fields	-	336,620	100	64,267	100
CHE	Chemistry	1	71,493	21.2	12,779	19.9
ENG	Engineering	2	34,092	10.1	8,056	12.5
PHY	Physics	3	32,942	9.8	6,154	9.6
CLM	Clinical Medicine	4	32,251	9.6	5,479	8.5
MTS	Materials Science	5	29,677	8.8	6,143	9.6
BBI	Biology & Biochemistry	6	21,130	6.3	3,958	6.2
AGS	Agricultural Sciences	7	15,941	4.7	2,730	4.2
PLA	Plant & Animal Sciences	8	14,626	4.3	2,754	4.3
PHT	Pharmacology & Toxicology	9	14,533	4.3	2,479	3.9
GSC	Geosciences	10	10,080	3.0	1,838	2.9
ENE	Environment/Ecology	11	10,041	3.0	2,020	3.1
CPS	Computer science	12	7,929	2.4	2,026	3.2
MAT	Mathematics	13	7,061	2.1	1,297	2.0
MOL	Molecular Biology & Genetics	14	6,747	2.0	1,358	2.1
MIC	Microbiology	15	5,692	1.7	924	1.4
SSS	Social sciences	16	5,304	1.6	966	1.5
NEB	Neuroscience & Behaviour	17	4,327	1.3	825	1.3
IMU	Immunology	18	4,251	1.3	826	1.3
SPA	Space Science	19	3,969	1.2	741	1.2
ECB	Economics & Business	20	1,529	0.5	320	0.5
PSS	Psychiatry/Psychology	21	1,431	0.4	320	0.5
MUL	Multidisciplinary	22	675	0.2	144	0.2

What are India's main research focuses?

The most productive fields for India are the physical sciences, applied sciences and technology; i.e. those areas that support the domestic economic agenda (**Section 6**).

Figure 2.5a shows that for the time period 2011 and 2016, India published more papers in chemistry than in other fields. Chemistry papers alone accounted for 21.2 % of all papers published by Indian researchers. The second most productive field of research is engineering (10.1), with about half the output of chemistry.

The trend for India's main research focuses for the year 2016 was similar to that for the time period 2011-2016. **Figure 2.5b** shows that for the year 2016, India published more papers in chemistry than in other fields. Chemistry papers alone accounted for 19.9 % of all papers published by Indian researchers. The second most productive field of research is engineering (12.5%), with about half the output of chemistry.

With around 3.0% to 10.0% of Indian papers between 2011 and 2016 are physics, and the applied fields of engineering, clinical medicine, materials science, agricultural sciences pharmacology & toxicology and computer science. Researchers in pharmacology & toxicology and computer science are most likely to collaborate with industry (**Section 12**) demonstrating that a proportion of the Indian workforce is focusing on fields with a proven history of, and potential for tech-transfer.

Fields in which Indian researchers publish fewer papers, accounting for around 2.0% or less of all Indian papers, are biomedical related fields, like microbiology and immunology and fields that worldwide have low annual outputs of papers compared to other fields, such as economic & business and space science.

How is India's research focus changing?

India's annual output of research publications across all fields grew by more than a third between 2011 and 2016 (36.5%) (**Figure 5.1.1**). However, the fields in which it publishes most frequently have generally remained the same. As of 2016, India still published more papers in chemistry than in other fields, although growth in its output of engineering and materials science publications has been faster than in other fields (**Figure 6.1-6.6**). See details for individual fields in **Theme 4**.

2.3.2 In which fields of science does India excel?

To compare differences in citation impact and output between research fields we use a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis.

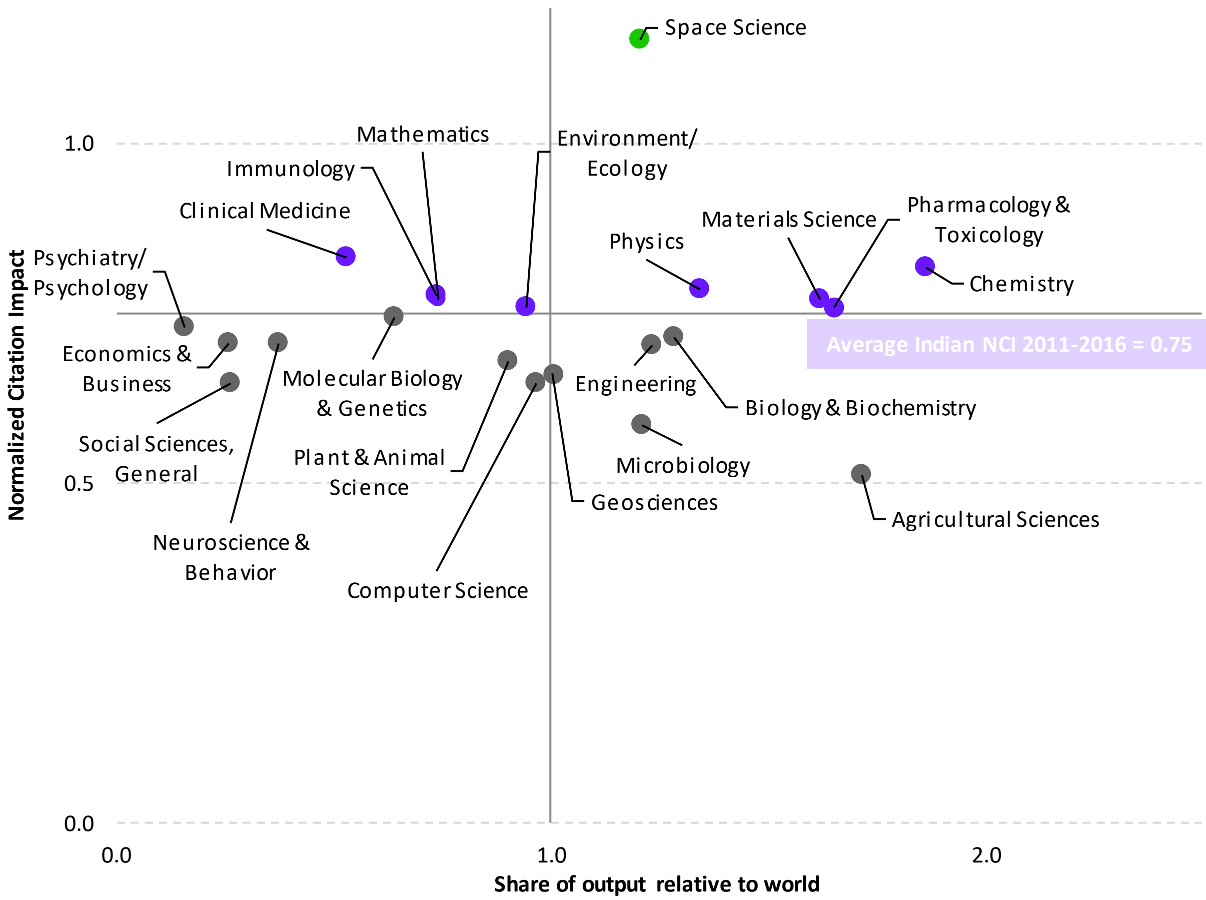

Figure 2.7a SWOT analysis for Indian research between 2011 and 2016

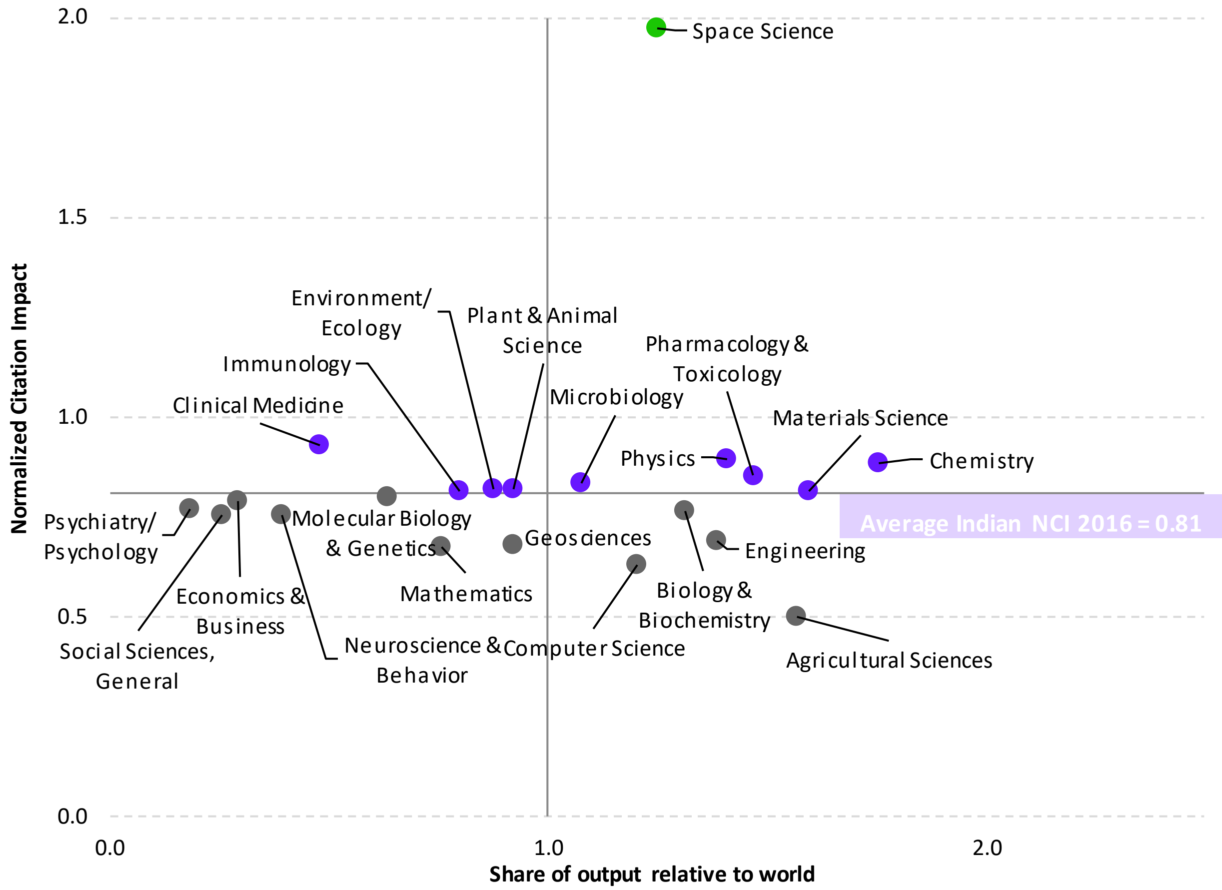

Figure 2.7b SWOT analysis for Indian research 2016

The relative citation impact of different fields is determined by comparing the average Normalised Citation Impact (NCI) in each field with the NCI of all Indian papers. The NCI for all Indian papers increases by around 2.0% each year, and the average value for 2011 to 2016 is 0.75 (**Table 5.1.7**) The citation impact can also be compared to the world average NCI 1.00.

The relative share of output in a field is determined by dividing the percentage of all Indian research that is assigned to that field by the percentage of all global research that is assigned to the same field. A relative output greater than 1, therefore, indicates that India has a higher percentage of research in that field than the world average. A value of less than 1 indicates that India publishes proportionally fewer papers in that field compared to the world average.

- Fields in the top right quadrant of **Figure 2.7a** and **Figure 2.7b** represent research strengths. These are areas of high citation impact, and high output compared to other Indian fields.
- Fields in the bottom left quadrant of **Figure 2.7a** and **Figure 2.7b** represent fields of weakness. These fields are poorly cited relative to similar research. However, these subjects do not form a significant part of Indian research activities.
- Fields in the top left quadrant of **Figure 2.7a** and **Figure 2.7b** represent opportunities. These are areas of high citation impact relative to other Indian fields of research but with a lower share Indian research activity.
- Fields in the bottom right quadrant of **Figure 2.7a** and **Figure 2.7b** are under threat due to underperforming citation impact but form a significant part of India's research portfolio.

How do Indian fields of research compare to each other?

The SWOT graphs for the Indian research landscape do not change much between 2011 and 2016 (**Figure 7.1-7.6**). Most fields are grouped around average values of impact and output and few research fields move between the quadrants of the SWOT graph.

All fields remain below the world average citation impact (NCI of 1.00) except space science in 2016 (**Figure 7.6**) and psychiatry/psychology in 2011 (**Figure 7.1**). However, these cases are generally driven by papers arising from highly-collaborative multinational projects and remain the exception rather than the rule.

- Consistent **strengths** are chemistry, physics and materials science. Chemistry is the most productive field, with an output of around twice the world average share. The impact is also stable and above the Indian average.
- Consistent **threats** are agriculture sciences, microbiology, engineering and biology & biochemistry. Agriculture sciences has the highest output of any of the threat fields, and consistently has the lowest NCI (around half the world average). Microbiology has impact and output that keep them in the threat quartile, unlike biology & biochemistry and engineering which has a higher impact, bringing it close to be a strength.
- Consistent **weaknesses** are psychiatry/psychology and social sciences. These fields are consistently among the fields with the lowest output of papers and those few papers have an exceedingly low impact. Except for 2011 when psychiatry/psychology exceeded world averages.
- Consistent **opportunities** are clinical medicine. Clinical medicine has a proportionally low output of papers compared to world average share. It is an opportunity as what research India does in the field is of higher impact than a lot of other Indian research conducted.

There are few examples of changes between the quadrants of the SWOT diagram that are maintained for more than a year. The encouraging exception is pharmacology & toxicology moving from being a threat to a strength in 2013, demonstrating that in this field the high output, is matched by an improving citation impact.

Smaller changes in the impact and output of plant & animal sciences(PLA) has shown positive progress having moved from opportunity to weakness and finally becoming a strength in 2016, although output and impact remain close to the averages. Similar changes are observed for geosciences (GSC), computer science and engineering which are very close to the average for both impact and output.

Low output fields, relative to both India and the world, cluster around the average impact, often move between being an opportunity or weakness or the other way around depending on small changes in impact. The fields that do this are mathematics, molecular biology & genetics, neuroscience & behaviour, immunology and economics and business. Though in later years, around 2014 (**Figure 7.4**) more of these fields are found to be weaknesses rather than opportunities.

The most erratic changes between quartiles of the SWOT graph are exhibited by space science which many times flips between a strength and threat, with an exceedingly high NCI of around twice the world average in 2014 (**Figure 7.4**) and 2016 (**Figure 7.8**). In other years, the NCI of this field is around or just below the world average of 1.00. Again, these changes in impact are due to a small number of very highly-cited space science papers.

Theme 4 provides a detailed examination of how impact and output changed for individual research fields between 2011 and 2016.

2.3.3 India's research landscape compared to other countries research landscapes

By comparing the shape of Research Footprints for different countries we can see what fields of scientific research different countries prioritize.

India compared to other emerging countries

Like India, emerging countries focus on the physical sciences, fields with the technological application or are economically advantageous. Chemistry is usually the field with the highest output field and engineering, physics and clinical medicine are preferred to the social and some biomedical sciences (**Section 6.1-6.9**) during the study period of 2011-2016. Materials science and biology & biochemistry are fields in which India and China were relatively more productive, while Argentina, Brazil and Mexico had more focus on fields like plant & animal science. In 2016, India had 19.9% of total output published in chemistry, followed by engineering (12.5%) and physics (9.6%). This is generally on par with BRICS countries on average, where they published 16.7%, 11.5% and 9.3% papers published in fields of chemistry, engineering and physics, respectively.

India compared to established countries

The major difference between India and the established countries' Research Footprints is that for established countries clinical medicine is always the highest output field (**Section 6.1-6.9**). Beyond clinical medicine, established countries do proportionally more social and biomedical sciences and far less chemistry and industrially relevant fields of engineering, materials science and agricultural sciences. In 2016, G8 countries only had almost one fifth (19.9%) papers published in the field of clinical medicine, while chemistry, engineering and physics only accounted for 9.0%, 6.8% and 7.0% of total output of papers. Of the established countries, Japan is most like India as it had a relatively strong technological focus, though the field with highest output of papers was still clinical medicine (17, 303 or 22.9%) in 2016.

Emerging countries compared to established countries.

Except for China, which is only second to the USA in terms of academic output, established countries tend to produce more papers than emerging countries. The most noticeable difference between the emerging and established countries' Research Footprints is that established countries most productive field is always clinical medicine while it is rarely so for emerging countries. This is clearly illustrated by comparing the Research Footprints for the BRICS and G8 for the period of 2011-2016 and year 2016 (**Figure 2.8a and Figure 2.8b**).

The high number of clinical medicine papers published by the established countries may be due to the vast cost associated with running clinical trials which require large funding grants, equipment, a highly educated workforce in both medicine and academia, hospitals and long-time frames which are beyond the resources of emerging countries. This situation may be changing for emerging countries like India, China, and Brazil as pharmaceutical corporations are increasingly conducting clinical trials in emerging markets in partnership with local clinical research organisations.[10]

The Research Footprints of established countries are more alike than that of emerging countries. Established countries tend to focus on the same fields, while the emerging countries are more diverse. The emerging countries appear to be more affected by regional variations that possibly arise from regional economic or environmental factors. For example, the Central and South American comparator countries, Mexico, Argentina and Brazil have a high-output in plant & animal sciences relative to other fields. Potentially this is because these countries are large

[10] www.pharmaceutical-technology.com/features/featurenew-frontiers-outsourcing-clinical-trials-in-emerging-markets-4939225/ - accessed 21 June 2018

food producers. A further example is that Taiwan and South Korea, leaders in device technology, publish proportionally more computer science than other emerging countries.

Alternatively, variation in emerging countries' research priorities could be due to the smaller size of the research landscapes. This means that there are fewer resources for research programs across all fields, and therefore these countries strategically select fields in which to developed expertise. Established countries, with greater resources, can afford to be less directed in their support of science, through strategic decisions around funding will still be made.

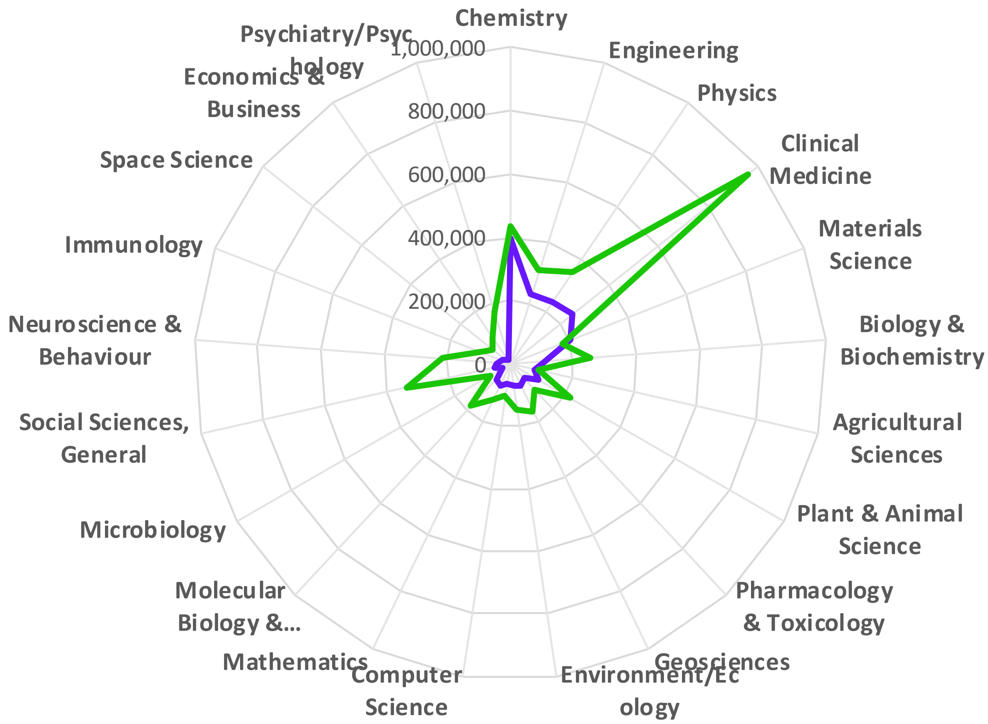

Figure 2.8a Research Footprints for BRICS (purple) and G8 (green) for papers published 2011 to 2016.

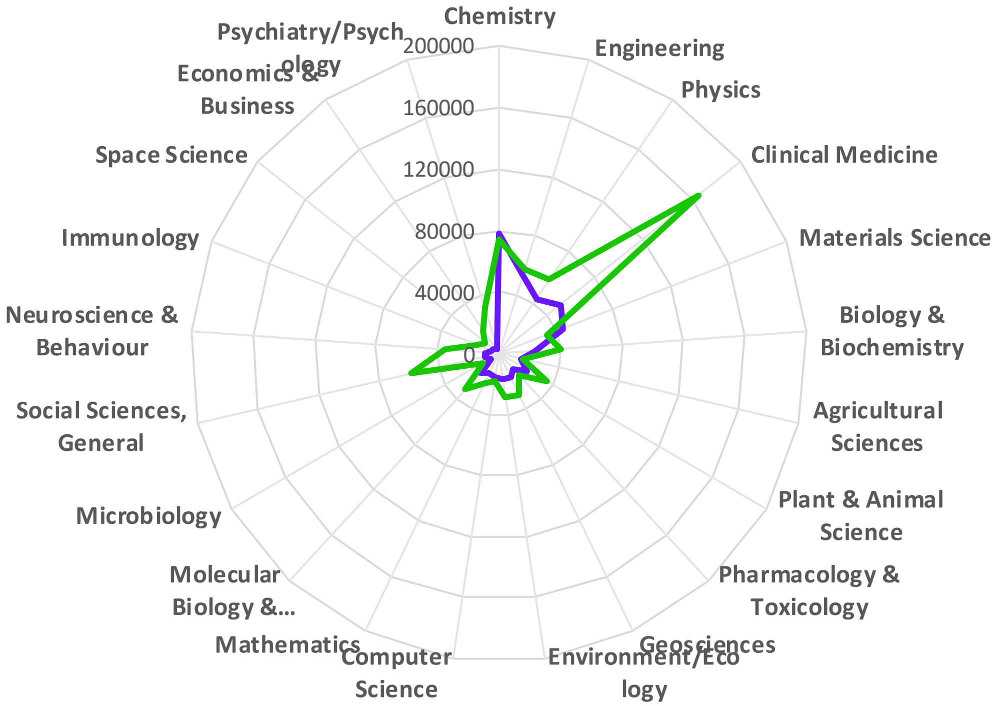

Figure 2.8b Research Footprints for BRICS (purple) and G8 (green) for papers published in 2016

2.4 Theme 4: Research Field Profiles

This Theme presents how Indian research perform in different research fields between 2011 and 2016 across all key indicators.

The 22 research fields are ordered by the number of papers produced by India in each category. Though we have included the Multidisciplinary category in the analysis results, the further interpretation/commentary was eliminated due to its errant citation behaviour owing to changing methodological definitions meaning that it is not comparable over time (see full description in **Section 4.2.3**).

Theme 4 relates to:

Section 5.2-5.23. Comparative bibliometric analysis by 22 ESI categories

Section 9.2-9.23 International collaboration by 22 ESI categories

Section 10.2.2-10.2.23 Journal analysis by 22 ESI categories

Section 13 Highly-cited papers by 22 ESI categories

2.4.1 Chemistry

Indian researchers publish more papers in Chemistry than in other fields. The citation impact of these papers is growing due to the increasing domestic excellence rather than because of international collaboration.

Number of papers

Chemistry is India's most productive field of research and Indian researchers publish around 7.0% of all chemistry papers worldwide. Since 2011 only China and USA published more papers in this field (**Figure 5.2.2**). India's rank in Chemistry improved from 5th in 2011 to 3rd in 2016. The share of world output in Chemistry also increased from 6.8% (2011) to 7.2% (2016).

As seen in the Research Footprints (**Figure 6.9**), chemistry is a research priority for India and other emerging countries. Global growth in the number of chemistry papers is primarily driven by emerging countries and in 2014 the BRICS countries' output of chemistry papers overtook the G8 (**Figure 5.2.1**).

Citation impact

Encouragingly, India's growth in chemistry output is matched by a steady increase in citation impact. As of 2016, India's chemistry papers have an NCI of 0.89, which is higher than its impact in many other research fields and is approaching the BRICS average of 0.93. Compared to the other emerging countries, India is seventh out of 13 countries in terms of citation impact (**Figure 5.2.6**).

Highly-cited papers

The percentage of Indian chemistry papers in the world's top 1% of most highly-cited papers increased from 0.7% in 2011 to 0.8% in 2016. There are also significant increases in the percentage of papers in the top 5% of most highly-cited papers, rising from 3.7% to 4.4% and more modest improvement in the top 10% and 25% papers (**Figure 5.2.7**). Established countries tend to produce a larger proportion of highly-cited papers than emerging countries, the successful exceptions are Spain, China, South Korea and Saudi Arabia which exceed the top 1%, 5%, 10% or 25% thresholds. Between 2011 and 2016, 444 Indian papers were published in the ten high impact chemistry journals in Indian papers were published most frequently (**Table 10.2.2**). Of these, the most frequently used was the *Journal of the American Chemical Society*. *Chemical Review* had the highest JIF (47.93) and is also among the top 10 highest impact journals that have published Indian papers, regardless of field (**Table 10.2.1**).

International collaboration

Indian chemistry is primarily a domestic endeavour, as chemists based in India rarely collaborate internationally. Between 2011 and 2016 across all research fields 23.6% of Indian papers had an international co-author while in chemistry only 20.7% did (**Figure 5.2.9**). Such low rates of collaboration combined with improving performance, suggests that India is building a strong research base in Chemistry.

When chemistry researchers do collaborate, they do so with scientists in both established countries, most frequently in North America and Europe, but also with emerging countries such as South Koreas and Saudi Arabia (**Figure 9.2.1**). India co-authors the most papers with the USA. The international institutions that collaborate most with India are located across the globe (**Table 9.2.2**). Of India's top 10 collaborating institutions, three are Saudi Arabian (King Saud University, King Abdulaziz University and King Fahd University Petroleum Minerals and Malaysia's University Sains Malaysia.

Highest cited paper

Chakrabarty, R; Mukherjee, PS; Stang, PJ (2011), Supramolecular Coordination: Self-Assembly of Finite Two- and Three-Dimensional Ensembles, CHEMICAL REVIEWS, Times Cited: 1,000

2.4.2 Engineering

There have been very rapid increases in the number of Indian engineering papers published annually, possibly driven by government initiatives to encourage engineering education and research.

Number of papers published

India's output of engineering publications grew rapidly between 2011 and 2016. India, in 2016, was the 4^{th} most productive country in this field worldwide, after China, USA, and UK as comapred to 10^{th} position in 2011. In 2011, engineering papers from India made up 4.1% of all engineering papers published globally and by 2016 that percentage had increased to 5.7% (**Figure 5.3.2** and **Table 5.3.2**). This may be the result of targeted government funding to increases the number of engineering doctoral students, and strategic funding provided via government various initiatives. As in chemistry, the number of engineering papers published by the established countries has been relatively stable or even fallen while emerging countries have become more productive (**Figure 5.3.1**).

Citation impact

The citation impact of Indian engineering research has been persistently low (0.69 in 2016), with an average NCI of 0.70 for the time period 2011 and 2016 (**Figure 5.3.6**). India's low citation impact is not unusual for the emerging countries, which, tend to have an NCI between 0.50 and 0.80. As in other fields, the established countries generally have a higher NCI with Australia, UK, Italy, and Switzerland surpassing the world average NCI (1.00) (**Table 5.3.6**).

Highly-cited papers

Few Indian engineering papers become highly-cited and to-date India has never attained world average thresholds for percentages of papers in the world's top 1%, 5%, 10% or 25% of most highly-cited papers (**Table 5.3.7**). The Indian research that is accepted by high impact journal engineering journals tends to relate to renewable energy technology and the removal of hazardous substances from the environment (**Table 10.3.9**). This is exemplified by the 590 Indian papers that appear in the high impact engineering journal *Renewable & Sustainable Energy*.

The percentage of India's papers in in the world's top 1%, 5%, 10% and 25% of most highly-cited papers in year 2016 was 0.6%, 3.3%, 6.2% and 17.4% respectively.

International collaboration

Indian engineering researchers are producing more papers, but are publishing a smaller percentage of internationally co-authored papers. As of 2016, less than one-fifth of Indian engineering papers (18.6%) had an international co-author (**Figure 5.3.9**). It is likely that the actual number of internationally co-authored papers has remained the same, but as the total number of Indian engineering papers increased the international papers represent a smaller percentage of the total. This hypothesis is supported by looking at the ten countries India most frequently collaborates with (**Table 9.3.1**), in each case the collaborations have become more, rather than less productive, producing a higher number of papers each year. The fastest growing collaboration is between Saudi Arabia and Indian which yielded 80 papers between 2011 and 2013, increasing to 223 papers between 2014 and 2016.

Highest cited paper

Gupta, VK; Agarwal, S; Saleh, TA (2011), Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal, JOURNAL OF HAZARDOUS MATERIALS, Times Cited: 362

2.4.3 Physics

India has shown steady, consistent growth in the number and citation impact of its physics papers. The opposite of many other emerging countries which have had falling output and impact.

Number of papers

India is one of the few emerging countries to have increased the number of physics papers it publishes annually. As of 2016, India accounts for 5.8% of all physics papers published worldwide and it is the eighth most productive nation, ahead of many established countries such as Canada (**Table 5.4.2**). Of the emerging countries, only China, with more than 20.0% of the world's output, and Russia published more papers.

Citation impact

Growth in output is matched by a growth in impact. The NCI of Indian physics papers has increased from 0.75 in 2011 to 0.89 in 2016 (**Figure 5.4.6**). If citation impact continues to increase at the same rate, Indian physics will reach world average impact within five years. As of 2016, India has a higher citation impact than other physics intensive emerging countries (i.e. China and Russia) and of the emerging countries, only Spain has an NCI consistently above the world average of 1.00 (**Table 5.4.6**).

Highly-cited papers

Despite increasing citation impact, there is little change in the percentage of Indian physics papers that have been highly-cited (**Table 5.4.7**). India, China, and Russia all have a smaller percentage of highly cited papers compared with other emerging countries. Notably, these three countries are the most physics intensive emerging countries and it is probable that the less productive countries derive high citations from involvement in international collaboration

International collaboration is also important to Indian physics, with two of its 10 most highly cited papers resulting from the CERN collaboration. About 10 Indian physics papers a year are published in high impact journals and the most frequently used journal is *Physics Reports – Review Section of Physics Letters* in which Indian researchers published 18 papers between 2011 and 2016 (**Table 10.2.4**).

International collaboration

India has a smaller percentage of internationally co-authored physics papers than the other countries analysed, excepting China (**Figure 5.4.9**). Though, in 2016 with 30.5% of Indian physics papers having at least one international co-author, international collaboration is more frequent in physics that other fields of Indian research (**Table 5.4.9**). However, the analysis also shows that smaller countries are more collaborative than larger countries across both emerging and established countries – the USA and China have some of the lowest rates of international co-authorship (**Table 5.4.9**). It may be that larger countries domestically maintain the infrastructure and expertise required to carry out and publish research which is beyond the capabilities of smaller countries. India's persistently low rate of international collaboration may be due to the large size of its research base in this field.

India mostly collaborates with established countries as well as with Russia and China (**Table 9.4.1**). The USA-India collaboration produces the most papers compared to the other countries collaborated with India, and India's most frequent collaborating organisation is the USA Department of Energy. All the top 10 collaborating institutions are from established countries except two Russian institutions: the A.I. Alikhanov Institute of Theoretical and Experimental Physics, and the Russian Academy of Sciences (**Table 9.4.2**).

Highest cited paper

Chatrchyan, S; Khachatryan, V; Sirunyan, AM; et al. (2012), Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, PHYSICS LETTERS B, Times Cited: 3,360

2.4.4 Clinical Medicine

Indian papers in clinical medicine have the highest citation impact of any Indian field of research.

Number of papers

For the time period 2011 to 2016, only 2.0% of the world's clinical medicine papers had an Indian author (**Table 5.5.2**), despite clinical medicine being India's fourth most productive field of research (**Table 2.6**). Across the world, more papers are published in clinical medicine journals than in any other field, and from the Research Footprints, we have observed that for established countries clinical medicine is the foremost research focus while emerging countries focus on engineering and physical sciences. Accordingly, all the established comparators publish more clinical medicine papers than India (**Table 5.5.2**), and India's 2.0% share of world clinical medicine papers is high for an emerging country. In year 2016, India's share of world output in clinical medicine (2%) was higher than many of the emerging countries, such as Argentina (0.4%), Indonesia (0.1%), Mexico (0.5%), Russia (0.6%), Saudi Arabia (0.7%), South Africa (0.6%) and Taiwan (1.8%).

Citation impact

Indian clinical medicine papers have a higher citation impact than Indian research in any other field. Citation impact has improved annually to a peak NCI of 0.93 in 2016 (**Figure 5.5.6**), and as of 2015, India's NCI has been higher than the BRICS average, China, Saudi Arabia, South Korea, and Taiwan (**Figure 5.5.6**). India's increasing citation impact is not a global trend, as many other countries have experienced the opposite, a reduction in NCI (**Table 5.5.6**).

Highly-cited papers

India's improved impact is paralleled by an increase in the percentage of clinical medicine papers that become highly-cited (**Table 5.5.7**). In the years 2014 and 2015, India's papers were amongst the world's top 1% of most highly-cited papers, reaching world average levels of research excellence (1.2% in 2014, and 1.0% in 2015). But in 2016, 0.7% of Indian papers were in top 1% of most highly cited papers. Despite moderate increases, India still underperforms in terms of the percentage of its papers in the world's top 5%, 10% and 25% of most highly-cited papers.

The three clinical medicine titles have the highest JIFs of any journals in which any Indian papers appear across all fields: *New England Journal of Medicine*, *Lancet* and *JAMA – Journal of the American Medical Association* (**Table 10.2.5**). The high impact journal most frequently used by Indian researchers is the *Lancet* which published 137 Indian papers between 2011 and 2016. There is a clear research focus on oncology and cancer, this being the focus of five out of the top 10 journals, which account for a total of 64 Indian papers between 2011 and 2016. This suggests oncology is an area in which Indian researchers do conduct some excellent research.

International collaboration

Indian clinical medicine research is increasingly collaborative and saw a consistent increase in the time period of analysis 2011-2016 (from 20% in 2011 to 29.2% in 2016). 29.2% of papers in the field had at least one international co-author in 2016, above both the BRICS and G20 averages (**Figure 5.5.9**).

Most of India's clinical medicine collaborations are mostly with established countries, particularly English-speaking nations (**Table 9.5.1**). This is unsurprising as the established countries have are far more research-intensive in this field. The primacy of established countries in clinical medicine is also seen at an institutional level, with five of the top 10 collaborating institutions coming from the USA and the rest, from the UK, Canada and Australia (**Table 9.5.2**).

Highest cited paper

Lozano, R; Naghavi, M; Foreman, K; et al. (2012), Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010, LANCET, Times Cited: 2,694

2.4.5 Materials Science

Indian materials scientist publishes more papers than material scientists in most other countries.

Number of papers

India is the fourth most productive country in materials science; only the USA, China and South Korea publish more papers in the field annually (**Figure 5.6.1**). Materials science is a field in which emerging countries are publishing more papers each year, while the proportion of papers coming from established countries is decreasing. This is demonstrated by the BRICS share of world output overtaking the G8 in 2012 (**Table 5.6.2**). India improved its rank in the share of world output from 6^{th} in 2011and 2012 to 4^{th} in 2013 and then remained on 4^{th} rank in 2014, 2015 and 2016.

Citation impact

The citation impact of Indian materials science research increased, to a peak NCI of 0.81 in 2016 (**Figure 5.6.6**); this is relatively high compared to Indian research in other fields, but remains below China and South Korea. Although the output of the established countries in this field is generally falling, they still produce most of the highest impact papers; Switzerland leads the world with an NCI of 1.56.

Highly-cited papers

Indian materials scientists have maintained standards of research excellence, publishing percentages of highly-cited papers close to international averages for the top 1%, 5% and 10% of most highly-cited papers. Encouragingly, in 2011 and 2013, India exceeded average percentage of papers in the world's top 25% of most highly-cited papers (**Table 5.6.7**). A further indication that the quality of Indian materials science research is improving has been yearly increases in the number of materials science papers, appearing in high-impact materials sciences journals (**Table 10.2.6**) from 14 papers in 2011 rising to 45 papers in 2016.

International collaboration

Indian rates of collaboration in materials science were around the Indian average with 22.2% of papers in this field having at least one international co-author in the time period 2011-2016(**Figure 5.6.9**). Compared to all other countries except Taiwan and China, this is very low percentage with 70.0% of papers from Switzerland, Australia, Indonesia and Saudi Arabia resulting from the international collaboration. However, materials science is a field in which India does proportionally more research compared to other countries (SWOT analysis – **Section 7**), as such there may be a large domestic research community that may not need to look abroad for intellectual input or infrastructure. India's percentage of internationally collaborative papers improved from 20.7% in 2011 to 24.3% in 2016.

While India's most frequent collaborative partner in most fields is the USA, India's most productive partnership in materials science is with South Korea; (**Table 9.6.1**) another emerging country which prioritises materials science research. Several other countries that collaborate frequently with India are located in East Asia - Japan, Taiwan, China, and Singapore - suggesting that materials science is a regional focus.

At the institutional level, Saudi Arabia's King Saud University is the most collaborative due to a remarkable recent increase in papers co-authored with Indian scientist, from 53 between 2011 and 2013 to 116 between 2014 and 2016. All the other top 10 collaborating institutions are based in Asia, except for CNRS in France (**Table 9.6.2**).

Highest Cited Paper

Roy, K; Padmanabhan, M; Goswami, S; et al. (2013), Graphene-MoS2 hybrid structures for multifunctional photoresponsive memory devices, NATURE NANOTECHNOLOGY, Times Cited: 304

2.4.6 Biology & Biochemistry

India is set to becoming one of the most productive countries in biology & biochemistry research as established countries publish fewer papers.

Number of papers

Apart from China, India leads the emerging countries in terms of the number of biology & biochemistry papers it publishes (**Figure 5.7.1**), annually producing three times more papers than the next most productive country, South Korea.

India's share of world biology & biochemistry papers increased from 4.38% to 5.20%, between 2011 and 2016 (**Figure 5.7.2**), partly due to the falling number of papers published by the USA and other established countries. As a group, the emerging countries (including India) are becoming increasingly productive in biology & biochemistry research compared established countries.

Citation impact

Growth in output is matched by modest increases in citation impact with the NCI of Indian molecular biology & genetics papers reaching 0.76 in 2016. This is a higher impact than the BRICS average NCI which has decreased primarily because of China's falling impact (**Table 5.7.6**). In biology & biochemistry, the NCI of the emerging countries tends to be below the world average, while the established countries have an above average NCI. Saudi Arabia and South Africa are the only emerging countries to have an NCI similar to the established countries, though both have a far smaller output of papers in this field than India.

Highly-cited papers

Despite biology & biochemistry being a productive field of research for India, few Indian papers become highly-cited. With less than 10 papers a year appear in high-impact journals (**Table 10.2.7**) and compared to other emerging countries, the percentage of Indian papers among the most highly-cited biology & biochemistry papers worldwide is small and has not increased significantly between 2011 and 2016 (**Table 5.7.7**).

International collaboration

Biology & biochemistry research is mostly a domestic endeavour for Indian researchers. Worldwide, India has the lowest rate of international collaboration, in 2016 only 22.9% of papers had one or more international co-authors (**Figure 5.7.9**). Emerging countries collaborate less frequently than established countries and Asian countries tend to be the least collaborative of all.

However, India's involvement in select international collaborations is increasing as each year the number of co-authored papers published with the top 10 collaborating countries rises (**Table 9.7.1**). The USA-India collaboration produces the most papers, and the Saudi Arabia-India collaboration has experienced the most rapid growth in output from 27 papers in 2011 to 115 in 2016. This growth has been driven by Saudi Arabian researchers at King Saud University, which is the international institution that collaborates most with Indian researchers (**Table 9.7.2**).

Highest Cited Paper

Uhlen, M; Fagerberg, L; Hallstrom, BM; et al. (2015), Tissue-based map of the human proteome, SCIENCE, Times Cited: 561

2.4.7 Agricultural Sciences

India publishes more agricultural sciences papers than most other counties. Papers tend to have application to Indian farming, rather than being of broader international interest.

Number of papers

In terms of the number of agricultural sciences papers published annually, since 2014 India has been the fourth most productive country; only USA, China, and Brazil publish more (**Table 5.8.3**). The USA is the only established country to publish more papers than India, and three out of the top four most productive countries are BRICS nations. In recent years the five BRICS countries produced nearly as many papers as the G8 countries combined (**Figure 5.8.1**). India's share of world output in agriculture improved from 6.3% in 2011 to 6.4% in 2016 and was highest in 2015 (7.3%) in the period of analysis.

Citation impact

With an average NCI of around 0.50, the citation impact of India's agricultural sciences has remained low, below all of the comparators (**Figure 5.8.6**). Brazil is in a comparable situation, both countries publish a large number of papers in this field but have a below average citation impact. As both countries are also among the globes largest food producers, it is highly likely that much of the agricultural science research these countries conduct will be relevant and of practical importance in the local environment rather than of international academic interest. This aligns with the Indian Government's focus on research that related to the economically important industry such as rice exports.[11]

Highly-cited papers

India publishes a larger percentage of highly-cited papers than Brazil, although both countries perform well below the world average (**Table 5.8.7**). In contrast, other productive emerging countries China and Spain, exceed the world average in terms of their NCI and the percentage of their papers that amongst the world's most highly-cited (**Figure 5.8.6** and **Table 5.8.7**).

Year-on-year, India has published a growing number of papers in the high impact agricultural sciences journals (**Table 10.2.8**) and while the total number of papers published by these titles is small, Indian papers make up a substantial proportion of the total. For example, just under a fifth of papers in *Critical Reviews in Food Science and Nutrition* and around 15.0% in *Advances in Agronomy* have Indian authors.

International collaboration

India participates in very few international collaborations in agricultural sciences research. In 2016 only 13.7% of papers had at least one international co-author, about half the average for all Indian papers (26.0%) (**Figure 5.8.9**). Of the top 10 collaborating countries, most collaborate with India on less than 20 papers a year (**Table 9.8.1**); the exception is the USA-India collaborations which yielded 118 papers in 2016.

The most frequent institutional collaborators tend to be international research organisations with a narrow agricultural purview, e.g. International Maize and Wheat Improvement Centre based in Mexico (**Table 9.8.2**). This is specific to agricultural sciences; India's most frequent collaborating organisations across all fields of science tend to be universities. The most productive collaboration is with the International Rice Research Institute (IRRI), which accounts for all India-Filipino collaborative papers.

Highest Cited Paper

[11] https://www.fas.usda.gov/data/india-s-agricultural-exports-climb-record-high - accessed 10 July 2018

Mishra, K; Ojha, H; Chaudhury, NK (2012), Estimation of antiradical properties of antioxidants using DPPH center dot assay: A critical review and results, FOOD CHEMISTRY, Times Cited: 144

2.4.8 Plant & Animal Science

India publishes few plant & animal science papers than established countries. However, there are indications that citation impact is improving.

Number of papers

The number of Indian plant & animal science papers has increased annually, reaching 2,735 papers in 2016 (3.8% of all world output) (**Figure 5.9.1** and **Figure 5.9.2**). As a field of research, plant & animal science is like agricultural sciences in that from the emerging countries, Spain, Brazil, India, and China produce the most papers. This is to be expected considering the overlap in the research fields. However, unlike the agricultural sciences, the established countries publish more papers than emerging countries in this field (**Table 5.9.2**).

Citation impact

Since 2014, there has been an upturn in India's citation impact in this field (**Figure 5.9.6**). It is too soon to confirm if this is an ongoing trend, but as of 2016 with an NCI of 0.81, India has attained the average impact for BRICS nations and has a higher impact than several other emerging countries, including Turkey, Mexico, Brazil, Argentina and South Korea. Of the emerging established countries, only Spain has an NCI consistently above the world average of 1.00; comparable to the impact of the established countries.

Highly-cited papers

The percentage of India's plant & animal sciences papers in the world's top 1% and 5% of most highly-cited papers has increased, although it has yet to achieve the world averages for either threshold (**Table 5.9.7**). Few emerging countries reach the world averages, except South Africa, Saudi Arabia with papers in the top 1%, and China in the top 10% and 25% of most highly-cited papers.

Only around 16 Indian papers a year are accepted by the highest impact plant & animal sciences journals (**Table 10.2.9**). However, compared to other fields, the total number of plant & animal science papers published worldwide is low. Therefore, India's small output still makes up a sizable proportion of the literature. For example, *Fungal Diversity*. publishes less than 50 papers a year thus Indian papers make up a substantial 9.0% of all papers.

International collaboration

Between 2011 and 2016, India has experienced a 7.0% increase in papers resulting from international collaboration, reaching 26.9%, which is above the average for India and far higher than for the related field of agricultural sciences (**Figure 5.9.9**). Worldwide, plant & animal science has become increasingly collaborative, so while its rate of collaboration has increased, India remains the least collaborative country analysed.

The USA-India collaboration is the most productive, yielding 874 papers between 2011 and 2016, double the number of papers resulting from any other collaboration (**Table 9.9.1**). Looking to the future, the USA might not maintain its position as India's most frequent collaborator, as year-on-year there is exceptional increases in the number of papers resulting from Indian collaborations with China, Japan, and Saud Arabia.

As for agricultural sciences, the International Rice Research Institute is the most frequent institution collaborator (**Table 9.9.2**). An array of different types of institution collaborate with India from the Natural History Museum London in the UK to the Chinese Academy of Sciences.

Highest cited paper

Kalia, RK; Rai, MK; Kalia, S; et al. (2011), Microsatellite markers: an overview of the recent progress in plants, EUPHYTICA, Times Cited: 208

2.4.9 Pharmacology & Toxicology

Despite the decrease in India's share of world output in the number of papers, its citation impact has improved rapidly.

Number of papers

In the field of pharmacology & toxicology, India published 2,479 papers in 2016. (**Figure 5.10.1**). During the time period of analysis 2011-2016, only Saudi Arabia and China have noticeably increased the number of papers they publish. By 2016 China's output of pharmacology & toxicology papers made up around 20.6% of global output (**Figure 5.10.2**). In the year 2016, India's share of world output in pharmacology and toxicology was 6% (as compared to 7% in 2011).

Citation impact

India's citation impact in pharmacology & toxicology improved by 27.1% between 2011 and 2016, reaching an NCI of 0.85 (**Figure 5.10.6**). If India maintains this rate of growth it will reach the world average NCI of 1.00 by 2021. This, steady growth means that India has a higher impact in this field than most other emerging countries and the BRICS average. Spain has the highest impact of any emerging country, with an NCI around 1.20, like that of the established countries which all remain above the world average.

Highly-cited paper

Except for Spain, emerging countries only sporadically attain world average percentages of papers in the top 1%, 5%, 10% or 25% of most highly-cited papers, while India has remained below the world average in all four thresholds of highly-cited papers (**Table 5.10.7**). India has shown slight increases in the percentages of papers in the top 5% and 10% of most highly-cited papers, though it is too soon to determine if this is an ongoing trend.

From 2011 to 2016, 125 Indian papers appeared in 10 high impact pharmacology & toxicology journals (**Table 10.2.10**). A number of these journals are related to drug administration, for example, the *Journal of Controlled Release* and *Advanced Drug Delivery Reviews* which is consistent which India's pharmaceutical sectors strength in generic drugs rather than developing new medicines.

International collaboration

India increasingly publishes pharmacology & toxicology papers in collaboration with other countries, and by 2016 22.0% of papers had at least one international co-author (**Figure 5.10.9**). This is low compared with most other countries but higher than the BRICS average.

The USA-India and Saudi Arabia-India collaborations are the most productive, yielding more than 100 papers year each (**Table 9.10.1**). Despite the small size of Malaysia's research base, the Malaysia-Indian collaboration is the third most productive due to a particularly strong partnership with the Universiti Sains Malaysia and the International Medical University (**Table 9.10.2**).

Unusually we also see an industrial collaborator in the top 10 collaborating institutions (**Table 9.10.2**). Novartis the multinational pharmaceuticals company, is listed as two entities - one based in the USA and the other Switzerland. Together, both entities of Novartis produce 89 papers and account for the most of the papers from the Switzerland-India collaboration.

Highest cited paper

Acharya, S; Sahoo, SK (2011), PLGA nanoparticles containing various anticancer agents and tumour delivery by EPR effect, ADVANCED DRUG DELIVERY REVIEWS, Times Cited: 308

2.4.10 Geosciences

India has published a lot of geosciences papers for an emerging country in a field dominated by established countries

Number of papers

Most emerging countries published less than 1,000 geosciences papers each year during the time period of the analysis. The exceptions were Spain, Russia and China (**Figure 5.11.1**). India is among these exceptions, publishing around 1,800 papers a year since 2014, which is 3.9% of all geosciences papers published worldwide each year. Generally, the established countries publish the most geosciences papers, and the USA has the highest yearly output with around 30.0% of the world share of papers followed by Germany and the UK with around 10.0% each (**Figure 5.11.2**).

While India's output of papers increased from 1,451 in 2011 to 1,838 in 2016, India's share of world output slightly decreased from 4% to 3.8%.

Citation impact

The citation impact of Indian geoscience papers remained nearly static between 2011 and 2016, with an average normalised citation impact (NCI) of 0.66 (**Figure 5.11.6**). This is below most other countries, though due to the small number of papers published by most emerging countries an accurate picture of their citation impact cannot be determined. Of the emerging countries that produce more than 1,000 papers, Spain was the only one to have an above world average impact with an NCI above 1.00, while China has seen a decrease in impact. All established countries have achieved and maintained NCI of above the world average.

Highly-cited papers

India publishes very few papers that become highly-cited, and the percentage of its papers which make the world's top 1%, 5%, 10% and 25% of most highly-cited papers is consistently low (**Table 5.11.7**). Some emerging countries produce a higher percentage of highly-cited papers, however as the total number of geosciences papers are low it is hard to determine if the perceived research excellence comes from collaboration, a handful of very highly-cited papers or consistent excellence in the geosciences literature. However, India does show some indications of research excellence, with around 45 Indian papers appearing in high impact geosciences journals each year (**Table 10.2.11**).

International collaboration

As a field, geoscience is highly collaborative, over half of the papers in this field from emerging economies (except Turkey, China and Russia) have co-authors from different countries. However, India is the least collaborative of the comparator countries with less 32.4% papers having at one or more international co-author in 2016(**Figure 5.11.9**).

India's most frequent collaborators are the established countries, China and South Africa (**Table 9.11.1**); the USA-India collaboration produces over 10.0% of all Indian geoscience papers. The top 10 collaborating institutions are exclusively located in France and the USA, except for the Chinese Academy of Sciences (**Table 9.11.2**).

Highest cited paper

Bolch, T; Kulkarni, A; Kaab, A; et al. (2012), The State and Fate of Himalayan Glaciers, SCIENCE, Times Cited: 319

2.4.11 Environment/Ecology

India publishes more environment/ecology papers than most other emerging countries

Number of papers

India published 2,020 environment/ecology papers in 2016, that is 3.6% of all papers in the field worldwide (**Figure 5.12.1** and **Figure 5.12.2**). Only China and Spain publish significantly more papers than India, and most emerging countries publish less than a 2.0% share of papers in the field. The most productive countries are established, led by the USA with around a 30.0% share of world output (**Table 5.12.2**).

Citation impact

Indian citation impact in environment/ecology field is steadily increasing; in 2016 India has exceeded the BRICS average NCI (0.82) (**Figure 5.12.6**). Among the emerging countries, only Brazil and Spain have a higher NCI.

Highly-cited papers

Each year India publishes more highly-cited papers. Since 2015, 1.0% of India's papers were amongst the world's top 1% of most highly-cited papers, indicating performance equivalent to the world average (**Table 5.12.7**). India's most highly-cited environment/ecology papers focus on the removal of pollutants from water, consistent with the Government's agenda of decontaminating the river Ganges (**Section 13**).

From 201 to 2016, Indian authors contributed around 15 papers a year to high impact environment/ecology journals (**Table 10.2.12**). The journal with the highest JIF of 19.30 was *Nature Climate Change* which published 13 Indian papers.

International collaboration

Environment/ecology is a field where large countries tend to have very low rates of international collaboration, as exemplified by the USA and China. Broadly, the most collaborative countries are small and established. India has consistently had the lowest rates of international collaboration, 28.6% of Indian papers in 2016 had one or more international co-authors. Brazil collaborates on nearly twice this proportion of papers (**Figure 5.12.9**), which may explain Brazil's higher citation impact (**Figure 5.12.7**).

Of India's top 10 collaborating countries, three are emerging Asian countries: Japan, China, and South Korea (**Table 9.12.1**). Collaborations between neighbouring countries may be due to regional similarities in the local environment and ecology. At an institutional level, collaborations are mostly with institutions in established countries, apart from the Chinese Academy of Sciences and King Saud University in Saudi Arabia (**Table 9.12.2**).

Highest cited paper

Gupta, VK; Agarwal, S; Saleh, TA (2011), Chromium removal by combining the magnetic properties of iron oxide with adsorption properties of carbon nanotubes, WATER RESEARCH, Times Cited: 310

2.4.12 Computer Science

India has the potential to become one of the world's most productive countries in computer science research.

Number of papers

In 2016, India published 2,026 papers in computer science; a huge increase from 860 papers in 2011 (**Figure 5.13.1**). Over six years India has overtaken most of the emerging and established countries in terms of the number of papers published annually, moving from thirteenth out of 23 comparator countries to fifth (**Table 5.13.3**). This growth is much faster than the other countries, except China.

Citation impact

The massive increase in Indian computer science papers has not had a detrimental affected on India's citation impact. Between 2011 and 2016 the average NCI has remained stable around 0.65 (**Figure 5.13.6**). For countries included in the analysis, papers in computer science have a low NCI such that India's impact is only just below that of the established countries and comparable to other emerging countries.

Highly-cited papers

In the most recent years analysed, 2015 and 2016, India published an above average percentage of papers in the world's top 1% and 5% of most highly-cited papers (**Table 5.13.7**). Furthermore, India's output of computer science papers in high impact journals has increased annually, reflecting an improvement in the quality of Indian research in this field (**Table 10.2.13**). The most frequently used high-impact journal is *Bioinformatics*, which published 39 Indian papers between 2011 and 2016.

International collaboration

India co-authored a smaller percentage of computer science papers with international co-authors in 2016 (24.7%) than it did in 2011 (29.2%) and it is now the least collaborative country globally (**Figure 5.13.9**). India most frequently co-authors papers with computer science researchers located in the USA, China, and UK (**Figure 9.13.1**).

Of the top 10 international collaborations, India's collaborations with emerging counties are becoming increasingly productive. The Saudi Arabia-Indian collaboration is the most impressive example, starting with just two papers in 2011 rising to 31 in 2015 (**Table 9.13.1**). It is likely that the Saudi Arabia-Indian collaboration will become increasingly productive since there is a memorandum of understanding between India's Centre for Development of Advanced Computing (C-DAC) and Saudi Arabia's King Abdulaziz City for Science & Technology (KACST) on cooperation in Information Technology and Services.[12] Another example is the Singapore-India collaboration, which involves researchers from three out of six of Singapore's public universities (**Table 9.13.2**).

Indian computer science research has also attracted an industrial partner, the USA computer multinational IBM which with Indian scientists co-authoring up to nine papers a year (**Table 9.13.2**) demonstrating the tech-transfer potential of the field.

Highest cited paper

Das, S; Suganthan, PN (2011), Differential Evolution: A Survey of the State-of-the-Art, IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, Times Cited: 624

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[12] Memorandum of Understanding between King Saud, Riyadh, Kingdom of Saudi Arabia and Indian Institute of Science, Bangalore, India for Co-operation in the Field of Research & Education, (2010). Available from www.mea.gov.in/Portal/LegalTreatiesDoc/SA10B2052.pdf - accessed 27 July 2018

2.4.13 Mathematics

Indian researchers are increasingly collaborating with other emerging countries in co-authoring mathematics papers.

Number of papers

Compared to other research fields, mathematics has a relatively low annual output of papers. USA (22%) and China (22.1%) publish the most papers, together accounting for 44.1% of all papers in mathematics field in 2016. India published 900 papers in 2011 increasing to around 1,300 in 2016 (**Figure 5.14.1**), and sustaining a 3.0% share of all mathematics papers published worldwide (**Figure 5.14.2**).

Citation impact

Unfortunately, India's citation impact in mathematics decreased between 2011 and 2016, reaching a minimum NCI of 0.67 in 2016 (**Figure 5.14.6**) which is low than for most other countries. The highest NCI papers are published by Italian mathematicians and other European based researchers.

Highly-cited papers

India is approaching world averages for percentages of mathematics papers in the top 1%, 5%, 10% and 25% of most highly-cited papers (**Figure 5.14.7**). The number of Indian mathematics papers that are accepted by high impact journals is low, around 10 a year (**Table 10.2.14**). The most Indian papers appear in *Complexit*y, 43 between 2011 and 2016 making up about 13.0% of papers published by the journal.

International collaboration

Indian mathematicians are more collaborative than Indian researcher in other fields. 38.7% of mathematics papers have one or more international co-authors in 2016 which exceed average collaboration rates for the G20 (34.3%) and BRICS groups (30.4%), and for countries like China (27.1%) and Russia (29.7%), which have a high annual output of mathematics papers (**Figure 5.14.9**).

As consistently seen in the other fields, the USA-Indian collaboration produces the most mathematics papers, however, next four most productive collaborations are with Saudi Arabia, China, South Korea and Turkey – emerging countries (**Table 9.14.1**). Furthermore, the institutions that collaborate most frequently with India are often located in emerging countries. Thus, at a country and institutional level, Indian mathematicians are increasingly collaborating with researchers in emerging countries (**Table 9.14.1 and Table 9.14.2)**.

Highest cited paper

Haubold, HJ; Mathai, AM; Saxena, RK (2011), Mittag-Leffler Functions and Their Applications, JOURNAL OF APPLIED MATHEMATICS, Times Cited: 103

2.4.14 Molecular Biology & Genetics

For six years India has published more biology & genetics papers than the majority of other established countries.

Number of papers

Out of all the countries analysed, India ranked fourteenth in terms of annual output of molecular biology & genetics papers (**Table 5.15.3**). In the most productive year, 2016, India published 1,358 molecular biology & genetics papers, around 2.5% of the world's total output in this field (**Figure 5.15.1**). This is less than the established countries, but compared to other emerging countries, only South Korea, Spain and China publish more papers than India.

Citation impact

From 2011 to 2016, India's citation impact has remained steady with an NCI around 0.80 (**Figure 5.15.6**). This is higher than the BRICS average for molecular biology & genetics papers, which has fallen in recent years as China's citation impact has declined. However, India's NCI is still lower than all 23 comparator countries as over half of the emerging comparator countries have an NCI above the world average of 1.00.

Highly-cited papers

Twice, in non-consecutive years 2011 and 2014, India exceeded the world average percentage of papers in the top 1% of most highly-cited papers (**Table 5.15.7**). However, this level of research excellence is not maintained in other years.

Annually, 4 to 13 Indian papers are published in the highest impact molecular biology & genetics journals. The journal most frequently used by Indian researchers is *Nature Genetics*, which published 29 Indian authored papers between 2011 and 2016 (**Table 10.2.15**).

International collaboration

As of 2016, a third of Indian of molecular biology & genetics papers had at least one international co-author (**Figure 5.15.9**). This is a higher rate of collaboration than China and the average for Indian research across all field (23.6%).

The list of India's top 10 collaborating countries comprises established countries, geographically close Asian countries, and Saudi Arabia (**Table 9.15.1**). The USA-India collaboration is four times more productive in terms of the number of papers published than the next most productive collaborations between the UK and India or Germany and India. The prevalence of the USA-India collaboration is seen at the institutional level, with six out of the top 10 collaborating organisation based in the USA, including esteemed universities Harvard and Johns Hopkins (**Table 9.15.2**).

Highest cited paper

Klionsky, DJ; Abdalla, FC; Abeliovich, H; et al. (2012), Guidelines for the use and interpretation of assays for monitoring autophagy, AUTOPHAGY, Times Cited: 1,638

2.4.15 Microbiology

India is publishing fewer microbiology papers than it used to, however recent papers have a much higher citation impact.

Number of papers

India researchers published fewer microbiology paper in 2016 (924) than they did in 2011 (941), in recent years falling below 1,000 papers annually (**Figure 5.16.1**). At the same time, other countries (notably the established countries and Brazil) have increased their output of microbiology papers. Consequently, India's world share of papers published in the field has decreased from a maximum of 5.36% in 2012 to 4.40% in 2016 (**Figure 5.16.2**).

Citation impact

The citation impact of Indian microbiology has increased rapidly from a very low NCI of 0.47 in 2011 to 0.83 in2016 (**Table 5.16.6**). As of 2016, Indian microbiology papers have a higher citation impact than those from most of the other emerging countries, including the most productive countries Brazil and China. However, established countries still lead the world in terms of impact and most have a citation impact of above the world average NCI of 1.00.

Highly-cited papers

India's increasing average citation impact in microbiology could be driven by the increasing rates of highly-cited papers. In 2016, 1.3% of Indian microbiology papers were among the world's top 1% of most highly-cited papers (**Table 5.16.7**). This is particularly impressive as in previous years the percentage of papers was very close to zero.

Consistent with the small number of microbiology paper authored by Indian scientists, annually 10 or fewer papers are published in high impact journals (**Table 10.2.16**).

International collaboration

Rates of international co-authorship on Indian microbiology papers have grown by 10.0% in six years from 18.5% in 2011 to 28.5% in 2016 (**Table 5.16.9**). Despite this growth, India remains the least collaborative of the countries analysed.

Collaborations between USA-Indian researchers have produced the most papers between 2011 and 2016. Other top collaborating countries are established countries, other Asian countries and Saudi Arabia (**Table 9.16.1**). The same countries are represented at an institutional level.

The Indian-Italian collaboration shows the most growth. The partnership accounted for 0.2% of Indian papers with an international collaboration in 2011 rising to 3.0% in 2016. The reason for this increased productivity can be seen at an institution level where a collaboration between Indian researchers and the University of Pisa in Italy only started producing papers in 2015, but within a year had yielded 20 papers (**Table 9.16.2**). The most papers resulting from an institutional collaboration in a single year.

Highest Cited Paper

Mutreja, A; Kim, DW; Thomson, NR; et al. (2011), Evidence for several waves of global transmission in the seventh cholera pandemic, NATURE, Times Cited: 200

2.4.16 Social Sciences, General

India and other emerging countries undertake very little social sciences research compared with established countries.

Number of papers

Each year India publishes around 900 papers or 1.0% of all papers published globally in social sciences (**Figure 5.17.1** and **Figure 5.17.2**). All established countries, led by the USA and the UK, generally produce more papers than emerging countries. Overall emerging countries produce a very small proportion of social sciences research, even China the most productive of the emerging country (both in social sciences and across all fields) only published 4,145 papers in 2016 (**Figure 5.17.1**).

Citation impact

Generally, established countries have an NCI above the world average 1.00 and emerging countries an NCI below 1.00. India has seen a large increase in citation impact, from an NCI of 0.59 in 2011 to 0.75 in 2016 (**Table 5.17.6**), which is around the India average across all research fields.

Highly-cited papers

India produces a very small number of highly-cited papers, consistently below the world average percentages of highly-cited papers (**Table 5.17.7**). China is the only emerging country to publish enough highly-cited papers to attain international thresholds of excellence.

Around 12 Indian papers a year are included in high-impact social sciences journals (**Table 10.2.17**). Of the top 10 highest impact journals in which Indian papers appeared, three are related to epidemiology research including the most frequently used journal - *International Journal of Epidemiology* - with included 28 Indian papers between 2011-2016.

International collaboration

The social sciences are among India's most internationally collaborative research fields. Nearly half of Indian papers (43.7%) have with one or more international co-authors in 2016 (**Figure 5.17.9**). Remarkably, social sciences is a field in which India's percentage of international collaborative papers in 2016 (43.7%) was higher than G8 (25.3%), G20 (23.4%) and BRICS groups (41%). India most frequently collaborates with established countries, China and South Africa. By far the most productive collaborations are with the USA and UK (**Table 9.17.1**). This is also seen at an institutional level, with seven out top 10 collaborating being based in the UK and USA with the London School of Hygiene and Tropical Medicine and Harvard University the top UK and USA institutions respectively (**Table 9.17.2**). The only non-university research institution listed is the World Health Organisation, part of the United Nations.

Highest cited paper

Maulik, PK; Mascarenhas, MN; Mathers, CD; et al. (2011), Prevalence of intellectual disability: A meta-analysis of population-based studies, RESEARCH IN DEVELOPMENTAL DISABILITIES, Times Cited: 162

2.4.17 Neuroscience & Behaviour

There have been modest increases in the number and impact of Indian neuroscience & behaviour papers.

Number of papers

India has had made small yearly increases in the number of neuroscience & behaviour papers published, reaching 825 in 2016 (**Figure 5.18.1**), around 1.5% of all papers published in the field worldwide (**Figure 5.18.2**). Out of the 24 countries analysed, India is the sixteenth most productive. The productivity of India and other emerging countries (except for China) is far behind that of all the established counties.

Citation impact

The citation impact of India's neuroscience & behaviour papers has shown modest increases from an NCI of 0.53 in 2011 to 0.76 in 2016, comparable to other emerging countries like South Korea and Brazil (**Figure 5.18.6**). Though India's impact has remained below the established countries and Spain, which all have an NCI above the world average of 1.00.

Highly-cited papers

India, like most emerging countries, publishes very few highly-cited papers and never reaches world average percentages of papers in the top 1%, 5%, 10% or 25% of most highly-cited papers. India has made gains in the percentage of papers in the top 5% and 10% of highly-cited papers, in 2015 producing 2.6% and 6.6% respectively (**Table 5.18.7**).

Around eight papers a year are published by high impact journals (**Table 10.2.18**). The most frequently used journal was *Lancet Neurology*, which accepted eight Indian neuroscience & behaviour papers between 2011 and 2016.

International collaboration

Less than a third (29.7%) of Indian neuroscience & behaviour papers had at least one international co-author in 2016 (**Figure 5.18.9**). India most frequently collaborates with established countries, China and Japan (**Table 9.18.1**). The USA-India collaboration is by far the most productive, with six of the top 10 collaborating institutions based in the USA (**Table 9.18.2**).

Highest cited paper

Akerboom, J; Chen, TW; Wardill, TJ; et al. (2012), Optimization of a GCaMP Calcium Indicator for Neural Activity Imaging, JOURNAL OF NEUROSCIENCE, Times Cited: 334

2.4.18 Immunology

India published a lot of immunology papers for an emerging country, and frequently takes part in international collaborations.

Number of papers published

Immunology papers tend to be published by a small number of countries, predominantly the USA which published 38.3% of all immunology papers between 2011 and 2016. Only the UK, USA and China have published more than 2,000 papers in a year, thus India's 826 papers published in 2016 (**Figure 5.19.1**) accounts for a respectable 3.3% share of the world's output (**Figure 5.19.2**). India is the fourteenth most productive country worldwide (**Table 5.19.3**).

Citation impact

With a normalised citation impact (NCI) of 0. 81 in 2016, Indian immunology research has a lower impact than many other countries (**Figure 5.19.6**). Yet, as very few emerging countries publish a significant number of immunology papers, the citation impacts of the comparator countries are hard to assess.

Highly-cited paper

India, along with Brazil and China, has never achieved world average percentages of highly-cited papers (**Table 5.19.7**). Accordingly, only a small number, around 10 Indian papers a year are included in high impact journals (**Table 10.2.19**). The most frequently used journal is the *Lancet Infection Diseases*, which between 2011 and 2016 published 35 Indian papers with an average NCI of 8.01.

International collaboration

In 2016, 40.0% of Indian immunology papers had one or more international co-authors, which is about average for the BRICS and G20, and only slightly less than established countries and those emerging countries which publish a lot immunology papers like Spain and Brazil (**Figure 5.19.9**).

In immunology, India most frequently collaborates with established countries, South Africa and Brazil (**Table 9.19.1**). The number of USA-India papers has rapidly grown between 2011 and 2016 and as of 2016 the partnership produces a quarter of India's internationally co-authored papers. The reason for this is seen at an institutional level as seven out of the top 10 collaborating institutions are based in the USA (**Table 9.19.2**).

Owing to its small size it is remarkable that Belgium is included in the top 10 collaborating countries. This is due to an extensive industrial collaboration between India and the multinational pharmaceutical company GlaxoSmithKline, which has a significant R&D presence in Belgium focusing on vaccines (**Table 9.19.2**).

Highest cited paper

Kumar, H; Kawai, T; Akira, S (2011), Pathogen Recognition by the Innate Immune System, INTERNATIONAL REVIEWS OF IMMUNOLOGY, Times Cited: 562

2.4.19 Space Science

Nearly half of India's space science papers appear in high impact journals.

Number of papers published

India published 741 space science papers in 2016 (**Figure 5.20.1**). This is a small number of papers, compared to other Indian fields of research. However, worldwide there are very few space science papers published each year, thus, India's papers accounted for 5.1% of all space science papers in 2016. This is more than other emerging countries apart from Russia, China and Spain (**Table 5.20.2**). The strength of India's space science is demonstrated by the Indian Space Research Organisation (ISRO) being among only four space agencies to successfully accomplish a mission to Mars, and is the only agency to have success on a first attempt[13].

Citation impact

In most years between 2011 and 2016, India had an NCI below the world average (1.00). The exceptions are 2014 and 2016 when India's NCI exceeded 1.90 (**Figure 5.20.6**). India is not the only country to have seen a sudden rise in impact in these years. The cause of the 2014 and 2016 impact increases was the *Planck 2013 Results* and *Planck 2015 Results* respectively. Planck is a European Space Agency satellite investigating the early Universe. Results were presented in 19 very highly-cited papers, the first of which - *Planck 2013 results. I. Overview of products and scientific results* - has been cited 5,086 times with over 100 international co-authors including Indian researchers from the Inter-University Centre for Astronomy and Astrophysics based at Savitribai Phyle Pune University[14].

Highly-cited papers

The highest cited space science papers with Indian co-authors relate to the Planck 2013 Results and Sloan Digital Sky Surveys observation study (**Section 13**). The Planck Results papers are so highly-cited that in 2014 and 2016 India exceeds the world averages for percentages of papers in the world's top 1% and 5% of most highly-cited space science papers (**Table 5.13.7**). However, even in years without Planck Results Indian researchers publish nearly half of their space science papers in top international journals. On average of 325 papers a year are accepted by high-impact titles (**Table 10.2.20**).

International collaboration

India is becoming more collaborative, as of 2016 57.0% of papers had one or more international co-authors though this is still lower than all the comparator countries. Space science is one of the most internationally collaborative fields as few countries have the money or facilities to run a domestic space programme. Across all countries, more than half of space science papers have one or more international co-authors (**Figure 5.20.9**).

India's most frequent collaborates with world leaders in space science - established countries and Russia. For decades Russia has maintained a massive domestic space program and the Russian Academy of Science is among India's most frequent institutional collaborators (**Table 9.20.1**). The USA-Indian collaboration produces the most papers at an institutional level, four French institutions appear in the top 10 collaborating institutions, notably three universities near Paris, suggesting a regional focus of space science clustered around the European Space Agency headquarters in Paris. (**Table 9.20.2**).

Highest cited paper

[13] www.theguardian.com/science/2014/sep/24/india-mars-satellite-successfully-enters-orbit - access 10 July 2018
[14] Ade, P.A. R., et al., (2014). Planck 2013 results. I. Overview of products and scientific results, Astronomy & Astrophysics, Volume 571, A16. https://doi.org/10.1051/0004-6361/201321529

Ade, PAR; Aghanim, N; Armitage-Caplan, C; et al. (2014), Planck 2013 results. XVI. Cosmological parameters, ASTRONOMY & ASTROPHYSICS, Times Cited: 4,055

2.4.20 Economics & Business

Indian publishes few economic & business papers compared to other Asian countries.

Papers published

India's output of papers in this field in 2016 (320) was lower than that of any established country, as well as some emerging countries including Turkey, Spain, Brazil, China, Taiwan and South Korea (**Figure 5.21.1**). Economics & business appear to be a regional strength, so it is unexpected that India publishes so few papers in the field, furthermore, the SWOT analysis identifies the field as an opportunity (**Section 7**).

Citation impact

India's normalised citation impact (NCI) improved from 0.57 in 2011 to 0.79 in 2016. Between 2011 and 2016, Indian economics & business papers had an average NCI of 0.71, which is around the average citation impact for emerging countries (**Figure 5.21.6**) and not much lower than some established countries including France, Australia, and Canada, which also have NCIs below the world average (1.00).

Highly-cited papers

As India publishes so few economics & business papers, in some years, India has no papers in the top 1% or 5% of most highly-cited papers (**Table 5.21.7**). Around four Indian papers a year appear in high impact economics & business journals, these titles tend to focus on online shopping and food suppliers which align with India's strength in service and food-related sectors (**Table 10.2.21**).

International collaboration

India has very high (and increasing) rates of international collaboration in economics & business. By 2016, 55.3% of Indian papers had one or more international co-authors (**Table 5.21.9**). Economics & business is a rare example of a field where India is more collaborative than other countries, surpassing the G8 and G20 averages and other Asian countries which publish more papers in the field.

The USA-India collaboration is the most productive in terms of the number of papers published (**Table 9.21.1**). Other productive collaborations are with established countries, geographically close Asian countries - Singapore, China and Japan (**Table 9.21.2**). Though the number of papers resulting from each collaboration is low.

Highest cited paper

Calvin, K; Clarke, L; Krey, V; et al. (2012), The role of Asia in mitigating climate change: Results from the Asia modeling exercise, ENERGY ECONOMICS, Times Cited: 56

2.4.21 Psychiatry/Psychology

This is India's least productive field of research, with a peak citation impact in 2011 that is driven by international collaboration.

Number of papers published

Compared to the rest of the world, India publishes very few psychiatry/psychology papers and it is India's smallest field of research with 320 papers published in 2016. (**Figure 5.22.1**). In the six years between 2011 and 2016, Indian researchers published 1,431 papers.

Citation impact

The impact of India psychiatry/psychology papers fluctuated greatly (as seen in the SWOT analysis, **Section 7**) with 1.48 (highest in the time period of analysis) in 2011 to 0.77 in 2016. The average NCI for 2011 to 2016 was 0.73 (**Figure 5.22.6**). The inflated impact seen in 2011 was due to seven internationally co-authored papers reporting on large clinical trials and mental health care guidelines with an exceedingly high citation impact. The effect of these papers is also seen in an increased percentage of papers with an international co-author in the same year.

Highly-cited papers

Because of the above-mentioned seven very highly-cited papers, 2011 is the only year that India exceed world average percentages of papers in the 1%, 5%, 10% and 25% of mostly highly-cited papers (**Table 5.22.7**).

Compared to rest of the world, India publishes very few psychiatry papers with a below average NCI, only an average of six Indian papers make it into high impact journals (**Table 10.2.22**).

International collaboration

In 2011 India's published nearly 60.0% of psychiatry/psychology papers with an international co-author. Since then, this percentage has fallen, reaching 44.0% in 2016, which is lower than most other countries (**Table 5.22.9**).

India most frequent collaborates with researchers in established countries, China, Japan and Brazil (**Table 9.22.1**). The most productive collaboration is with the USA, which in 2016 resulted in 74 papers accounting for 23% of all Indian psychiatry/psychology papers published that year. At an institutional level there most, productive collaborations are with London based universities in the UK (**Table 9.22.2**).

Highest cited paper

Merikangas, KR; Jin, R; He, JP; et al. (2011), Prevalence and Correlates of Bipolar Spectrum Disorder in the World Mental Health Survey Initiative, ARCHIVES OF GENERAL PSYCHIATRY, Times Cited: 434

3 INTRODUCTION

3.1 Background

In 2011, the Department of Science and Technology, Government of India (DST), commissioned *Evidence*, Thomson Reuters to provide a high-level analysis of India's volume of research activity, research quality and international collaboration in an internationally comparative context, in order to inform a more focused analysis by identifying disciplinary or functional areas where further work may be beneficial.

In 2014, DST commissioned Thomson Reuters for the second Phase of this evaluation, in order to expand the previous analyses, demonstrate India's competitive strengths and weaknesses in science and technology, and key areas in which India is well placed to leverage its strengths whilst tackling its weaknesses.

As the third phase of this evaluation, Clarivate Analytics (formerly the IP and Science business of Thomson Reuters) has been commissioned by DST to further expand and elaborate the analyses, in order to track the progress that Indian research community has made over the years compared to the other countries worldwide and gain a broader understanding of India's research portfolio.

The outcome of this report will feed into the Indian Government's Science and Technology policy formulation and strategy for continued growth.

3.2 About the Department of Science and Technology, Government of India (DST)

The Department of Science and Technology, Government of India was established in May 1971 to promote new areas of science and technology and to play the role of a nodal department for organising, coordinating and promoting Scientific and Technological activities in India. It has wide-ranging activities from promoting high-end basic research and the development of cutting-edge technologies on the one hand, to servicing the technological requirements of the common person through the development of appropriate skills and technologies on the other [15].

- DST India has responsibilities for specific projects and programmes, such as:
- The formulation of policies relating to science and technology
- Matters relating to the Scientific Advisory Committee of the Cabinet (SACC)
- Promotion of new areas of science and technology with special emphasis on emerging areas
- Futurology
- Coordination and integration of areas of science and technology having cross-sectoral linkages in which a number of institutions and departments have interests and capabilities
- Undertaking or financially sponsoring scientific and technological surveys, research design and development
- Support and grants-in-aid to Scientific Research Institutions, Scientific Associations and Bodies
- All matters concerning:

[15] www.dst.gov.in

- Science and Engineering Research Council
- Technology Development Board and related Acts
- National Council for Science and Technology Communication
- National Science and Technology Entrepreneurship Development Board
- International Science and Technology Cooperation
- Autonomous Science and Technology Institutions
- Professional Science Academies
- The Survey of India and National Atlas and Thematic Mapping Organisation
- National Spatial Data Infrastructure
- National Innovation Foundation (Ahmedabad)

3.3 About Clarivate Analytics

Clarivate Analytics accelerates the pace of innovation by providing trusted insights and analytics to customers around the world, enabling them to discover, protect and commercialize new ideas faster. We own and operate a collection of leading subscription-based services focused on scientific and academic research, patent analytics and regulatory standards, pharmaceutical and biotech intelligence, trademark protection, domain brand protection and intellectual property management. Clarivate Analytics is now an independent company with over 4,000 employees, operating in more than 100 countries and owns well-known brands that include Web of Science, Cortellis, Derwent, CompuMark, MarkMonitor and Techstreet, among others. For more information, visit clarivate.com.

Clarivate Analytics Research Data & Services team provides reporting and consultancy services within Research Analytics using customized analyses to bring together several indicators of research performance in such a way as to enable customers to rapidly make sense of and interpret a wide-range of data points to facilitate research strategy decision-making. We have extensive experience with databases on research inputs, activity and outputs and have developed innovative analytical approaches for benchmarking, interpreting and visualization of international, national and institutional research impact.

For over half a century we have pioneered the world of citation indexing and analysis, helping to connect scientific and scholarly thought around the world. Today, academic and research institutions, governments, not-for-profits, funding agencies, and all others with a stake in research, need reliable, objective methods for managing and measuring performance.

Our consultants have up to 20 years of experience in research performance analysis and interpretation. In addition, the Clarivate regional Sales team will provide effective project management and on-site support to maximize values of our projects and meet the expectations of DST.

4 DATA SOURCES, INDICATORS AND INTERPRETATION

This section outlines key concepts and methodology. A detailed description of the bibliometric methodology used by Clarivate Analytics is provided in **Section 5**.

4.1 Bibliometric data and citation analysis

Research evaluation is increasingly making wider use of bibliometric data and analyses. Bibliometrics is the analysis of data derived from publications and their citations. Publication of research outcomes is an integral part of the research process and is a universal activity. Consequently, bibliometric data have a currency across subjects, time and location that are found in few other sources of research-relevant data. The use of bibliometric analysis, allied to informed review by experts, increases the objectivity of and confidence in evaluation.

Research publications accumulate citation counts when they are referred to by more recent publications. Citations to prior work are a normal part of publication, and reflect the value placed on a work by later researchers. Some papers get cited frequently and many remain uncited. Highly cited work is recognised as having a greater impact and Thomson Reuters has shown that high citation rates are correlated with other qualitative evaluations of research performance, such as peer review.[16] This relationship holds across most science and technology areas and, to a limited extent, in social sciences and even in some humanities subjects.

Indicators derived from publication and citation data should always be used with caution. Some fields publish at faster rates than others and citation rates also vary. Citation counts must be carefully normalised to account for such variations by field. Because citation counts naturally grow over time, it is essential to account for growth by year. Normalisation is usually done by reference to the relevant global average for the field and for the year of publication.

Bibliometric indicators have been found to be more informative for core natural sciences, especially for basic science, than they are for applied and professional areas and for social sciences. In professional areas the range of publication modes used by leading researchers is likely to be diverse as they target a diverse, non-academic audience. In social sciences there is also a diversity of publication modes and citation rates are typically much lower than in natural sciences.

Bibliometrics work best with large data samples. As the data are disaggregated, so the relationship weakens. Average indicator values (e.g. of citation impact) for small numbers of publications can be skewed by single outlier values. At a finer scale, when analysing the specific outcome for individual departments, the statistical relationship is rarely a sufficient guide by itself. For this reason, bibliometrics are best used in support of, but not as a substitute for, expert decision processes. Well-founded analyses can enable conclusions to be reached more rapidly and with greater certainty, and are therefore an aid to management and to increased confidence among stakeholders, but they cannot substitute for review by well-informed and experienced peers.

4.2 Publication and citation data sources

For this project, citation data have been sourced from Clarivate Analytics **Web of Science™ Core Collection**. The Web of Science Core Collection is part of the Web of Science and focuses on research published in journals and conferences in science, medicine, arts, humanities and social sciences. The authoritative, multidisciplinary content

[16] *Evidence* Ltd. (2002) Maintaining Research Excellence and Volume: A report by Evidence Ltd to the Higher Education Funding Councils for England, Scotland and Wales and to Universities UK. (*Adams J, et al.)* 48pp .

covers over 18,000 of the highest impact journals worldwide, including Open Access journals and over 180,000 conference proceedings. Coverage is both current and retrospective in the sciences, social sciences, arts and humanities, in some cases back to 1900. Within the research community these data are often still referred to by the acronym 'ISI'[17].

Web of Science Core Collection is hosted on Web of Science platform. Web of science hosts various databases (including Web of Science Core Collection) to provide conference proceedings, patents, chemical structures, compounds and reactions in addition to journals. However only Web of Science Core Collection was used for the analysis; Web of Science core collection is as a standard bibliometric analysis source globally for performance evaluation. Unlike other databases, the Web of Science Core Collection databases are selective, that is: the journals abstracted are selected using rigorous editorial and quality criteria. The authoritative, multidisciplinary content covers over 18,000 of the highest impact journals worldwide, including Open Access journals, and over 180,000 conference proceedings. The abstracted journals encompass the majority of significant, frequently cited scientific reports and, more importantly, an even greater proportion of the scientific research output which is cited. This selective process ensures that the citation counts remain relatively stable in given research fields and do not fluctuate unduly from year to year, which increases the usability of such data for performance evaluation.

If any search on web of science platform is done on all the different databases hosted on it (included Web of Science Core Collection), then the results may require to be interpreted with caution and may not be suitable for performance evaluation purposes without de-duplication of the data.

4.2.1 Country coverage

In order to benchmark India's performance against other countries, **Section 5 and 6** comprises analyses comparing India's research performance to two comparator groups selected by DST, India. One group is termed the 'established research economies', which includes Australia, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, United Kingdom, and USA. The other group is termed the 'emerging research economies', and includes Argentina, the BRICS countries (Brazil, Russia, India, China, and South Africa) as well as Indonesia, Mexico, South Korea, Saudi Arabia, Spain, Taiwan and Turkey.

In order to simplify the visual presentation of this information, 3-letter UN abbreviations[18] have been used in this report. India (IND) is compared with both groups and compared within both sets of Figures.

Code	Country	Report Group	Aggregation Group
IND	India		G20, BRICS
AUS	Australia	Established research economies	G20
CAN	Canada	Established research economies	G8, G20
FRA	France	Established research economies	G8, G20
DEU	Germany	Established research economies	G8, G20
ITA	Italy	Established research economies	G8, G20
JPN	Japan	Established research economies	G8, G20
NLD	Netherlands	Established research economies	
SWE	Sweden	Established research economies	
CHE	Switzerland	Established research economies	

[17] The origins of citation analysis as a tool that could be applied to research performance can be traced to the mid-1950s, when Eugene Garfield proposed the concept of citation indexing and introduced the Science Citation Index, the Social Sciences Citation Index and the Arts & Humanities Citation Index, produced by the Institute of Scientific Information – ISI (now Clarivate Analytics).

[18] http://unstats.un.org/unsd/methods/m49/m49alpha.htm

Code	Country	Report Group	Aggregation Group
GBR	United Kingdom	Established research economies	G8, G20
USA	United States of America	Established research economies	G8, G20
ARG	Argentina	Emerging research economies	G20
BRA	Brazil	Emerging research economies	G20, BRICS
CHN	China	Emerging research economies	G20, BRICS
IDN	Indonesia	Emerging research economies	G20
MEX	Mexico	Emerging research economies	G20
RUS	Russia	Emerging research economies	G8, G20, BRICS
SAU	Saudi Arabia	Emerging research economies	G20
ZAF	South Africa	Emerging research economies	G20, BRICS
KOR	South Korea	Emerging research economies	G20
ESP	Spain	Emerging research economies	
TWN	Taiwan	Emerging research economies	
TUR	Turkey	Emerging research economies	G20

4.2.2 Time coverage

Several time periods are used in this report. In general, all analyses are conducted within the 6 years 2011 to 2016, further splits into two periods: 2011-2013 and 2014-2016, and then presented by individual years as requested by DST.

4.2.3 Research fields

Standard bibliometric methodology uses journal categories as a proxy for research fields or areas. Clarivate Analytics assigns all journals to one or more subject areas and these are used to indicate the subject matter of papers in those journals. We have used one such classification scheme in this report to assign published research to research areas. These are the InCites: Essential Science Indicators^{SM} fields, which aggregate data at a higher level than the Web of Science journal categories. The Essential Science Indicators fields and Web of Science Journal Subject Categories do not map directly but complement each other to provide both a high-level and detailed analysis of research.

There are 22 ESI fields compared to 254 Web of Science journal categories. Analyses using ESI fields are useful to gain a headline understanding of the strengths and weaknesses of a research system, whereas analyses using Web of Science journal categories are useful to identify strengths and weaknesses in more specific research areas. ESI fields are defined by a unique grouping of journals with no journal being assigned to more than one field. Articles in journals such as *Science* and *Nature*, are assigned to Multidisciplinary field on the basis of an article-level classification. Therefore, the category 'Multidisciplinary' does not describe research that is inter-disciplinary in nature, but refers to research work which appears in multidisciplinary journals. Though we have included the Multidisciplinary category in this report, the further interpretation/commentary was eliminated due to its errant citation behaviour owing to changing methodological definitions meaning that it is not comparable over time.

The 22 Essential Science Indicators fields are:

Category Code	Full Description
AGS	Agricultural Sciences
BBI	Biology & Biochemistry
CHE	Chemistry
CLM	Clinical Medicine
CPS	Computer Science
ECB	Economics & Business

Category Code	Full Description
ENG	Engineering
ENE	Environment/Ecology
GSC	Geosciences
IMU	Immunology
MTS	Materials Science
MAT	Mathematics
MIC	Microbiology
MOL	Molecular Biology & Genetics
MUL	Multidisciplinary
NEB	Neuroscience & Behaviour
PHT	Pharmacology & Toxicology
PHY	Physics
PLA	Plant & Animal Science
PSS	Psychiatry/Psychology
SPA	Space Sciences
SSS	Social Sciences, general

4.2.4 Data collection

In this report, all the publication data between 2011 and 2016 was collected with citation data up to the end of 2016, by using country name searches of the address affiliation data provided by authors and indexed in SCI-EXPANDED, SSCI and A&HCI of Web of Science Core Collection.

More specifically, only the publications with document types of articles and reviews are included in the analyses, and editorials, meeting abstracts or other types of publications are not included. More details on methodology can be found in the following **Section 4.3**.

4.3 Bibliometric and citation data definitions and indicators

Papers/publications: Thomson Reuters abstracts publications including editorials, meeting abstracts and book reviews as well as research journal articles. The terms 'paper' and 'publication' are often used interchangeably to refer to the printed and electronic outputs of many types. In this report, the term 'paper' has been used exclusively to refer to substantive journal articles, reviews, and some proceedings papers, and excludes editorials, meeting abstracts or other types of publications. **Papers** are the subset of publications for which citation data are most informative and which are used in the calculation of citation impact. Furthermore, papers tend to be those that report research findings and they are peer-reviewed, whereas other publication types often cover other materials and are not reviewed in the same way, which also explains why they are most often used in research evaluations as an internationally accepted best practice.

Citations: The citation count is the number of times that a citation has been recorded for a given publication since it was published. Not all citations are necessarily recorded since not all publications are indexed. However, the material indexed by Thomson Reuters is estimated to attract about 95% of global citations.

Citation impact: 'Citations per paper' is an index of academic or research impact (as compared with economic or social impact). It is calculated by dividing the sum of citations by the total number of papers in any given dataset (so, for a single paper, raw impact is the same as its citation count). Impact can be calculated for papers within a specific research field such as Clinical Neurology, or for a specific institution or group of institutions, or a specific country.

Citation count declines in the most recent years of any time period as papers have had less time to accumulate citations (papers published in 2009 will typically have more citations than papers published in 2013).

Field Normalised citation impact (NCI_F): Citation rates vary between research fields and with time, consequently, analyses must take both field and year into account. In addition, the type of publication will influence the citation count. For this reason, only citation counts of papers (as defined above) are used in calculations of citation impact. The standard normalisation factor is the world average citations per paper for the year and journal category in which the paper was published. When a publication is assigned to more than one subject area, an average of the ratios of the normalization factor is used.

Normalised citation impact (NCI): In this report, the term "normalised citation impact" (NCI) is used to refer to the average field normalised citation impact for a paper or group of papers.

Journal Impact Factor (JIF): In the same way that citation impact can be used as an index of research quality, the average number of citations per paper can be used to indicate the impact and/or importance of a journal. The Impact Factor for a journal is calculated using data for a three-year period. For example, the 2012 Impact Factor for a given journal is calculated by Thomson Reuters as the average number of times which articles from the journal published in the past two years (2010 and 2011) were cited in 2012. Thus, a Journal Impact Factor of 2.0 means that, on average, the articles published in 2010 or 2011 have been cited twice. Citing articles may be from the same journal; however, most citing articles are from other journals.

For the journal *Fertility and Sterility*, the 2012 Journal Impact Factor would be calculated as follows:

Cites in 2012 to items published in 2010 =	3 259	Number of items published in 2010 =	744
Cites in 2012 to items published in 2011 =	2 556	Number of items published in 2011 =	649
Total	**5 815**		**1 393**

$$\frac{Number\ of\ citations}{Number\ of\ \mathrm{items}} = \frac{5\,815}{1\,393} = \mathbf{4.174}$$

The calculation of the Journal Impact Factor is fully described on the Clarivate Analytics website at: https://clarivate.com/essays/impact-factor/

When looking at Journal Impact Factor data it is important to remember that, as citation rates vary between research fields and publication type, these will affect the Journal Impact Factor. That is, a Journal Impact Factor of 4.174 ranks the journal *Fertility and Sterility* fourth out of 77 journals in the Obstetrics & Gynaecology journal category and therefore in the top quartile. However, *Journal of Alzheimer's Disease* with the same Journal Impact Factor of 4.174 is ranked in the second quartile (64 out of 251 journals) in the journal category Neurosciences.

Percentage of highly cited papers: For the purpose of this report, highly cited papers have been defined as those articles and reviews which belong to the world's top 1%, 5%, 10% or 25% of papers in that journal category and year of publication, when ranked by number of citations received. A percentage that is above 1, 5, 10 or 25 indicates above-average performance.

Research field: Standard bibliometric methodology uses journal category as a proxy for research field. Journals are assigned to one or more categories, and every article within that journal is subsequently assigned to that category. Publications from prestigious, 'multidisciplinary' and general medical journals such as *Nature*, *Science*, The *Lancet*, *The BMJ*, *The New England Journal of Medicine and the Proceedings of the National Academy of Sciences* (PNAS) are assigned to specific categories based on the journal categories of the references cited in the article. The selection procedures for the journals included in the citation databases are documented here http://mjl.clarivate.com/.For this evaluation, the standard classification of Web of Science journal categories has been used.

4.4 Interpretation of bibliometric indicators and citation analyses

The following points should be borne in mind when considering the results of these analyses.

- Bibliometrics work best with large data samples. As the data are disaggregated, so the relationship weakens. Average indicator values (e.g. of citation impact) for small numbers of publications can be skewed by single outlier values. At a finer scale, when analysing the specific outcome for individual departments, the statistical relationship is rarely a sufficient guide by itself. For this reason, bibliometrics are best used in support of, but not as a substitute for, expert decision processes. Well-founded analyses can enable conclusions to be reached more rapidly and with greater certainty, and are therefore an aid to management and to increased confidence among stakeholders, but they cannot substitute for review by well-informed and experienced peers.
- Publications accumulate citations over time and it may take years until a given publication is cited. While citation counts in early years have been shown to reflect long-term citation performance,[19] indicators based on citation counts may be relatively more volatile in the years immediately following publication.
- Citation rates vary between disciplines and fields. For example, for the UK science base as a whole, 10 years produces a general plateau beyond which few additional citations would be expected. On the whole, citations accumulate more rapidly and plateau at a higher level in biomedical sciences than physical sciences, and natural sciences generally cite at a higher rate than social sciences.

4.5 Indicator thresholds

- **Papers**: The minimum number of papers suitable as a sample for quantitative research evaluation is the subject of widespread discussion. Larger samples are always more reliable, but a very high minimum may defeat the scope and specificity of analysis. Experience has indicated that a threshold between 20 and 50 papers can generally be deemed appropriate. For work that is likely to be published with little contextual information, the upper boundary (≥ 50) is a desirable starting point. For work that will be used primarily by an expert, in-house group then the lower boundary (≥ 20) may be approached. Because comparisons for in-house evaluation often involve smaller, more specific research groups (compared to broad institutional comparisons), a high volume threshold is self-defeating. Smaller samples may be used but outcomes must be interpreted with caution and expert review should draw on multiple information sources before reaching any conclusions.
- **Field Normalised citation impact**: Such values for individual papers vary widely and it is more useful to consider the average for a set of papers. This average can be at several granularities: field (either journal category or field), annual and overall (total output under consideration). When considering such average data points, care must be taken to understand that these data are highly skewed and the average can be driven by a single, highly cited paper (this would be highlighted in accompanying text though not apparent from Tables and Figures). The world average is 1.0, so any value higher than this indicates a paper, or set of papers, which are cited more than average for similar research worldwide. For research management purposes, experience suggests that values between 1.0 and 2.0 should be considered to be indicative of

[19] Adams, J. *et al.* (2002) Maintaining Research Excellence and Volume: A report by *Evidence* Ltd to the Higher Education Funding Councils for England, Scotland and Wales and to Universities UK, http://www.hefce.ac.uk/pubs/rdreports/2002/rd08_02/rd08_02.pdf

research which is influential at a national level whilst that cited more than twice the world average has international recognition.

- **Research field**: A problem frequently encountered in the analysis of data about the research process is that of 'mapping'. For example, a funding body allocates money for chemistry, but this goes to researchers in biology and engineering as well as to chemistry departments. Clinicians publish in mathematics and education journals. Publications in environmental journals come from a diversity of disciplines. This creates a problem when we try to define, for example, 'Parasitology research'. Is this the work funded under Parasitology programmes, the work of researchers in Parasitology units or the work published in Parasitology journals? For the first two options we need to track individual grants and researchers to their outputs, which is feasible but not within the scope of this study or for every comparator institution. Therefore, to create a simple and transparent dataset of equal validity across time and geography, we rely on the set of journals associated with Parasitology as a proxy for the body of research reflecting the field.

4.6 Data presentation

4.6.1 Data descriptions and rounding

All Figure titles are fully described with:

- Indicator name
- Field
- Country/Countries
- Time period
- Data source
- Special notes (if applicable) on ordering or methodology

Data are rounded to two decimal places for indices of citation impact and one decimal place for percentages.

4.6.2 Presentation of axes and scaling of figures

Axes may be set at different scales for the established economies and for the emerging economies (**Section 5 and 6**), as well as for different aggregation of time periods (**Section 6**), in order to reflect different levels of research output and citation impact.

METHODOLOGY APPENDIX

The following section includes detailed description of bibliometric methodologies and metrics that could provide instructive guidelines for the analyses presented above.

5 BIBLIOMETRICS AND CITATION ANALYSIS METHODOLOGY

Bibliometrics are about publications and their citations. The academic field emerged from 'information science' and now usually refers to the methods used to study and index texts and information.

Publications cite other publications. These citation links grow into networks, and their numbers are likely to be related to the significance or impact of the publication. The meaning of the publication is determined from keywords and content. Citation analysis and content analysis have therefore become a common part of bibliometric methodology. Historically, bibliometric methods were used to trace relationships amongst academic journal citations. Now, bibliometrics are important in indexing research performance.

Bibliometric data have particular characteristics of which the user should be aware, and these are considered here.

Journal papers (publications, sources) report research work. Papers refer to or 'cite' earlier work relevant to the material being reported. New papers are cited in their turn. Papers that accumulate more citations are thought of as having greater 'impact', which is interpreted as significance or influence on their field. Citation counts are therefore recognized as a measure of impact, which can be used to index the excellence of the research from a particular group, institution or country.

The origins of citation analysis as a tool that could be applied to research performance can be traced to the mid-1950s, when Eugene Garfield proposed the concept of citation indexing and introduced the Science Citation Index, the Social Sciences Citation Index and the Arts & Humanities Citation Index, produced by the Institute of Scientific Information (currently the Clarivate Analytics).

We can count citations, but they are only 'indicators' of impact or quality – not metrics. Most impact indicators use average citation counts from groups of papers, because some individual papers may have unusual or misleading citation profiles. These outliers are diluted in larger samples.

5.1 Data Source

The data used in this report came from the Clarivate Analytics Web of Science databases which give access not only to journals but also to conference proceedings, books, patents, websites, and chemical structures, compounds and reactions. Web of Science has a unified structure that integrates all data and search terms together and therefore provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The Web of Science focuses on research published in journals, conferences and books in science, medicine, arts, humanities and social sciences.

The Web of Science was originally created as an awareness and information retrieval tool but it has acquired an important primary use as a tool for research evaluation, using citation analysis and bibliometrics. Data coverage is both current and retrospective in the sciences, social sciences, arts and humanities, in some cases back to 1900. Within the research community this data source was previously referred to by the acronym 'ISI'.

Unlike other databases, the Web of Science and underlying databases are selective, that is: the journals abstracted are selected using rigorous editorial and quality criteria. The authoritative, multidisciplinary content covers over 18,000 of the highest impact journals worldwide, including Open Access journals, and over 180,000 conference proceedings. The abstracted journals encompass the majority of significant, frequently cited scientific reports and, more importantly, an even greater proportion of the scientific research output which is cited. This selective process ensures that the citation counts remain relatively stable in given research fields and do not fluctuate unduly from year to year, which increases the usability of such data for performance evaluation.

Clarivate Analytics has extensive experience with databases on research inputs, activities and outputs and has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

5.2 Database Categories

The source data can be grouped in various classification systems. Most of these are based on groups of journals that have a relatively high cross-citation linkage and naturally cluster together. Custom classifications use subject maps in third-party data such as the OECD categories set out in the Frascati manual.

Clarivate Analytics frequently uses the broader field categories in the Essential Science Indicators system and the finer journal categories in the Web of Science. There are 22 fields in Essential Science Indicators and 254 fields in Web of Science. In either case, our bibliometric analyses draw on the full range of data available in the underlying database, so analyses in our reports will differ slightly from anything created 'on the fly' from data in the web interface.

Most analyses start with an overall view across the data, then move to a view across broad categories and only then focus in at a finer level in the areas of greatest interest to policy, program or institutional purpose.

5.3 Assigning Papers to Addresses

A paper is assigned to each country and each institution whose address appears at least once for any author on that paper. One paper counts once and only once for each assignment, however many address variants may occur for the country or institution. No weighting is applied.

For example, a paper has five authors, thus:

Author	Institution	Country		
Gurney, KA	Univ Leeds	UK	Counts for Univ Leeds	Counts for UK
Adams, J	Univ Leeds	UK	No gain for Univ Leeds	No gain for UK
Kochalko, D	Univ C San Diego	USA	Counts for UCSD	Counts for USA
Munshi, S	Gujarat Univ	India	Counts for Gujarat Univ	Counts for India
Pendlebury, D	Univ Oregon	USA	Counts for Univ Oregon	No gain for USA

So this one paper with five authors would be included once in the tallies for each of four universities and once in the tallies for each of three countries.

Work carried out within Clarivate Analytics, and research published elsewhere, indicates that fractional weighting based on the balance of authors by institution and country makes little difference to the conclusions of an analysis at an aggregate level. Such fractional analysis can introduce unforeseen errors in the attempt to create a detailed but uncertain assignment. Partitioning credit would make a greater difference at a detailed, group level but the analysis can then be manually validated.

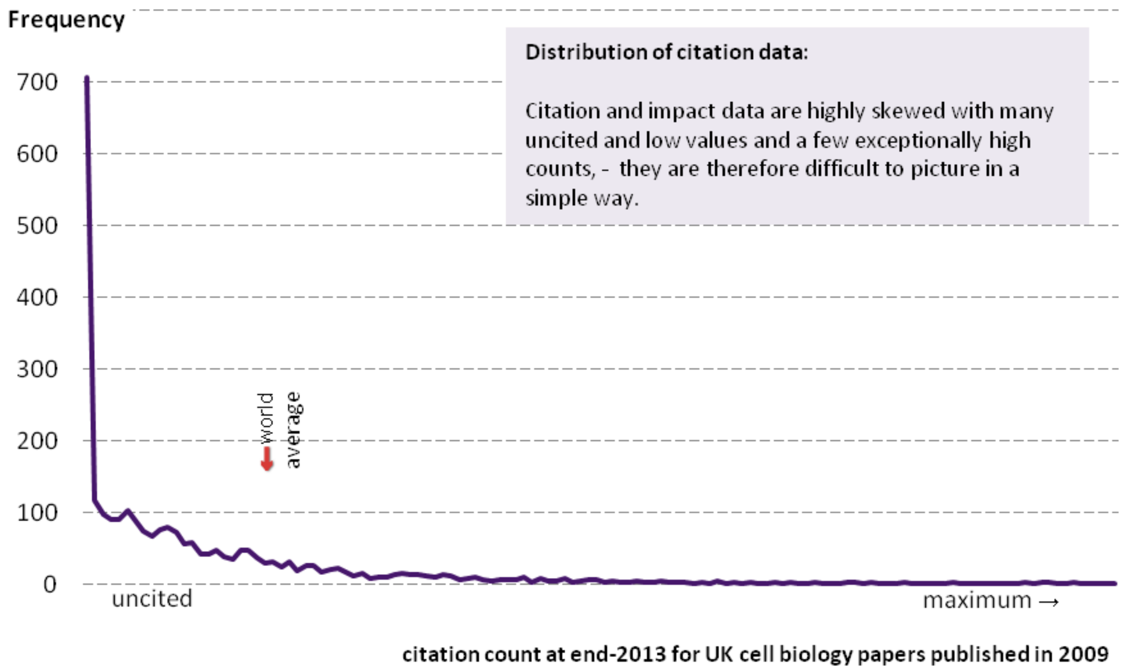
5.4 Citation Counts

A publication accumulates citation counts when it is referred to by more recent publications. Some papers get cited frequently and many get cited rarely or never, so the distribution of citations is highly skewed.

Why are many papers never cited? Certainly some papers remain uncited because their content is of little or no impact, but that is not the only reason. It might be because they have been published in a journal not read by researchers to whom the paper might be interesting. It might be that they represent important but 'negative' work reporting a blind alley to be avoided by others. The publication may be a commentary in an editorial, rather than a normal journal article and thus of general rather than research interest, or it might be that the work is a 'sleeping beauty' that has yet to be recognized for its significance.

Other papers can be very highly cited: hundreds, even thousands of times. Again, there are multiple reasons for this. Most frequently cited work is being recognized for its innovative significance and impact on the research field of which it speaks. Impact here is a good reflection of quality: it is an indicator of excellence. But there are other papers which are frequently cited because their significance is slightly different: they describe key methodology; they are a thoughtful and wide-ranging review of a field; or they represent contentious views which others seek to refute.

Citation analysis cannot make value judgments about why an article is uncited nor about why it is highly cited. The analysis can only report the citation impact that the publication has achieved. We normally assume, based on many other studies linking bibliometric and peer judgments, that high citation counts correlate on average with the quality of the research.



The figure shows the skewed distribution of more or less frequently cited papers from a sample of UK authored publications in cell biology. The skew in the distribution varies from field to field. It is to compensate for such factors that actual citation counts must be normalized, or rebased, against a world baseline.

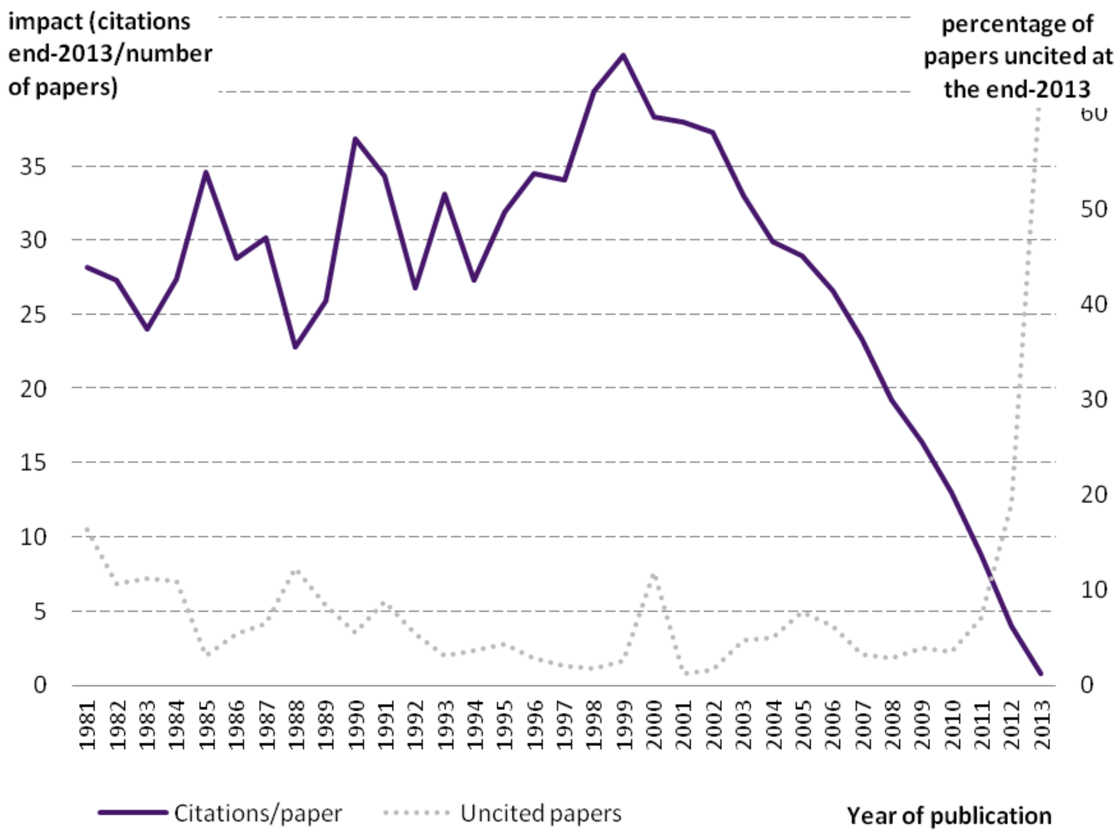
We do not seek to account separately for the effect of self-citation. If the citation count is significantly affected by self-citation then the paper is likely to have been infrequently cited. This is therefore only of consequence for low impact activity. Studies show that for large samples at national and institutional level, the effect of self-citation has little or no effect on the analytical outcomes and would not alter interpretation of the results.

5.5 Time Factors

Citations accumulate over time. Older papers therefore have, on average, more citations than more recent work. The graph below shows the pattern of citation accumulation for a set of 33 journals in the journal category ***Materials Science, Biomaterials***. Papers less than eight years old are, on average, still accumulating additional citations. The citation count goes on to reach a plateau for older sources.

The graph shows that the percentage of papers that have never been cited drops over about five years. Beyond five years, between 5% and 10% or more of papers remain uncited.

Account must be taken of these time factors in comparing current research with historical patterns. For these reasons, it is sometimes more appropriate to use a fixed five-year window of papers and citations to compare two periods than to look at the longer term profile of citations and of uncitedness for a recent year and an historical year.



5.6 Discipline Factors

Citation rates vary between disciplines and fields. For the UK science base as a whole, ten years produces a general plateau beyond which few additional citations would be expected. On the whole, citations accumulate more rapidly and plateau at a higher level in biological sciences than physical sciences, and natural sciences generally cite at a higher rate than social sciences.

Papers are assigned to disciplines (journal categories or research fields) by Clarivate Analytics, bringing cognate research areas together. Before 2007, journals were assigned to the older, well established Current Contents categories which were informed by extensive work by Thomson and with the research community since the early 1960s. This scheme has been superseded by the 252 Web of Science journal categories which allow for greater disaggregation for the growing volume of research which is published and abstracted.

Papers are allocated according to the journal in which the paper is published. Some journals may be considered to be part of the publication record for more than one research field. As the example below illustrates, the journal Acta Biomaterialia is assigned to two journal categories: ***Materials Science, Biomaterials and Engineering, Biomedical***.

Very few papers are not assigned to any research field and as such will not be included in specific analyses using normalized citation impact data. The journals included in the Clarivate Analytics databases and how they are selected are detailed here http://scientific.thomsonreuters.com/mjl/.

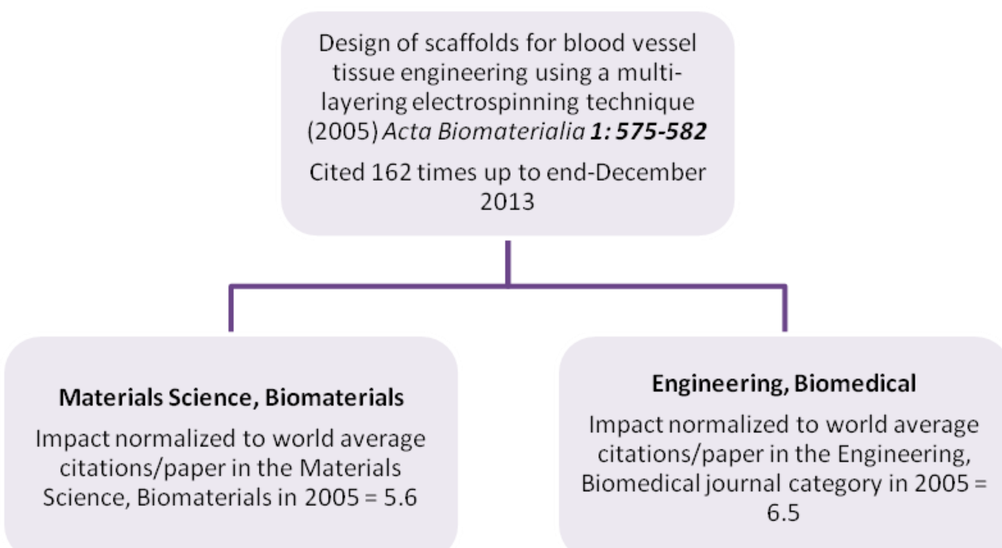
Some journals with a very diverse content, including the prestigious journals Nature and Science were classified as ***Multidisciplinary*** in databases created prior to 2007. The papers from these ***Multidisciplinary*** journals are now re-assigned to more specific research fields using an algorithm based on the research area(s) of the references cited by the article.

5.7 Field Normalised Citation Impact

Because citations accumulate over time at a rate that is dependent upon the field of research, all analyses must take both field and year into account. In other words, because the absolute citation count for a specific article is influenced by its field and by the year it was published, we can only make comparisons of indexed data after normalizing with reference to these two variables.

We only use citation counts for reviews and articles in calculations of impact, because document type influences the citation count. For example, a review will often be cited more frequently than an article in the same field, but editorials and meeting abstracts are rarely cited and citation rates for conference proceedings are extremely variable. The most common normalization factors are the average citations per paper for (1) the year and (2) either the field or the journal in which the paper was published. This normalization is also referred to as 'rebasing' the citation count.

Impact is therefore most commonly analyzed in terms of 'normalized citation impact', or nci. The following schematic illustrates how the normalized citation impact is calculated at the paper level and journal category level.



This article in the journal Acta Biomaterialia is assigned to two journal categories: ***Materials Science, Biomaterials and Engineering, Biomedical***. The world average baselines for, as an example, ***Materials science, Biomaterials*** are calculated by summing the citations to all the articles and reviews published worldwide in the journal Acta Biomaterialia and the other 32 journals assigned to this category for each year and dividing this by the total number of articles and reviews published in the journal category. This gives the category-specific normalized citation impact (in the above example the category-specific NCI_F for ***Materials Science, Biomaterials*** is 5.6 and the category-specific NCI_F for Engineering, Biomedical is higher at 6.5). Most papers (nearly two-thirds) are assigned to a single journal category while a minority of them are assigned to more than five.

The average (normalized) citation impact can be calculated at an individual paper level where it can be associated with more than one journal category. It can also be calculated for a set of papers at any level from a single country to an individual researcher's output. In the example above, the average citation impact of the Acta Biomaterialia paper can be expressed as ((5.6 + 6.5)/2) = 6.1.

In this study, world average impact data are sourced from the Clarivate Analytics Web of Science Core Collection's baseline data for 2016.

5.8 Normalised Citation Impact

Research performance has historically been indexed by using average citation impact, usually compared to a world average that accounts for time and discipline. As noted, however, the distribution of citations amongst papers is highly skewed because many papers are never cited while a few papers accumulate very large citation counts. That means that an average may be misleading if assumptions are made about the distribution of the underlying data.

In fact, almost all research activity metrics are skewed: for research income, PhD numbers and publications there are many low activity values and a few exceptionally high values. In reality, therefore, the skewed distribution means that average impact tends to be greater than and often significantly different from either the median or mode in the distribution. This should be borne in mind when reviewing analytical outcomes.

5.9 What is the Threshold for "Highly Cited"?

Clarivate Analytics has traditionally used the term "Highly Cited Paper" to refer to the world's 1% of most frequently cited papers, taking into account year of publication and field. After reviewing the outcomes of a number of analyses, we have chosen a more relaxed definition for our descriptive and analytical work. Normally, we deem papers that are in the world's top 10% of most frequently cited papers, taking into account year of publication and field, to be relatively highly cited for national comparisons.

Special Addendum*: Early trends of year 2017-2018 for India

Year 2017

Number of Web of Science Publications: **73,529**

Times Cited: **2,24,384**

India's Rank in number of publications: **10th**

Top 10 Research Areas in the order of decreasing number of publications: **Chemistry, Engineering, Materials Science, Physics, Clinical Medicine, Biology & Biochemistry, Plant & Animal Science, Agricultural Sciences, Computer Science, Pharmacology & Toxicology**

Top 10 Countries in the order of decreasing number of publications: **USA, China, UK, Germany, Japan, France, Canada, Italy, Australia, India**

Year 2018

Number of Web of Science Publications: **73,813**

Times Cited: **56,304**

Rank in number of publications: **9th**

Top 10 Research Areas in the order of decreasing number of publications: **Chemistry, Engineering, Materials Science, Physics, Clinical Medicine, Biology & Biochemistry, Computer Science, Plant & Animal Science, Agricultural Sciences, Pharmacology & Toxicology**

Top 10 Countries in the order of decreasing number of publications: **USA, China, UK, Germany, Japan, France, Canada, Italy, India, Australia**

Country	No. of publications in 2017	No. of publications in 2018
USA	4,57,149	4,32,788
China	3,42,901	3,84,888
UK	1,43,662	1,35,331
Germany	1,21,625	1,17,208
Japan	84,523	82,199
France	82,103	77,618
Canada	77,543	75,173
Italy	76,084	74,779
Australia	73,909	72,483
India	73,529	73,813

**Data provided in special addendum was pulled out at a different time than the main report*