Mapping the research output from Indian states

*Anurag Kanaujia, Abhirup Nandy, Prashasti Singh and Vivek Kumar Singh**

India is now one of the major knowledge producers in the world, ranking among the top five countries in total research output. The research output is contributed by various institutions located in different states and regions of the country. There are, however, no existing studies on the amount of research output contributed by each state. Therefore, in this study, we undertook a territorial mapping of research output from India at the level of different states. Research output data for the country for the last 20 years (2001–20) were obtained from the Web of Science database, and publications were tagged to different states based on the location of the affiliating institution of the publication. The results show that Tamil Nadu, Maharashtra, Delhi, West Bengal, Karnataka, and Uttar Pradesh are among the top contributors, in that order. Almost all major states showed an increase in absolute research output during 2001–20. However, in relative terms, Tamil Nadu, Bihar and Punjab showed interesting growth patterns. Chandigarh and Puducherry had high total publications/gross state domestic product values. The analytical results of this study present useful quantitative measures of the research contributions of different states in India. Some probable reasons for the observed patterns and certain policy suggestions are also discussed in this study.

Keywords: Knowledge producers, mapping, quantitative measures, research output, scientific institutions.

INDIA is now one of the major knowledge producers of the world, ranking among the top five countries in total research output with an extensive institutional network for knowledge creation[1]. The institutional set-up for research and development (R&D) in India comprises a diverse set of institutions, including universities, Government departments, research laboratories, private sector institutions, etc. These institutions are spread across 28 states and 8 Union Territories (UTs) and vary in their individual structures and approaches towards their shared goals. Further, the funding and administrative structures of the institutions also vary, with some being administered by the Central Government, various others by the state Governments and some by the private sector.

Several previous studies have explored the research output of India as a whole[2–5], including comparing it with various other countries[1,5]. These studies thus present an overview of India's research strength in the global landscape. Some studies have explored the research output of various institutional groups such as Central Universities[6], Indian Institutes of Technology (IITs)[7–9], National Institutes of Technology (NITs)[10,11], Indian Institutes of Science Education and Research (IISERs)[12], Indian Council of Agricultural Research (ICAR)[13], Indian Institute of Management (IIMs)[14–16], private universities[17,18], Indian Medical Institutions[19], All India Institute of Medical Sciences (AIIMS)[20] and research-intensive higher education institutions[21,22]. Studies specific to different subject domains have also been conducted for Indian institutions, such as medical sciences[23–25], computer science[26–30], agriculture[31], etc. However, to the best of our knowledge, there are no studies measuring the contribution of different states to the overall research output of India. The present study attempts to bridge this gap. Therefore, it is novel in terms of its subject, analysis and results.

The research output data for India for 2001–20 were obtained from the Web of Science (WoS) database. Each publication record was then computationally processed to identify and tag it with the affiliating state. This was done by extracting the 'affiliation' field from publication records, identifying city names and subsequently tagging publications to a state. Once each publication record was tagged with the affiliating state, the total publications from each state were identified. The proportionate share of each state in India's total research output was computed along with the rate of growth of research output in different states and the ratio of Gross State Domestic Product (GSDP) to its

Anurag Kanaujia, Abhirup Nandy, Prashasti Singh and Vivek Kumar Singh are in the Department of Computer Science, Banaras Hindu University, Varanasi 221 005, India; Prashasti Singh is also in the School of Computer Science, University of Petroleum and Energy Studies, Dehradun 248 007, India.
*For correspondence. (e-mail: vivek@bhu.ac.in)

respective yearly publications. Researchers have explored the relationship between Gross Domestic Product (GDP) and research productivity of states in previous studies[32–34], but have mainly focused on specific domains and made international comparisons. The size-normalized indicator, transformative activity index (TAI), was also calculated for each state to understand relative growth patterns. Thus, the present study measures the research output contribution of different states and their growth patterns.

Data and method

The data for analysis were obtained from WoS. Publication records of type 'articles' and 'review articles' were downloaded for each year between 2001 and 2020 (including both years). Data download was performed in May 2022. The following search query was used for the purpose: PY = (XXXX) AND CU = 'India' AND DT = ('Article' OR 'Review') to collect research output data for India. Here, PY represents publication year (which ranged from 2001 to 2020), CU represents country and DT, document type, which was set to include articles and review articles. The data retrieved in this manner was cleaned to remove rows with missing affiliations, total citation count (TC), or publication ID (UT). A total of 835,795 publication records were retrieved after pre-processing.

The publication data obtained for India from WoS was then analysed by writing programs in Python. The first task was to tag each publication with its affiliated institutions using the 'Affiliation' field provided in the WoS metadata. Thereafter, the address, city, state, latitude and longitude data for each institution were extracted and verified using Google Maps. This process has resulted in the development of a valuable dataset of Indian institutions, which is available for further use (A dataset containing the geographical data of Indian institutions, namely latitude and longitude information, states, city and detailed addresses has been developed, and is available for academic and non-commercial uses upon request to the authors.). Each publication record was tagged to one or more states. Some publication records involved collaboration among authors from institutions in different states; therefore, such publication records were tagged in all such states. The institutions with less than 50 publications in the 20 years were not considered for analysis. Figure 1 illustrates the main data sources used and the key steps of analysis. This approach of geo-tagging assigns publications to a city/state based on their institutional address. Hence, the bifurcation of Andhra Pradesh in 2014 did not affect the publication count for Telangana and Andhra Pradesh. Similarly, the bifurcation of Jammu and Kashmir into Jammu and Kashmir, and Ladakh did not affect the count of publications in these regions.

After tagging state names with publication records, the standard indicators of total research output, proportionate share and ratio of publications to state domestic productivity were computed for all the states. GSDP data for the states were retrieved from the Reserve Bank of India website[35] and utilized to estimate the GSDP to publications ratio for the last assessment year, i.e. 2020. The publications to GSDP ratio (z) for each state is given by

$$z_{\text{state}} = \frac{\text{TP}_{\text{state}}}{\text{GSDP}_{\text{state}}}, \tag{1}$$

where TP_{state} is the total publications of a state in 2020 and $\text{GSDP}_{\text{state}}$ is GSDP of a state in 2020. Although not an absolute measure of R&D investment, this value indicates the correlation between economic status and research output of the states. The effectiveness of India's scientific productivity and GDP have been related in previous studies[36], and the importance of a well-developed scientific research ecosystem for economic stability of a region has been explored.

Transformative activity index (TAI) is another indicator used in previous studies to compare areas of different sizes with different levels of financial capability[37,38]. The calculation of TAI shows relative changes in research output of the states during the period of analysis. It is calculated as follows

$$\text{TAI} = \frac{\text{State}_{\text{Year block}} / \text{State}_{\text{fulltime}}}{\text{Country}_{\text{Year block}} / \text{Country}_{\text{fulltime}}}, \tag{2}$$

where $\text{State}_{\text{Year block}}$ is the total number of publications from the selected state in the selected time period, $\text{State}_{\text{Fulltime}}$ is the total number of publications from the selected state in the study period, $\text{Country}_{\text{Year block}}$ is the total number of publications from all states of India in the selected period, and $\text{Country}_{\text{Fulltime}}$ is the total number of publications from all states of India during the study period.

Research output from different states

The research output from different states and UTs, their proportionate contribution to India's total research output, and TP/GSDP ratio were computed (Table 1). It can be observed that Tamil Nadu, Maharashtra, Delhi, West Bengal, Karnataka and Uttar Pradesh have each contributed more than 100,000 publications to India's research output. Then there is a large gap in the total number of publications, with the next state being Telangana with 54,180 publications. In terms of proportionate share in the national research output, Tamil Nadu contributes 17.67% followed by Maharashtra with 16.38%. Other major contributors include Delhi (14.29%), West Bengal (13.94%), Karnataka (12.79%) and Uttar Pradesh (12.14%). It may be noted that the sum of proportionate share of all states is more than 100, since there is a good amount of research output that involves collaboration between institutions in different states, and the publication data from such collaborations would have

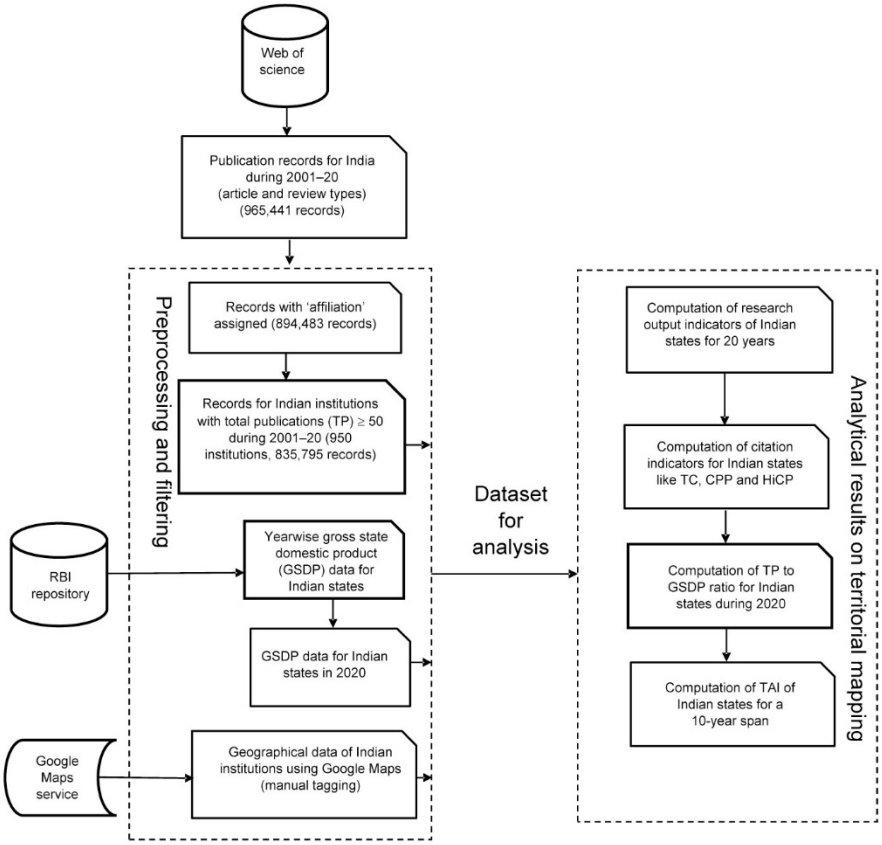

Figure 1. The process for extraction of publication data and assignment of geographical information for each publication.

been assigned to all the collaborating states. The TP/GSDP ratio (z) of 19 states is greater than the national average (0.82). Larger states such as Maharashtra, Telangana, Gujarat, Kerala, Madhya Pradesh, Rajasthan and Andhra Pradesh have relatively low z-values. This indicates that most of the institutions in these states have low efficiency.

Tamil Nadu (147,669 publications) and Maharashtra (136,917 publications) had the highest productivity. Among the states with high TP (above 10,000), the average TP/GSDP ratio for 2020 was between 0 and 2 (Figure 2). A higher value of this ratio would suggest higher productivity. A state with a low GSDP would generally have lower amounts of funds directed towards the science and technology sector. This, when considered along with TP, indicates that a state with low GSDP and high TP/GSDP ratio would have higher-efficiency institutions and an ecosystem that can convert available limited resources into impactful research. With this metric, it can be inferred that Chandigarh (7.02) and Puducherry (3.10) have a set of institutions with comparatively high efficiency. Among the relatively larger states, West Bengal (1.32) and Delhi (1.88) have reasonable TP and TP/GSDP ratios.

The per capita resource utilization per publication was also mapped using the TP/(per capita SDP) ratio. The per capita net GSDP data for the states were retrieved from the Reserve Bank of India website[39] and used to estimate the resource utilization ratio for the last assessment year, i.e. 2020. Figure 3 shows a better visualization of this ratio. The colour intensity of the fill-in-the-state map shows this measure. It may be observed that Uttar Pradesh (2.274), West Bengal (1.624), Tamil Nadu (0.989) and Maharashtra (0.897) have higher per capita resource utilization per publication among the states with high TP.

$$\text{Resource utilization per publication} = \frac{\text{TP}}{\text{Per capita SDP}}. \quad (3)$$

State-wise trends in publications

In order to explore the changes in publication patterns of the states, the size-normalized indicator, i.e. TAI was calculated for each state, as described by eq. (2). For the calculation of TAI, data were grouped into two blocks of 10 years each (2001–10 and 2011–20). The change in TAI for each state reflects the change in research activity in that state relative to the overall research activity of all states (Figure 4). A total of 22 states showed a positive change in TAI over the two blocks, indicating a higher-than-average growth in research publications from these states. Among them, Bihar had the largest change in research publications with a TAI

Table 1. Research output from Indian states

State	Total publications (TP) (2001–20)	Proportionate share in national output[#] (%)	TP (2001)	TP (2020)	Gross state domestic product (GSDP) 2020 (₹ billion)	TP/GSDP (2020)[+] (*z*-value)
Tamil Nadu	147,669	17.67	1804	17,541	12785.59	1.37
Maharashtra	136,917	16.38	2859	13,170	21340.65	0.62
Delhi	119,406	14.29	2266	11,536	6138.43	1.88
West Bengal	116,491	13.94	2206	10,338	7844.24	1.32
Karnataka	106,898	12.79	2246	10,155	11437.81	0.89
Uttar Pradesh	101,452	12.14	1898	9838	11668.17	0.84
Telangana*	54,180	6.48	976	4677	6485.95	0.72
Punjab	40,320	4.82	327	5683	4135.78	1.37
Gujarat	30,602	3.66	535	3197	12689.57	0.25
Kerala	29,964	3.59	545	3313	5686.36	0.58
Odisha	28,346	3.39	321	4110	4123.75	1.00
Uttarakhand	27,972	3.35	350	3172	1997.18	1.59
Madhya Pradesh	25,741	3.08	360	2814	5804.06	0.48
Assam	23,670	2.83	194	2790	2378.44	1.17
Rajasthan	23,297	2.79	415	3132	6887.14	0.45
Chandigarh	22,528	2.70	474	2193	312.35	7.02
Andhra Pradesh*	20,623	2.47	374	2558	6688.48	0.38
Haryana	20,430	2.44	314	2440	5597.05	0.44
Jharkhand	13,670	1.64	145	1826	2383.95	0.77
Himachal Pradesh	11,876	1.42	142	1599	1222.84	1.31
Jammu and Kashmir	10,135	1.21	72	1242	1190.43	1.04
Puducherry	7,554	0.90	122	776	250.09	3.10
Goa	5,614	0.67	98	674	531	1.27
Chhattisgarh	4,816	0.58	45	773	2498.75	0.31
Bihar	3,764	0.45	10	857	4096.45	0.21
Meghalaya	3,644	0.44	60	411	251.9	1.63
Tripura	1,735	0.21	10	288	402.07	0.72
Manipur	1,497	0.18	13	185	206.73	0.89
Arunachal Pradesh	1,281	0.15	23	185	179.16	1.03
Mizoram	957	0.11	1	200	180.34	1.11
Sikkim	869	0.10	1	166	197	0.84
Nagaland	577	0.07	6	92	181.21	0.51
Andaman and Nicobar Islands	160	0.02	4	8	71.98	0.11

[#]The total number of publications from India in the 20-year period was 835,795 records.

*The state of Andhra Pradesh was bifurcated into Andhra Pradesh and Telangana. The publication trends were assigned based on the new territorial arrangements for all the years.

[+]The ratio between TP and GSDP reflects the correlation between economic status and research output of the states.

change of 109.16%. Rest 11 states showed a negative change in TAI, which indicates slower-than-average growth in research publications from them. For instance, in the case of Delhi, TAI for 2010 was 111.36 and for 2020 it was 95.61, and the change in TAI (2010–20) was negative (–15.76). This showed that relative to the previous decade, the increase in number of publications was 15% slower. It may be noted that high changes in TAI are seen in the case of states that have a low number of publications, as small changes in the publications would be more pronounced in such cases. These states can also be attributed to most of the growth in overall research output from India relative to the previous years. Among the larger states, which have significant publication records, the variation in TAI was mostly below 25%. Almost all the states with high research output volumes had a negative change in TAI, except Tamil Nadu, where, despite having the most publications, the number of publications has grown at a rate comparable to small states. This indicates an overall conducive environment for research in Tamil Nadu.

Citation impact of research

To further assess the impact of research from the states, citation metrices were explored. It was observed that the publications from Maharashtra received the largest number of citations (3,619,174) in the 20-year period and had the highest CPP value at 26.43. Tamil Nadu (3,286,345), Delhi (3,083,400), Karnataka (2,690,225), West Bengal (2,634,057) and Uttar Pradesh (2,397,185) were the states with publications that received higher citations. CPP, HiCP and HiCP/TP values for all the states were also computed. High values of CPP and HiCP of the states indicate higher visibility and the impact of research done in the respective institutions of these states (Table 2).

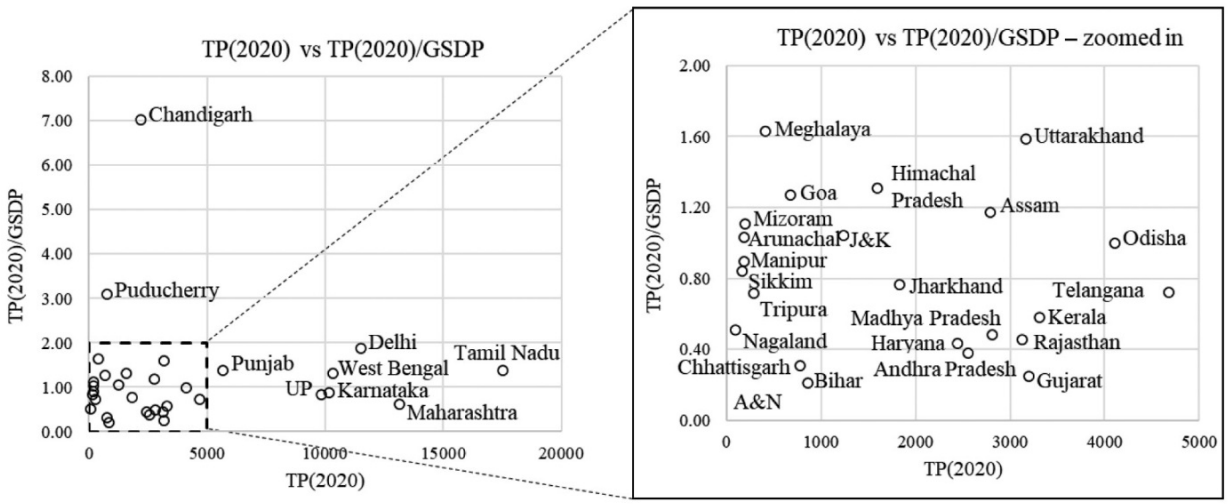

Figure 2. TP (2020) versus TP (2020)/GSDP for the Indian states.

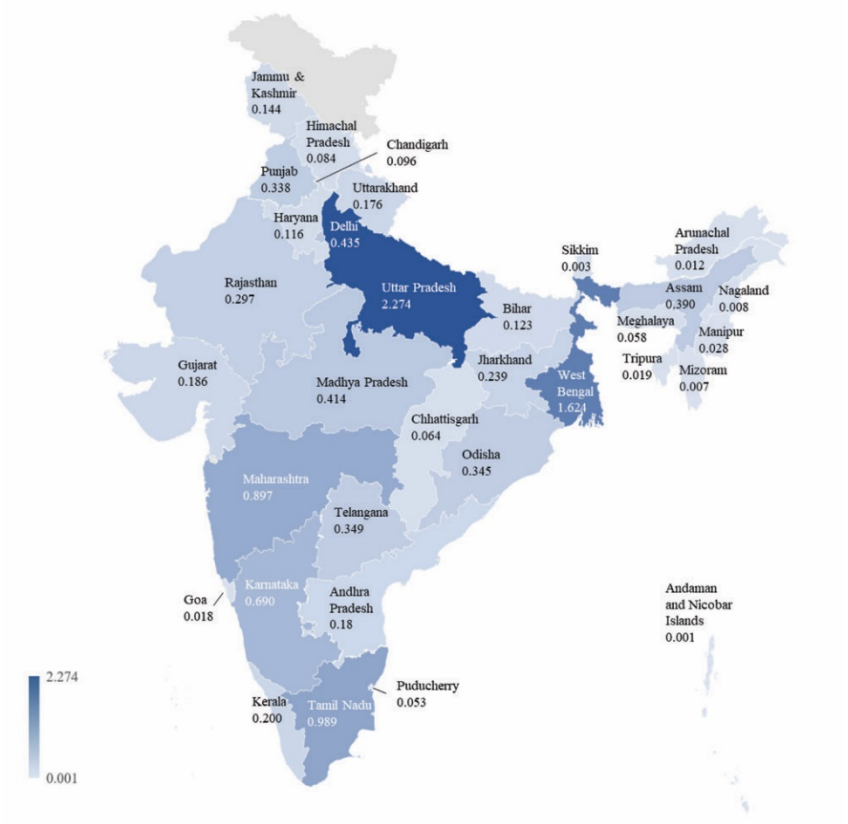

Figure 3. Map of India showing the ratio of total publications versus per capita net state domestic product from different states and Union Territories (UTs) during the last 20 years (2001–20). Note: The number of publications from institutions in three UTs (Ladakh, Lakshadweep and Dadra, Nagar Haveli and Diu) was below the threshold of minimum 50 publications; hence their data are not presented in the figure.

The plot between CPP and HiCP/TP was used to map the impact of research conducted in the states (Figure 5). CPP and HiCP/TP for data of all the states taken together was 23.58 and 0.01 respectively. Eight states (Chandigarh, Odisha, Uttarakhand, Maharashtra, Delhi, Karnataka, Kerala, and Jammu and Kashmir) had high HiCP/TP values, while six states (Chandigarh, Odisha, Uttarakhand, Maharashtra, Delhi and Karnataka) had high CPP values, indicating that their contribution drives Indian research productivity. Some states (like Tamil Nadu) have high TP (Table 1), but relatively low

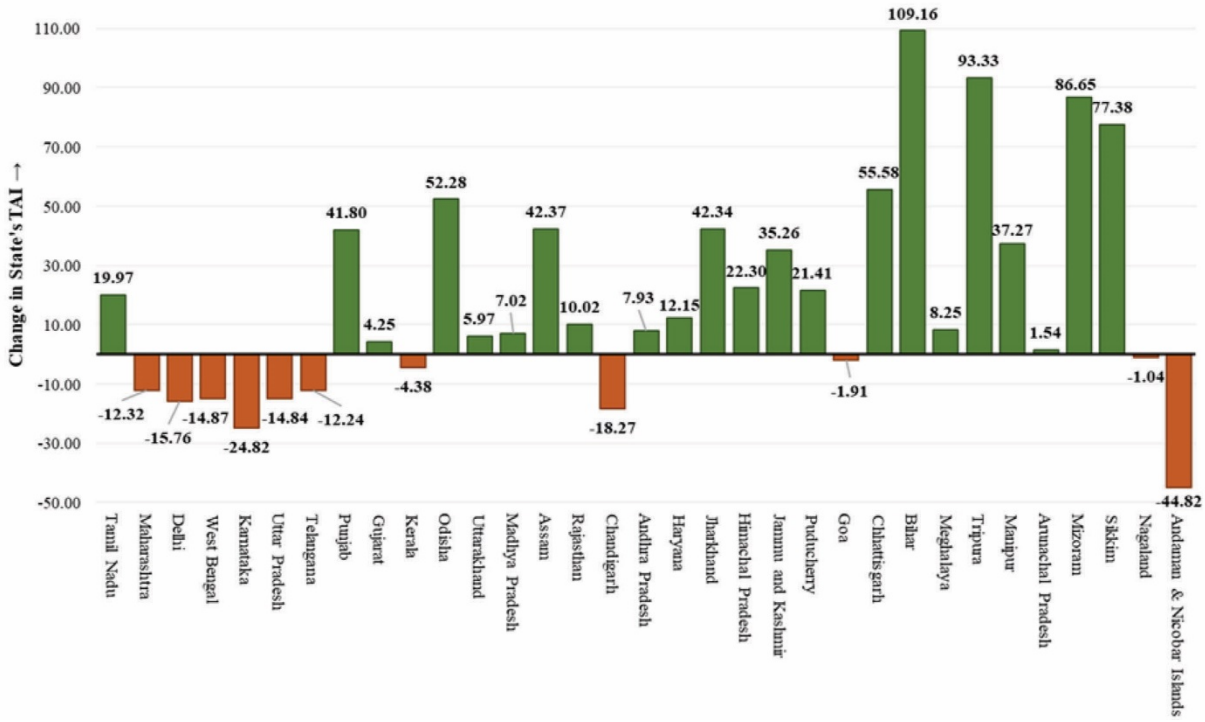

Figure 4. Change in transformative activity index (TAI) of states between 2001–10 and 2011–20 showing relative rate of increase in research publications.

average CPP and HiCP/TP ratio. This may indicate a relatively high focus on research in these states, while the impact of research conducted in these states varies. One possible reason for the growth in research publications of these states may be the setting up of new institutions in them. For example, IITs in Punjab (Ropar), Odisha (Bhubaneswar) and Bihar (Patna) and IISER in Punjab (Mohali). State policies for the promotion of science and technology in addition to a push from the national Government can also be correlated with the quick growth in research output from these states. It may be an area of interest to explore the connections between the observed trends and state policies in a future study.

Discussion

This study has identified states with the highest and lowest research outputs, along with quantifying the impact of research conducted in them. The finer observations in the productivity of states with respect to their economic status and relative changes across them (TAI) showed large changes in small states and moderate changes in large states. Small states have contributed significantly to the overall research growth of the country, while larger states have more or less maintained their productivity through the years. Among the large states, Tamil Nadu showed a remarkable increase in publications. It is the only state with a positive change in TAI among the states with a TP of more than 100,000. In this context, examining the ecosystem and policies for promoting research in Tamil Nadu may provide useful insights for other states. On closer observation, it was found that the states which recorded a high number of publications have universities and organizations which are leading the research activity in the country (Appendix 1 provides a list of the top-five publishing institutions for each state and UT). For instance, Tamil Nadu which has the highest number of publications among the states, has IIT Madras, Anna University and Vellore Institute of Technology, which are leading institutions in the country. Thus, the research output volume of a state is dependent on the presence of research-producing institutions in it. It was also observed in the case of many states that some of the research-producing institutions were governed and funded by the respective state (for example, Anna University and University of Madras in Tamil Nadu). Similarly, some states had a higher number of private universities which contributed to the research output. A favourable and encouraging atmosphere in a state may be the reason for a higher number of private universities there. Thus, states can play a significant role in the establishment and promotion of research environments in them.

In this study, the biggest changes in the percentage growth of publications from 2011–15 to 2016–20 were observed in Bihar, Chhattisgarh, Jharkhand, Mizoram, Tripura and Nagaland. The change in TAI for these states was also high. These were the states that were earlier considered backward or remote and have seen economic development in the past decade. There can be multiple models for economic development, and several studies have explored the factors of

Table 2. Impact of research output from Indian states

State	TP (2001–20)	TC (2001–20)	CPP	HiCP	HiCP/TP
Tamil Nadu	147,669	3,286,345	22.25	1227	0.0083
Maharashtra	136,917	3,619,174	26.43	1721	0.0126
Delhi	119,406	3,083,400	25.82	1392	0.0117
West Bengal	116,491	2,634,057	22.61	996	0.0086
Karnataka	106,898	2,690,225	25.17	1241	0.0116
Uttar Pradesh	101,452	2,397,185	23.63	952	0.0094
Telangana	54,180	1,291,712	23.84	480	0.0089
Punjab	40,320	936,825	23.24	403	0.0100
Gujarat	30,602	685,497	22.40	256	0.0084
Kerala	29,964	705,522	23.55	343	0.0114
Odisha	28,346	766,502	27.04	427	0.0151
Uttarakhand	27,972	688,935	24.63	363	0.0130
Madhya Pradesh	25,741	555,345	21.57	220	0.0085
Assam	23,670	494,955	20.91	155	0.0065
Rajasthan	23,297	451,573	19.38	180	0.0077
Chandigarh	22,528	654,894	29.07	373	0.0166
Andhra Pradesh	20,623	352,455	17.09	88	0.0043
Haryana	20,430	373,401	18.28	121	0.0059
Jharkhand	13,670	273,925	20.04	100	0.0073
Himachal Pradesh	11,876	246,230	20.73	100	0.0084
Jammu and Kashmir	10,135	223,661	22.07	105	0.0104
Puducherry	7554	159,071	21.06	63	0.0083
Goa	5614	123,718	22.04	54	0.0096
Chhattisgarh	4816	80,608	16.74	28	0.0058
Bihar	3764	60,895	16.18	13	0.0035
Meghalaya	3644	47,380	13.00	5	0.0014
Tripura	1735	26,757	15.42	8	0.0046
Manipur	1497	21,881	14.62	4	0.0027
Arunachal Pradesh	1281	19,236	15.02	10	0.0078
Mizoram	957	16,253	16.98	7	0.0073
Sikkim	869	16,007	18.42	8	0.0092
Nagaland	577	6325	10.96	2	0.0035
Andaman and Nicobar Islands	160	3084	19.28	1	0.0063

Note: Corresponds to 835,795 Indian research publications (article + review document types) during 2001–20. TP, Total papers; TC, Total citations; CPP, Citations per paper; HiCP, Highly cited papers (number of papers in top 1% of absolute TP in India).

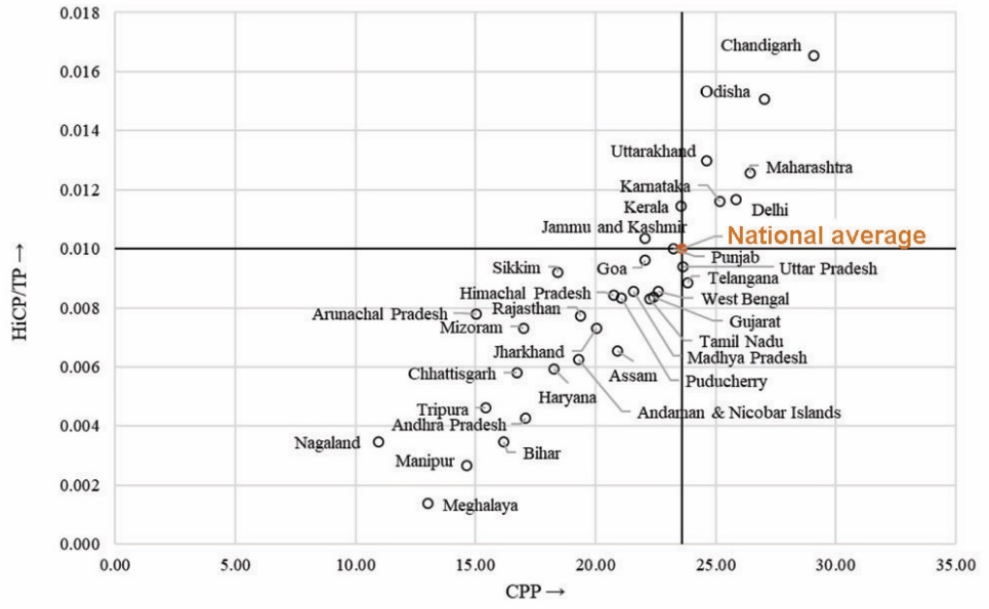

Figure 5. Citations per paper (CPP) versus highly cited papers/total papers (HiCP/TP) for each Indian state.

Appendix 1. List of up to five major research output-producing institutions in each state of India

State	Institution				
	1	2	3	4	5
Tamil Nadu	Indian Institute of Technology Madras	Anna University	Vellore Institute of Technology	Annamalai University	University of Madras
Maharashtra	Bhabha Atomic Research Centre	Indian Institute of Technology Bombay	Tata Institute of Fundamental Research	CSIR-National Chemical Laboratory	Savitribai Phule Pune University
Delhi	University of Delhi	Indian Institute of Technology Delhi	All India Institute of Medical Sciences, New Delhi	ICAR-Indian Agricultural Research Institute	Jawaharlal Nehru University, New Delhi
Uttar Pradesh	Banaras Hindu University	Indian Institute of Technology Kanpur	Aligarh Muslim University	Indian Institute of Technology, Varanasi	CSIR-Central Drug Research Institute
Karnataka	Indian Institute of Science, Bengaluru	Manipal Academy of Higher Education	Jawaharlal Nehru Center for Advanced Scientific Research	University of Mysore	CSIR-Central Food Technological Research Institute
West Bengal	Indian Institute of Technology Kharagpur	Jadavpur University	University of Calcutta	Indian Association for the Cultivation of Science	Indian Statistical Institute, Kolkata
Andhra Pradesh	Sri Venkateswara University	Andhra University	Acharya Nagarjuna University	Gandhi Institute of Technology and Management	Sri Krishnadevaraya University
Kerala	Cochin University Science and Technology	CSIR-National Institute Interdisciplinary Science and Technology	Mahatma Gandhi University	University of Kerala	Vikram Sarabhai Space Centre
Gujarat	Maharaja Sayajirao University	Physical Research Laboratory	CSIR-Central Salt and Marine Chemical Research Institute	Institute for Plasma Research	Sardar Vallabhbhai National Institute of Technology
Punjab	Thapar Institute of Engineering and Technology	Guru Nanak Dev University	National Institute of Pharmaceutical Education and Research	Punjab Agricultural University	Punjabi University
Chandigarh	Panjab University	Post Graduate Institute of Medical Education and Research	CSIR-Institute of Microbial Technology	CSIR-Central Scientific Instruments Organisation	National Institute of Technical Teachers Training and Research, Chandigarh
Odisha	National Institute of Technology, Rourkela	Institute of Physics Bhubaneswar	CSIR-Institute of Minerals and Materials Technology	National Institute of Science Education and Research	Siksha 'O' Anusandhan University
Haryana	ICAR-National Dairy Research Institute	Kurukshetra University	Maharshi Dayanand University	CCS Haryana Agricultural University	National Institute of Technology, Kurukshetra
Madhya Pradesh	UGC DAE Consortium for Scientific Research	Raja Ramanna Centre for Advanced Technology	Indian Institute of Technology, Indore	Dr Hari Singh Gour University	Devi Ahilya University
Rajasthan	Birla Institute of Technology and Science	University of Rajasthan	Malaviya National Institute of Technology	Banasthali Vidyapith	Jai Narain Vyas University
Assam	Indian Institute of Technology Guwahati	Tezpur University	Gauhati University	CSIR-North East Institute of Science and Technology	Assam University
Telangana	CSIR-Indian Institute of Chemical Technology	University of Hyderabad	Osmania University	Indian Institute of Technology-Hyderabad	CSIR-National Geophysical Research Institute

(*Contd*)

Appendix 1. (*Contd*)

State	Institution				
	1	2	3	4	5
Bihar	Indian Institute of Technology-Patna	National Institute of Technology, Patna	ICMR-Rajendra Memorial Research Institute of Medical Sciences	ICAR-Research Complex for the Eastern Region	Patna University
Uttarakhand	Indian Institute of Technology-Roorkee	Govind Ballabh Pant University of Agriculture Technology	Kumaun University	Hemwati Nandan Bahuguna Garhwal University	Wadia Institute of Himalayan Geology
Jammu and Kashmir	University of Jammu	University of Kashmir	CSIR-Indian Institute of Integrative Medicine	Sher-e-Kashmir University of Agri-cultural Sciences and Technology of Kashmir	Sher-i-Kashmir Institute of Medical Sciences
Puducherry	Pondicherry University	Jawaharlal Institute of Postgraduate Medical Education and Research	Pondicherry Engineering College	ICMR-Vector Control Research Center	Kanchi Mamunivar Government Institute for Post graduate Studies and Research
Himachal Pradesh	Himachal Pradesh University	National Institute of Technology-Hamirpur	CSIR-Institute of Himalayan Bioresource Technology	Indian Institute of Technology-Mandi	Ch. Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya
Goa	CSIR-National Institute of Oceanography	Goa University	National Centre for Polar and Ocean Research	ICAR-Central Coastal Agricultural Research Institute	National Institute of Technology-Goa
Jharkhand	Indian Institute of Technology (Indian School of Mines), Dhanbad	Birla Institute of Technology, Mesra	CSIR-National Metallurgical Laboratory	CSIR-Central Institute of Mining and Fuel Research	National Institute of Technology-Jamshedpur
Meghalaya	North Eastern Hill University	ICAR Research Complex for the NEH Region	National Institute of Technology-Meghalaya	North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences	
Chhattisgarh	Pt. Ravishankar Shukla University	National Institute of Technology-Raipur	Guru Ghasidas Vishwavidyalaya	Indira Gandhi Krishi Vishwavidyalaya	Govt Vishwanath Yadav Tamskar P.G. Autonomous College
Tripura	National Institute of Technology-Agartala	Tripura University			
Manipur	Manipur University	National Institute of Technology-Manipur	Institute of Bioresources and Sustainable Development	Regional Institute of Medical Sciences, Imphal	
Sikkim	Sikkim Manipal University	Sikkim University	National Institute of Technology-Sikkim		
Mizoram	Mizoram University	National Institute of Technology-Mizoram			
Nagaland	Nagaland University	ICAR-National Research Centre on Mithun	National Institute of Technology-Nagaland		
Arunachal Pradesh	North Eastern Regional Institute of Science and Technology	Rajiv Gandhi University, Itanagar	ICAR-National Research Centre on Yak	National Institute of Technology-Arunachal Pradesh	
Andaman and Nicobar Islands	ICMR-Regional Medical Research Centre, Port Blair				

economic growth and the role of R&D institutions in different regions. The specific 'contributions of European universities to innovation and employment' of their local communities have been studied by the European Expert Network on Education[40]. It was observed that patenting, licensing and spin-offs were the primary modes of contribution of universities to regional development in terms of technology transfer. Universities and research centres also create knowledge spillovers as their alumni engage in economic activities with the local community[40]. Therefore, it would be beneficial for state governments to promote existing R&D institutions and establish new ones. This has been identified as the policy instrument to revitalize peripheral regions[41].

Innovation and development studies have observed that the R&D centres located in a state (region) help in the growth of that state by directing research, education and societal activities towards locally and societally relevant subjects and resources[42–44]. It may be possible that the existence of major R&D institutions in states could be an important factor in its development and social upliftment. Studies correlating contributions of university/R&D institutions with development and economic growth are available in developed countries, namely Sweden, Austria[45], USA and the UK[40], such studies are lacking for India. Therefore, this is another interesting aspect to explore when analysing the research output of Indian states.

More studies can be done to understand the correlations between R&D activities and the growth and development levels of a state. The observations of this study can be further explored to see what more can be done for science policy. Some of the possible studies can be focused on (a) identifying major central and state-funded institutions in each state that contribute to research output; (b) creating a portfolio of major research expertise of each state, and (c) understanding the linkages between thematic strength and resource availability of the states. The present study is an effort towards territorial mapping of Indian research output. There are further possibilities for analysis of R&D activities, including considering research contribution shares of central versus state-funded institutions of each state.

Conclusion

This study has analysed and characterized the research output of all the states and UTs in India. It presents an overview of the national research output from the perspective of administrative units and highlights the major contributors, most improved and less productive states. Tamil Nadu, Maharashtra, Delhi, West Bengal, Karnataka, and Uttar Pradesh were the top contributors to the research output. Uttar Pradesh, West Bengal, Tamil Nadu and Maharashtra had higher publications per capita net GSDP. In terms of quality, measured by HiCP/TP ratio, Chandigarh, Odisha, Uttarakhand, Maharashtra, Delhi and Karnataka were the major states. The trends in publication growth for the 20-year period showed relative historic performance improvement over time. Statewise comparisons can be drawn from the observations of resource utilization per publication. It was also observed that the states which were once considered backward or remote (such as Bihar, Chhattisgarh, Jharkhand, Mizoram, Tripura and Nagaland) showed impressive TAI values, indicating a positive growth in their research output. However, these results are only indicative, as number of publications from some of these states is relatively low.

The association of states with their publication records in this study directly represents the geographical location of the author's affiliated organization, which was mapped using latitude and longitude data of the respective organizations retrieved from primarily Google Maps and the organizational websites in some cases. This annotated dataset of organizations and states and latitude–longitude data for organizations is another contribution of the present study. This study, however, has a limitation that it did not capture innovation activities, products and technologies developed in different states. An analysis of patents filed and innovations registered from each state can provide an equally interesting insight into the overall environment in them to promote R&D activities.

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