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Andrey S. Mikhaylov
Institute of Geography of the RAS, Moscow, Russian Federation
Immanuel Kant Baltic Federal University, Kaliningrad, Russian Federation.

Spatial Scientometrics in Measuring the Geography of Knowledge and Innovation: The Case of India[1]

Abstract. The global landscape of science, technology, and innovation (STI) is increasingly shifting toward developing countries. China and India—two Asian economies with fast-growing innovation sectors—are at the forefront of this process, yet the regional dimension of their knowledge economies, especially in India, remains insufficiently studied. This article examines territorial and sectoral patterns of knowledge production and commercialization across Indian states, applying a spatial scientometric approach. The analysis draws on data from Scopus, Intellectual Property India, and the National Manufacturing Innovation Survey (2017–2022), aligned with India's national development priorities. The study explores how regional scientific output relates to inventive and innovation activity. The results show a strong positive link between scientific productivity and both patenting and innovation, with a particularly strong connection between regional knowledge production and inventive activity. The strength of this link varies by field: the spatial distribution of patents closely aligns with publication centres in natural sciences, life sciences, and medicine, but shows the weakest association with arts and humanities. Innovation indicators—such as India's Industrial Innovation Index and the number of innovative firms—are most strongly linked to output in life sciences and medicine as well as social sciences and management. These findings underscore the potential of scientometric indicators to complement traditional measures of innovation, particularly in data-scarce regional contexts. They offer empirical support for integrating bibliometric data into regional STI assessments and for forecasting innovation potential at the subnational level.

Keywords: spatial scientometrics, spatial bibliometrics, geography of knowledge, geography of innovation, regional innovation system, patent analysis, innovation, India

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

А.С. Михайлов
Балтийский федеральный университет им. И. Канта, г. Калининград, Российская Федерация
Институт географии РАН, г. Москва, Российская Федерация

ПРОСТРАНСТВЕННАЯ НАУКОМЕТРИЯ В ИЗМЕРЕНИИ ГЕОГРАФИИ ЗНАНИЯ И ИННОВАЦИЙ (НА ПРИМЕРЕ ИНДИИ)

Аннотация. География мировой науки, технологий и инноваций (НТИ) все больше смещается в сторону развивающихся стран как новых драйверов глобального экономического роста. На переднем крае находятся Китай и Индия — две азиатские экономики, демонстрирующие ускоренную инновационную динамику. Исследования экономики знаний на национальном уровне — не редкость, однако региональное измерение инноваций остается недостаточно изученным, особенно в отношении развивающихся стран. В статье определяются территориальные и отраслевые закономерности производства и коммерциализации научных знаний в штатах Индии. В исследовании использована методология пространственной наукометрии. Количественные данные получены из базы данных Скопус, Национального патентного ведомства и Национального обзора инноваций в обрабатывающей промышленности Индии. Временной период охватывает 2017–2022 гг. Это исследование вносит вклад в изучение взаимосвязи между наукой, технологиями и инновациями путем оценки влияния региональных научных публикаций на патенты и инновации. Обнаружена сильная положительная корреляция между научной производительностью индийских регионов и их изобретательской и инновационной активностью. Выявлено, что функция производства знаний региона сильнее связана с его изобретательской деятельностью, нежели инновационной, и дифференцирована по областям исследований. География патентования тесно увязана с центрами публикационной активности в области естественных наук, наук о жизни и медицины, и наименее — в области искусства и гуманитарных наук. Производство инноваций, измеряемое Индийским индексом промышленных инноваций, и количество инновационных компаний тяготеют к научным центрам в области наук о жизни и медицины, социальных наук и менеджмента. Результаты исследования важны для прогнозирования инновационной деятельности на региональном уровне. Они дают эмпирическое обоснование использования наукометрических показателей наряду с традиционными статистическими данными о патентах и инновациях при оценке инновационной активности регионов.

Ключевые слова: пространственная наукометрия, пространственная библиометрия, география знания, география инноваций, региональная инновационная система, патентный анализ, инновации, Индия

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Introduction

Since the late 20th century, the role of knowledge and innovation in driving economic growth, competitiveness, and sustainable development has attracted increasing attention in academic research, as shown by the growing number of publications on the subject (Shapira & Youtie, 2006). The knowledge economy, based on human capital and technology, has become the priority model of the economy. Its construction involves investments in the higher education, science and technology sectors (Badran & Badran, 2022). The transition to the post-industrial stage of development has secured the role of technology as the main resource of a knowledge-intensive economy, positively linking investment, technological development and innovation (Pogodina et al., 2019).

Developing countries, which often face shortages of investment and capital, are just as interested in pursuing innovative development as developed countries. In the early stages, their emerging economies focused on less capital-intensive sectors, such as information and communication technologies (Sharma et al., 2016). However, over time, a number of developing countries (China, India and others) have moved from the catch-up phase to the leading stage (Ivanova & Mamedyarov, 2019). These trends reflect targeted state policies in the field of research and development (R&D), aimed at strengthening national scientific and technological (S&T) potential, increasing patenting and publishing activity, developing specialized research and technology areas, expanding high-tech sectors, and attracting investment.

These countries are becoming more actively involved in global competition in the high-tech sector, which expands opportunities for innovation and entrepreneurship at the national level (Régnier, 2023). This progress is stimulated through the establishment of local R&D centres, open innovation partnerships, technology adaptation, and cost-effective innovation. Countries such as China, India, the Philippines, Singapore, Malaysia and Indonesia have significantly increased their share in the global export of high-tech industrial products in recent years, demonstrating better values than many high-income countries (Desai, 2013).

India is a particularly noteworthy example of a new global innovator. Between 1958 and 2013, the country revised its innovation policy four times, with the most recent program launched in 2020 to strengthen the national innovation system (Sattiraju & Janodia, 2024). India strives to become a world power in the field of innovation, combining S&T, innovation, educational policies and five-year development plans at the national level (Mammen & A. K., 2024). Much attention in the country is paid to the development of science and the transfer of its achievements to the economy by improving the infrastructure for innovation and supporting startups (Kopala et al., 2023; Rakshit & Moitra, 2024).

However, comprehensive empirical studies (e.g. Mehta, 2018) show that India still lags behind developed countries and even some developing countries in terms of both innovation costs (R&D expenditure, highly skilled labour force) and innovation results (number of patents issued, share of high-tech exports, etc.). Although in absolute terms the country demonstrates positive dynamics of R&D investments, number of publications and patents, the share of science expenditure in the country's GDP remains low (0.7 % in 2019–2020) (Sharma & Haldar, 2020).

Against this background, the "Strategy for New India @ 75" 1 recognizes basic science as a driving force behind innovation and highlights the need for continued investment to support the nation's economy (Jain, Roy, 2024). Traditionally, basic science has been centred in higher education institutions, which have become key components of the national innovation system (NIS) over recent decades. Initially focused on education alone, universities later expanded their roles to include research and innovation activities. The entrepreneurial university model has since grown significantly, offering various institutional formats for direct innovation efforts and support infrastructure, such as incubators, technology parks, and innovation centres (Krishna, 2019). For India, the traditional educational role of universities is still strong, but there is a growing trend towards commercialization of the results of fundamental academic research and their patenting (Bhardwaj et al., 2021).

Support programmes overseen by the Ministry of Science and Technology of India (Srinivasaiah et al., 2021) positively influence publication output and international collaboration in Indian academia. The results of the study on publication and patent activity of 347 Indian universities and institutes over a period of more than ten years demonstrate, on the one hand, an increase in absolute quantitative knowledge, and, on the other hand, a still low contribution of academic organizations to the country's overall publication and patent indicators, as well as a significant asymmetry by subject area (Sharma & Jain, 2014).

Enhancing research and innovation in India's academic sector remains a key priority. Javed et al. (2024), using data from universities in India, Bangladesh, Nepal, Pakistan, and Sri Lanka, highlight the crucial role of higher education in generating knowledge and supporting regional socio-economic development through local partnerships and resource-sharing for technological advancement.

As in developed countries, the triple helix model is relevant for India to better integrate local innovation potential in order to engage and connect all participants in the innovation process. At the same time, the country is characterized by territorial heterogeneity in the concentration of scientific, technological and innovative (STI) potential, and sectoral differences in the generation of new knowledge and technologies are still strong (Mikhaylov et al., 2020). Another problem is that limited data on the knowledge economy at the state level hampers the assessment and forecasting of regional innovation in India.

In this regard, the idea behind this study is to measure the geography of knowledge production in the states of India using the modern tools of spatial scientometrics as an objective source of digital information on the development of science. The collected geographically coded data on the volume of scientific production in the states of India will then be compared with the two most widely used aspects of the discipline of "geography of innovation", namely, patents (i. e. the knowledge processing domain) and innovation

[1] Strategy for New India @ 75, NITI Aayog, 2018. https://www.phdcci.in/wp-content/uploads/2022/01/Strategy_for_New_India-NITI-Aayog-Report.pdf (Date of access: 01.11.2024)

(i. e. the knowledge commercialization domain). The article presents the level of interrelationship between these indicators and reflects the sequential scheme of the innovation process: knowledge production — knowledge processing — knowledge commercialization.

We expect this approach to reveal the relationship between scientific, technological, and innovative development, considering the industry specialization of the scientific sector across Indian regions. The study also offers a spatial perspective on the geography of scientific knowledge and innovation in contemporary India. While India has been the subject of scientometric research, such work typically focuses on national-level comparisons (e.g., for BRICS countries—Venkata et al., 2021; Wong & Wang, 2015) or on analyzing scientific collaboration (e.g., for African countries—Chakrabarti & Mondal, 2022). Another strand of research examines the publication output of specific institutions, such as those under the Department of Biotechnology (Mondal et al., 2021). However, comprehensive spatial analyses of the distribution and concentration of scientific, technological, and innovative activity across Indian regions remain scarce. This study seeks to address that gap.

The following section of the article presents a brief overview of the research on the geography of knowledge and innovation. The methodology section describes the research protocol, including the sources of data and the processing techniques used. Research results present findings structured by the three dimensions of the innovation process: knowledge production — knowledge processing — knowledge commercialization. The findings are then further analysed in the Discussion section against prior research on the geography of knowledge and innovation. The paper concludes with an outlook of applying spatial scientometrics techniques in studies on regional innovation capacity.

Literature Review

Scientific, technological, and innovative (STI) activities are deeply interconnected. Given the non-linear nature of innovation, the influence between science, technology, and innovation is mutual rather than unidirectional. Science drives technological and innovative progress, while these, in turn, shape scientific agendas and methods (Brooks, 1994). Countries are increasingly focusing on forecasting scientific outcomes and identifying where they will occur. To support this, states are developing technological foresight systems that rely heavily on scientometrics as a crucial tool and information source (Mesropyan & Ovsyannikov, 2014; Kalachikhin, 2020).

The use of scholarly publications to assess scientific activity began in the early 20th century with simple counts of publications and citations (Godin, 2006; Garg, 2019). With the rise of mathematical methods in the social sciences and humanities, this evolved into bibliometrics, which gained prominence by the 1960s as a tool for quantitative analysis. Alan Pritchard (1969, p. 349) gave perhaps the most popular definition of bibliometrics as “the application of mathematics and statistical methods to books and other media of communication”. However, pioneers in this field were the British scientist Derek de Solla Price (1951; 1965; 1975), the American researcher and businessman Eugene Garfield (1964), and the Soviet scientist Vasily Nalimov (1966; 1969). In particular, Nalimov was the first to propose the term “scientometrics” — as quantitative (mathematical and statistical) methods for studying science as an information process (Nalimov & Mul’chenko, 1969, p. 12), laying the foundation for scientometrics (Bonitz, 2001).

Nowadays, scientometrics is increasingly used in research with a geographical context, providing information on the spatial distribution, localization, density and network collaboration of research. Gao (2015) defines spatial scientometrics as a research field that deals with the measurement, analysis and visualization of science with spatial components. The spatial dimension can have different degrees of depth (Bielecka & Burek, 2019; Matthiessen & Schwarz, 1999). The geographical factor has been analysed in numerous studies on research collaboration, exploring the causes and consequences of strong and effective research ties.

At the country level, Jiang et al. (2018) compared the influence of geographic and economic proximity, finding the latter to be more significant. Narin and Carpenter (1991) examined international co-authorship and found that cultural, historical, and linguistic barriers remained strong, even within the seemingly homogeneous community of European countries. Spatial scientometrics has proven effective in identifying global industry centres of excellence at the city and regional levels (Bornmann et al., 2011; Bornmann, de Moya-Anegón, 2019; Bornmann & Waltman, 2011). Mapping corporate R&D activity using publication data has helped to identify the most significant areas of innovation activity (Csomós, 2017; Csomós & Tóth, 2016).

Currently, an important task of scientometric research is to forecast the global and national publication domains (Mueller, 2016) and their impact on economic indicators. Based on country analysis, Mueller (2016) has found a significant direct positive relationship between the size of the national publication output and such indicators as R&D expenditure, the number of universities, especially those in the world's top 500 and the real size of GDP. The population size is positively related to the total number of universities, and the number of people employed in R&D is positively related to GDP per capita.

R&D expenditures are crucial for countries to maintain their leadership in the global market and ensure competitiveness and national security. In this regard, there is a global increase in R&D budgets with a shift towards the development of knowledge-intensive industries, as well as stratification between rich and poor countries (Badran & Badran, 2022). Arana Barbier (2023) shows that R&D investments are strongly correlated with the economic growth demonstrated by a country. The special importance of increasing scientific production (as the number of articles per 1 % of R&D investments) is emphasized for developing countries, since R&D investments are a significant factor in their economic development due to the manifestation of a dynamic cumulative effect.

Publications and patents remain the primary indicators for measuring science and innovation (Shapira & Youtie, 2006; Kumar, 2021). Patents are widely used to assess technology transfer and innovation (Badran & Badran, 2022), while their relationship with publications—reflecting fundamental research—is often evaluated through citation analysis (Meyer, 2000; Wang & Ye, 2021). A study by Popp (2017) on research flows in the energy sector found that highly cited scientific publications significantly contribute to the development of applied technologies.

The demand for different types of formalized knowledge in technology production varies. A study at the University of Arkansas (Salisbury et al., 2021) found that patents most often cite peer-reviewed journal articles less than 20 years old and other patents. In contrast, books and monographs are cited far less frequently—on average, once per patent—and tend to be older than 15 years, indicating a focus on foundational works.

Wang and Ye (2021), examining the CRISPR/CAS9 technology, found that knowledge flows—measured through cross-citations—differ in strength and timing. Scientific publications have a stronger influence on patents than the reverse, and knowledge tends to circulate more easily within publications or within patents than between the two.

Another study by Veugelers and Wang (2019), using data from Web of Science SCIE and PATSTAT, showed that highly novel scientific articles have the strongest positive impact on technological development and are more likely to lead to patents than less novel work.

In addition to differences in the strength of the mutual influence between types of scientific information, the geographic factor plays an important role. Citation flows decrease with the distance between co-authors, but research impact increases with increasing R&D funding (Pan et al., 2012). Inglesi-Lotz et al. (2018), using data from 25 countries including India, found that national R&D spending plays a key role in linking scientific publications and patents. As shown by Hennemann et al. (2011), who used spatial scientometrics to assess regional research potential, bibliometric indicators can help identify research impacts, specializations, and knowledge flows (de Queiroz, 2021). They can also supplement or even replace traditional innovation statistics, particularly at regional levels where data are limited.

This paper proposes that scientometrics can be used to provide information on the regional innovation development as part of economic analysis. The paper compares the volume of publications (knowledge production) with patenting (knowledge processing) and innovation (knowledge commercialization) activity to identify the level of relationship between these indicators. The hypotheses to be tested are as follows:

H1: The volume of scholarly output correlates with the volume of patenting and innovation activity.

H2: Natural sciences and technical fields of science are more correlated with patenting and innovation activity.

Data and Methodology

The study design is structured in sections that follow the stages of the innovation process — knowledge production, knowledge processing, and knowledge commercialization, focusing on verification of the two hypotheses set — the general and the field-specific research domains (i. e. by output volume and by research focus).

The first stage of knowledge production is represented by scholarly publications. The dataset, sourced from the Scopus database [1] in August 2023, covers six years (2017–2022), corresponding to India's Thirteenth Five-Year Plan (March 2017 — February 2022), which remains relevant in some regional development strate-

[1] Scopus database. www.scopus.com (Date of access: 01.11.2024).

gies 1. The study applies a regional-level analysis encompassing all Indian states.

For data sourcing, an advanced search option is used to create a complex search query for capturing the geographical dimension of scientometric data, including the name of the country, the region (state), and its cities. For this purpose, the "AFFIL" search operator used, which is a combined field that searches the following address fields: AFFILCITY, AFFILCOUNTRY, and AFFILORG. Thus, the search query attributed to a particular state was composed of all major cities located within its administrative boundaries. All publication types are included, providing information on the volume of annual scholarly output and the total distribution of documents by top-10 subject areas.

An example of a search query used for Tamil Nadu is as follows: *AFFILCOUNTRY (india) AND AFFIL ("Tamil Nadu" OR chennai OR coimbatore OR madurai OR tiruchirappalli OR salem OR tirunelveli OR ambattur OR tiruppur OR avadi OR tiruvottiyur OR thoothukkudi OR nagercoil OR thanjavur OR pallavaram OR dindigul OR vellore OR tambaram OR cuddalore OR alandur OR kancheepuram OR erode OR tiruvannamalai OR kumbakonam OR rajapalayam OR kurichi OR madavaram OR pudukkottai OR hosur OR ambur OR karaikkudi OR neyveli OR nagapattinam) AND PUBYEAR > 2016 AND PUBYEAR < 2023*

To verify the second hypothesis, publications were evaluated by field using the Scopus All Science Journal Classification (ASJC), following the approach used by Quacquarelli Symonds in the QS World University Rankings 2. A total of five broad research areas are identified: 1) Arts & Humanities (A&H), 2) Engineering & Technology (E&T), 3) Life Sciences & Medicine (LS&M), 4) Natural Sciences (NS), and 5) Social Sciences & Management (SS&M). Aggregation is done manually using SUBJMAIN search operator. For example, the following subject codes were combined for Engineering & Technology: 1500–1508; 1605–1606; 1700–1712; 1800–1804; 1900, 1901, 1905, 1906; 1909; 2100–2105; 2200–2215; 2300–2302; 2304–2306; 2312; 2500, 2501; 2613, 2614; 1100–1111; 1300–1315; 2307; 2400–2406; 2700–2748; 2800–2809; 2900–2923; 3000–3005; 3202–3206; 3400–3404; 3500–3506; 3600–3616. These five broad research areas were used to calculate the regional specialization coefficient using the following equation:

$$\text{Regional specialization coefficient} = \frac{\text{Regional subject area} / \text{Regional total}}{\text{Country subject area} / \text{Country total}} \quad (1)$$

In addition to regional (state) level of analysis, the geography of research institutions is studied in order to reflect the diversity and the divergence of the Indian research landscape. An example of a search query for top-15 performing institutions by scholarly output in 2017–2022 is as follows: *AF-ID("Vellore Institute of Technology" 60010618) OR AF-ID("Indian Institute of Technology Delhi" 60032730) OR AF-ID("Indian Institute of Science" 60014097) OR AF-ID("Indian Institute of Technology Madras" 60025757) OR AF-ID("Indian Institute of Technology Kharagpur" 60004750) OR AF-ID("Indian Institute of Technology Bombay" 60014153) OR AF-ID("University of Delhi" 60029284) OR AF-ID("All India Institute of Medical Sciences New Delhi" 60009790) OR AF-ID("Amity University" 60076774) OR AF-ID("SRM Institute of Science and Technology" 60014340) OR AF-ID("Indian Institute of Technology Roorkee" 60031818) OR AF-ID("Manipal Academy of Higher Education" 60016524) OR AF-ID("Academy of Scientific and Innovative Research AcSIR" 60121522) OR AF-ID("Indian Institute of Technology Guwahati" 60010126) OR AF-ID("Indian Institute of Technology Kanpur" 60021988) AND PUBYEAR > 2016 AND PUBYEAR < 2023*

As the second step, bibliometric data is compared with the region's knowledge processing domain. Patent data, representing this domain's development function within R&D, is sourced from the annual reports of Intellectual Property India 3, administered by the Office of Controller General of Patents, Designs & Trade Marks (CGPDTM) of the Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry, Government of India. The data period matches that of the publications, spanning 2017–2022. The key indicator is "Patent applications by state of origin." For comparison and mapping, publication and patenting performance figures were normalized using the following formula:

$$Normalization = \frac{(X \ \ region\,value - \ Min\,value)}{(Max\,value - \ Min\,value)} \quad (2)$$

[1] Thirteenth Five-Year Plan 2017-22, Government of Kerala, 2018. https://spb.kerala.gov.in/sites/default/files/2021-09/13PlanEng.pdf (Date of access: 01.11.2024).

[2] Elsevier Support Center. https://service.elsevier.com/app/answers/detail/a_id/21717 (Date of access: 01.11.2024).

[3] Intellectual Property India. www.ipindia.gov.in (Date of access: 01.11.2024)

Lastly, the indicators of the knowledge commercialization domain are studied. Data on innovation activity, indicating the regional ability to commercialize knowledge, are used from the Indian Manufacturing Innovation Index (IMII), based on the National Manufacturing Innovation Survey 2021–22 published in March 2023[1]. This joint study by the Department of Science and Technology (DST) and the United Nations Industrial Development Organization (UNIDO) is based on responses from 8,087 enterprises nationwide across sectors including food, textile, automotive, pharmaceutical, and ICT. Along with the IMII score, the report details the number and spatial distribution of innovative companies, covering both product and process innovators.

The initial IMII database has some limitations. Data are missing for two states—Andaman and Nicobar Islands and Ladakh. Additionally, seven northeastern states (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura) are grouped together, resulting in a combined value. The IMII score is based on 80 criteria across three parameters: 1) innovation enablers, 2) barriers to innovation, and 3) innovation efficiency, providing a more complex measure than publications and patents.

Research Results

Knowledge production

Over the past six years, India has significantly strengthened its position in the global science landscape, increasing its national scholarly output by an average annual growth rate of 11 %—from 159,793 publications in 2017 to 287,163 in 2022 (Scopus data as of August 2023). India ranks fourth globally by total publications indexed in Scopus, following China (4.6 million), the United States (4.4 million), and the United Kingdom (1.4 million), with India's total reaching 1.3 million documents.

National knowledge production is concentrated in leading research institutions. The top 15 organizations—including Vellore Institute of Technology, Indian Institutes of Technology (Delhi, Madras, Kharagpur, Bombay, Roorkee, Guwahati, Kanpur), Indian Institute of Science (Bengaluru), University of Delhi, All India Institute of Medical Sciences (New Delhi), Amity University (Noida), SRM Institute of Science and Technology, Manipal Academy of Higher Education, and Academy of Scientific and Innovative Research—account for 17.8 % of the total output. The top 50 institutions contribute 36.6 % of the country's publications.

As shown in Figure 1, there is significant territorial divergence in scientific output. The top 50 institutions are spread across 31 cities, with New Delhi leading (8 institutions), followed by Chennai and Manipal (5 each). At the regional level, Tamil Nadu leads with 11 institutions, followed by Delhi (8), Karnataka (7), Uttar Pradesh (6), and West Bengal (4). Tamil Nadu, the state with the highest scholarly output, produces five times more publications than the national average and surpasses the lowest-performing state, Lakshadweep, by over ten thousand times. These "major states" dominate scholarly output, representing 80 % of the top 20 performing states (Fig. 2).

The top 10 research subject areas nationwide are Engineering (16.3 %), Computer Science (12.1 %), Medicine (9.4 %), Physics and Astronomy (7.5 %), Materials Science (7.4 %), Chemistry (5.0 %), Mathematics (5.0 %), Biochemistry, Genetics, and Molecular Biology (4.9 %), Environmental Science (4.0 %), and Agricultural and Biological Sciences (3.9 %). Engineering is the leading research area in 28 states, ranks second in five states, and appears outside the top 10 only in Lakshadweep. Regionally, Engineering is often grouped with Computer Science and Materials Science, reflecting the national pattern, especially in the highest-performing states by publication volume. Figure 1 shows the spatial distribution of publication output across India, highlighting regional research focuses and locations of top institutions.

For analysis, scientometric data on knowledge production is classified into five broad research areas as outlined in the Methodology section: 1) Arts & Humanities (A&H), 2) Engineering & Technology (E&T), 3) Life Sciences & Medicine (LS&M), 4) Natural Sciences (NS), and 5) Social Sciences & Management (SS&M).

Figure 3 shows the distribution of regional specialization in knowledge production. The national average is set at 1.0. Values below 1.0 indicate little or no specialization, while values above 1.0 show a certain degree of specialization. For example, Chandigarh has a specialization value of 1.584 in Life Sciences & Medicine (LS&M), meaning it is about 58 % more specialized in this field than the national average.

Regions with low overall publication output often show very high specialization values. For instance, Lakshadweep has only 20 publications, including just one in Arts & Humanities (A&H), resulting in a specialization score of 3.796—almost four times the national average. To avoid such distortions, a minimum threshold of 100 publications

[1] The National Manufacturing Innovation Survey 2021-22, 2023. www.nstmis-dst.org/NMIS (Date of access: 01.11.2024).

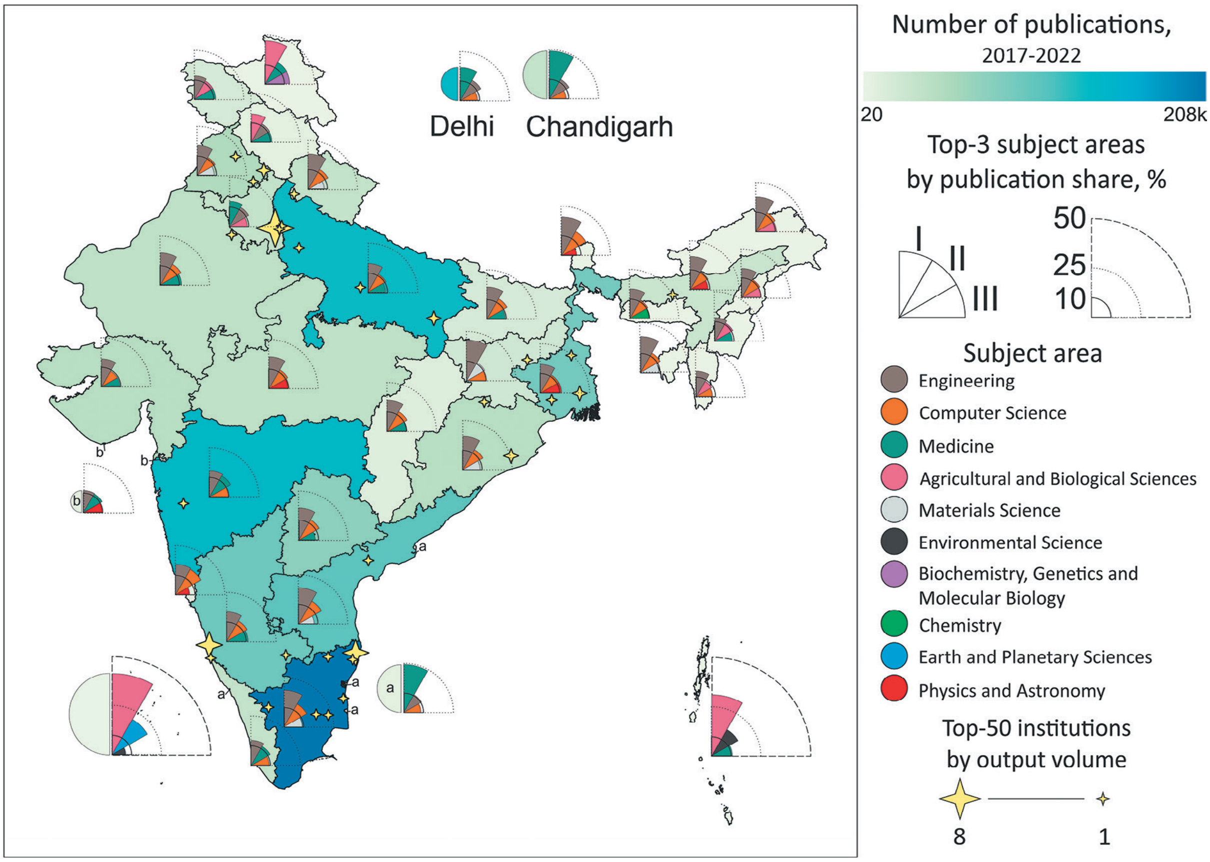

Fig. 1. *Spatial distribution of publications, research focus, and the location of top performing institutions, 2017–2022*
Source: developed by the author based on Scopus data (sourced on 08.2023)

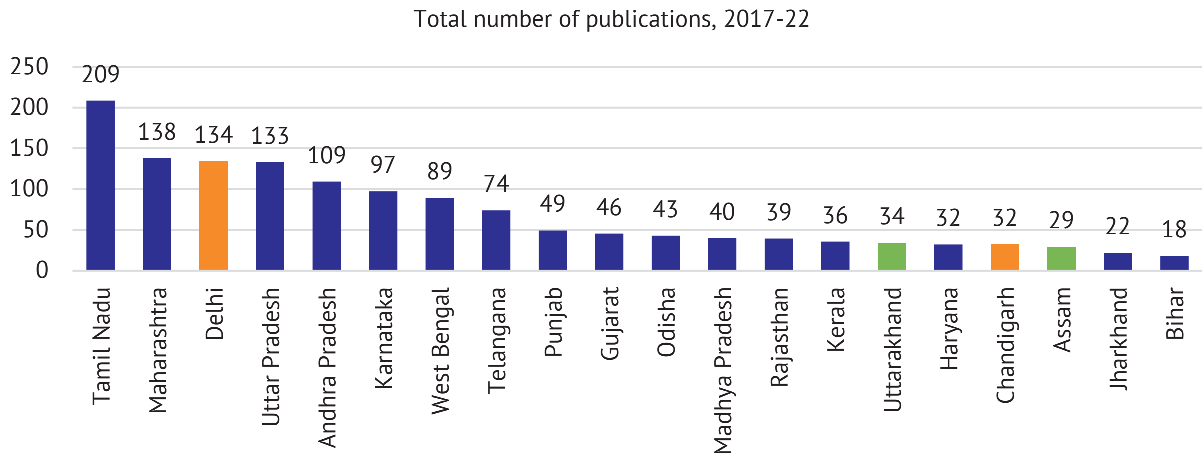

Fig. 2. *Total number of publications by top-20 performing states, in thousands, 2017–2022*
Note: blue — major states, orange — UT & city states, green — hill states.
Source: developed by the author based on Scopus data (sourced on 08.2023)

per research area was set. This threshold excludes Lakshadweep from the analysis.

Ladakh meets this threshold only in LS&M. Additionally, 14 states—including Andaman and Nicobar Islands, Arunachal Pradesh, Chhattisgarh, Dadra and Nagar Haveli and Daman and Diu, Goa, Himachal Pradesh, Manipur, Mizoram, Nagaland, Puducherry, Sikkim, and Tripura—are excluded from the specialization analysis for A&H due to insufficient publication volume.

Data on regional specialization in knowledge production suggests that A&H as well as SS&M are least represented in India: A&H above 1.0 is observed in 6 states (Meghalaya — 1.736, Assam — 1.483, Delhi — 1.425, Bihar — 1.252, West Bengal — 1.147, and Telangana — 1.006) and SS&M in

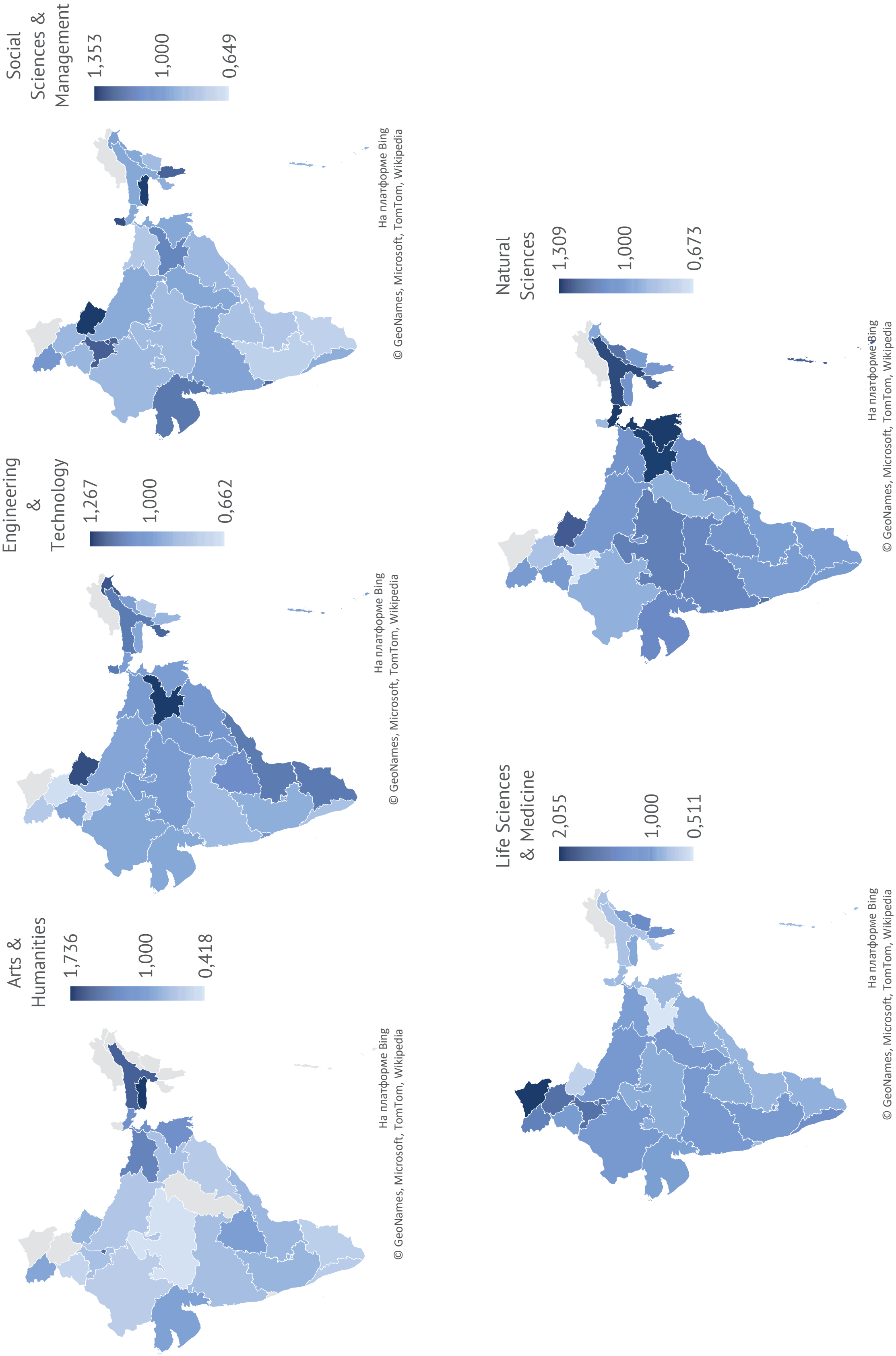

Fig. 3. *Regional specialization in knowledge production, 2017–2022*

Source: developed by the author based on Scopus data (sourced on 08.2023)

10 states (Uttarakhand — 1.353, Meghalaya — 1.338, Sikkim — 1.287, Delhi — 1.276, Haryana — 1.241, Mizoram — 1.224, Goa — 1.204, Gujarat — 1.159, Jharkhand — 1.114, Jammu and Kashmir — 1.047). Whereas E&T specialization have 15 states (the strongest is in Jharkhand — 1.267), LS&M — 19 (lead by Ladakh — 2.055), and NS — 24 (West Bengal — 1.309).

The regional research focus and total output are then compared with patents, which represent the knowledge processing function within regional innovation systems, as well as with innovation activity that reflects each region's capacity to commercialize knowledge.

Knowledge processing

Publications mainly reflect early-stage research, representing the knowledge production function. In contrast, patents (including patent applications) indicate the knowledge processing stage, which covers the development phase of the R&D cycle. According to the latest IP India annual report, patent activity showed strong growth between 2017 and 2022: patent applications increased by 39 % (1.4 times), while patents granted rose by 131 % (2.3 times). The top three invention fields in 2021–22 were Computer Science & Electronics (23.4 %), Mechanical Engineering (18.0 %), and Communication (11.0 %) (see Fig. 4).

From a geographical perspective, Maharashtra filed the highest number of patent applications by Indian applicants during the six-year period, with 21,598 applications, accounting for 21.0 % of the country's average annual total. It was followed by Tamil Nadu with 17,885 applications (16.55 %) and Karnataka with 12,443 applications (11.78 %). The territorial distribution of patent activity is uneven and closely mirrors the spatial pattern of knowledge production, with leading regions in publications also leading in patent filings (Fig. 5).

The ranking of states differs depending on whether scholarly or patent output is considered. Tamil Nadu leads in publication output but ranks second to Maharashtra in patent activity. Andhra Pradesh is among the top five regions for scholarly output but accounts for only 2.4 % of patent applications, placing it 10th. Karnataka ranks third in patent activity (11.8 %) but sixth in scholarly output.

The relationship between these two indicators is illustrated in Figure 6, which shows the number of publications per patent application filed (Fig. 6a). A smaller gap between these values (papers per patent) indicates a stronger connection between knowledge production and knowledge processing in a region's innovation system.

The correlation coefficient between publication and patenting activity is 0.865, and regression analysis yields an R-squared value of 0.748, indicating a strong relationship between the two variables in approximately 75 % of cases (Fig. 6b).

The study proceeds by analysing the link between patenting activity and publication output within distinct research domains. Table 1 pre-

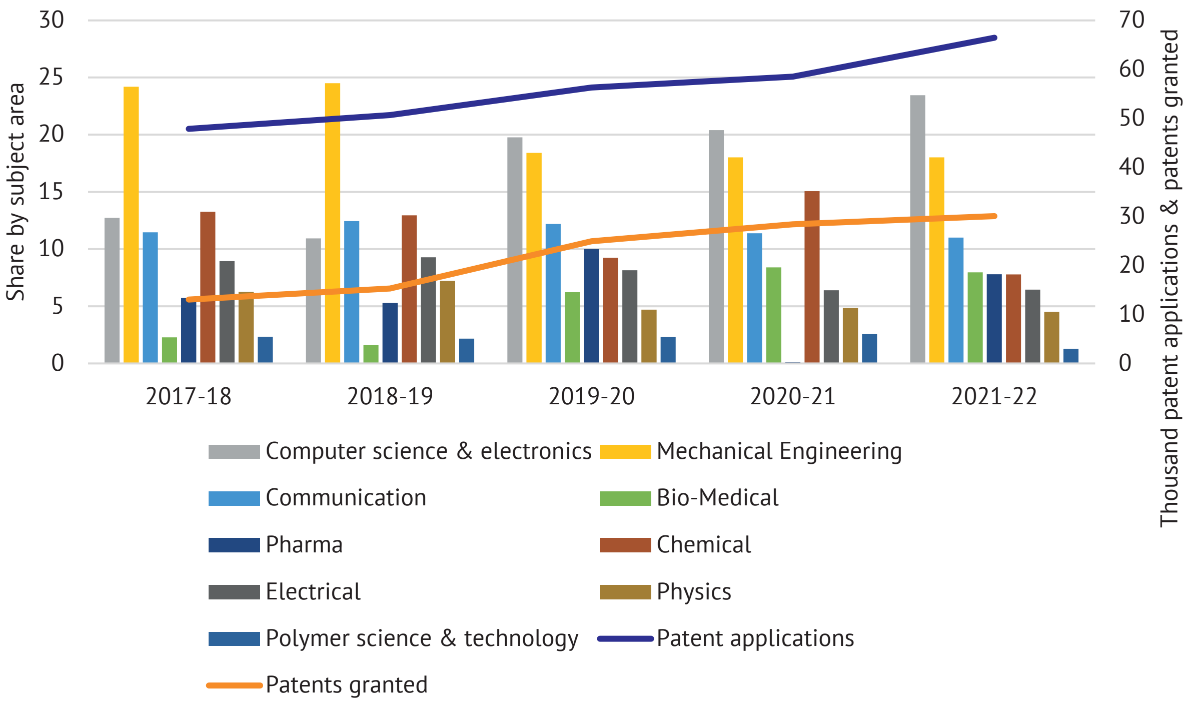

Fig. 4. *Patent activity dynamics by field of invention, 2017–2022*

Source: developed by the author based on ipIndia data (sourced on 08.2023)

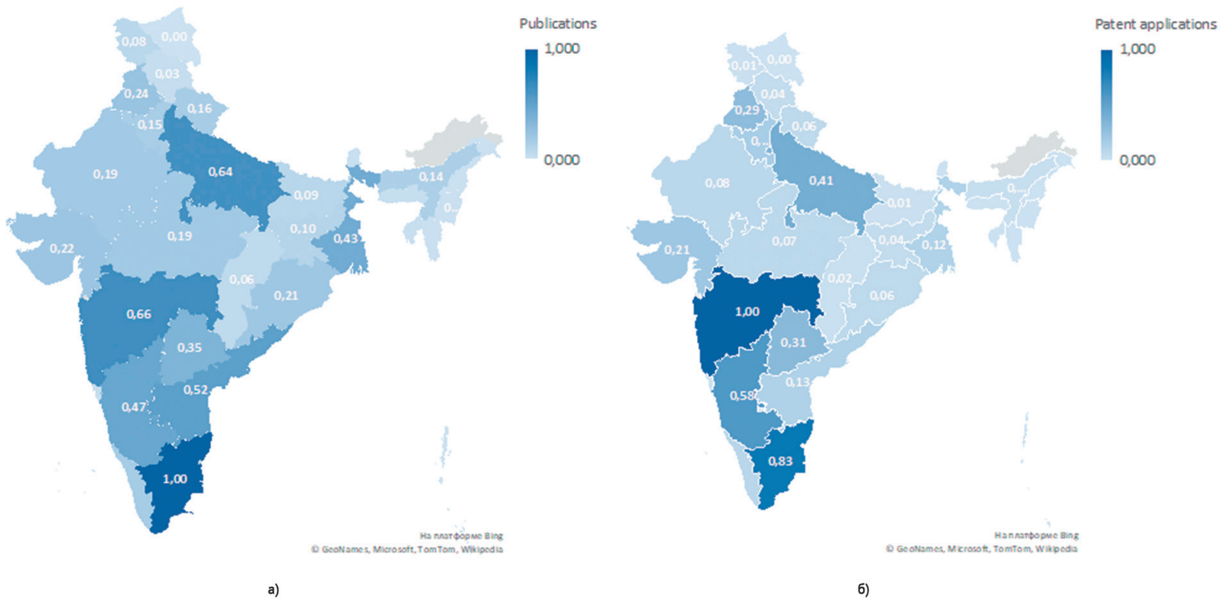

Fig. 5. *Spatial distribution of patenting activity against publication activity, 2017–2022*
Source: developed by the author based on Scopus and ipIndia data (sourced on 08.2023)

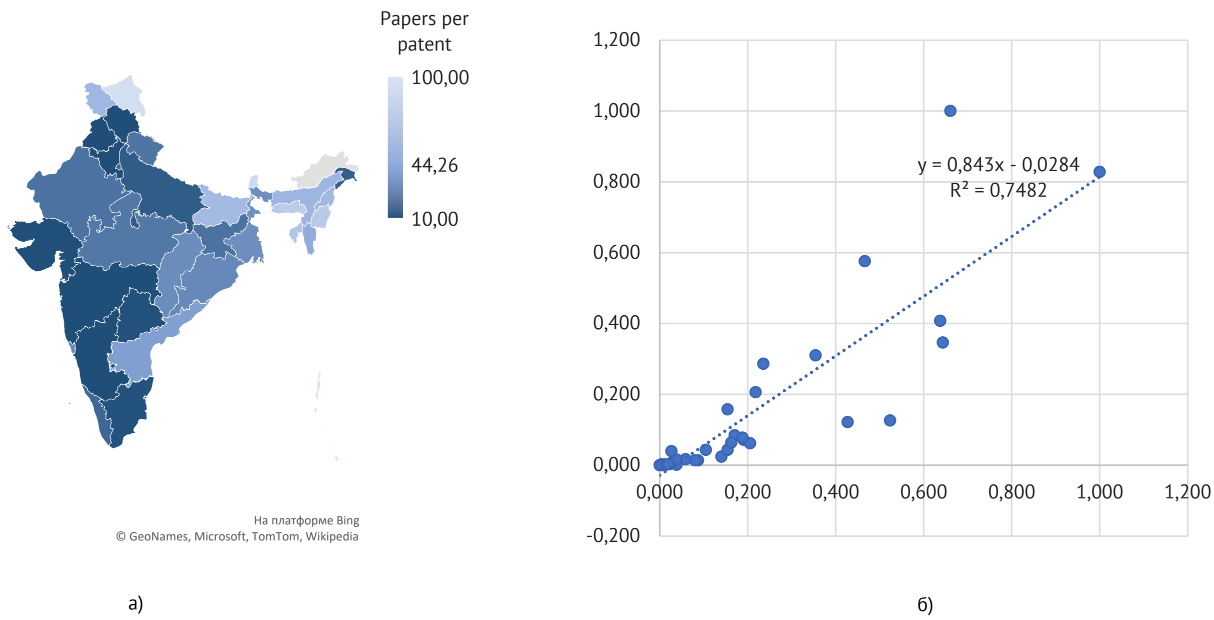

Fig. 6. *Correlation of regional knowledge production and knowledge processing systems, 2017–2022*
Source: developed by the author based on Scopus and ipIndia data (sourced on 08.2023)

Table 1.

Interdependence of research subject areas on patent activity, 2017–2022

	Arts & Humanities	Engineering & Technology	Life Sciences & Medicine	Natural Sciences	Social Sciences & Management	Total
Rank	5	3	2	1	4	
Correlation	0.733	0.836	0.861	0.863	0.825	0.865
R-squared	0.537	0.699	0.742	0.745	0.681	0.748

Source: developed by the author based on Scopus and ipIndia data (sourced on 08.2023) sents the correlation coefficients and corresponding R-squared values from the regression analysis across the five broad research categories.

Subject-specific relationship values are somewhat lower compared to the total output values but are still at a very strong level. The strongest interdependence is found in case of NS and LS&M, intermediate values are found for E&T and SS&M, while the least predictive capacity is for A&H.

Knowledge commercialization

The territorial distribution of innovation activity and the ranking of regions by the number of innovation companies in presented in Figure 7. The most innovative regions by IMII score are Karnataka — 33.4, Dadra & Nagar Haveli & Daman & Diu — 32.9, Telangana — 32.9, Tamil Nadu — 32.5, and Uttarakhand — 31.7. The highest share of firms that engage in innovation activity are found in Telangana (46.2 %), Karnataka (39.1 %), and Tamil Nadu (31.9 %). Telangana also has the highest proportion of companies pursuing business process innovation (39.9 %), while Karnataka (25.1 %) and Uttarakhand (24.9 %) lead in the share of product innovators. The lowest share of innovative firms is recorded in Odisha (12.8 %), Bihar (13.5 %), and Jharkhand (13.7 %).

When assessing the strength of the relationship between the IMII score and publication volume, a moderate correlation is observed ($r = 0.498$, $R^2 = 0.3953$) (see Figure 8a). A similar pattern is observed if we compare the number of innovative companies with a state's publication activity, showing a correlation of 0.508 ($R^2 = 0.2134$)

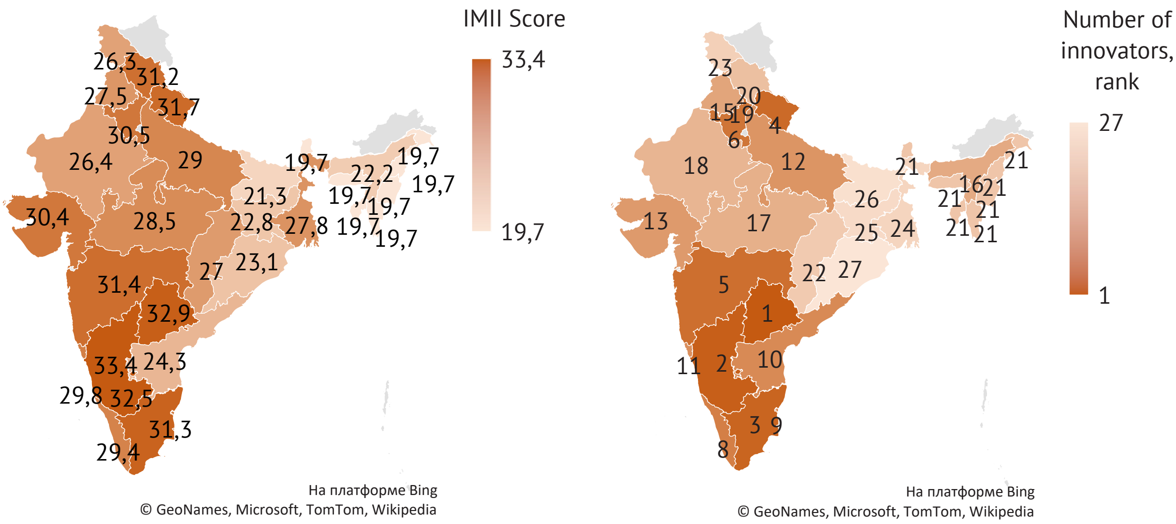

Fig. 7. *Regional distribution of innovation activity*

Source: developed by the author based on India Manufacturing Innovation Index (IMII), 2021–22

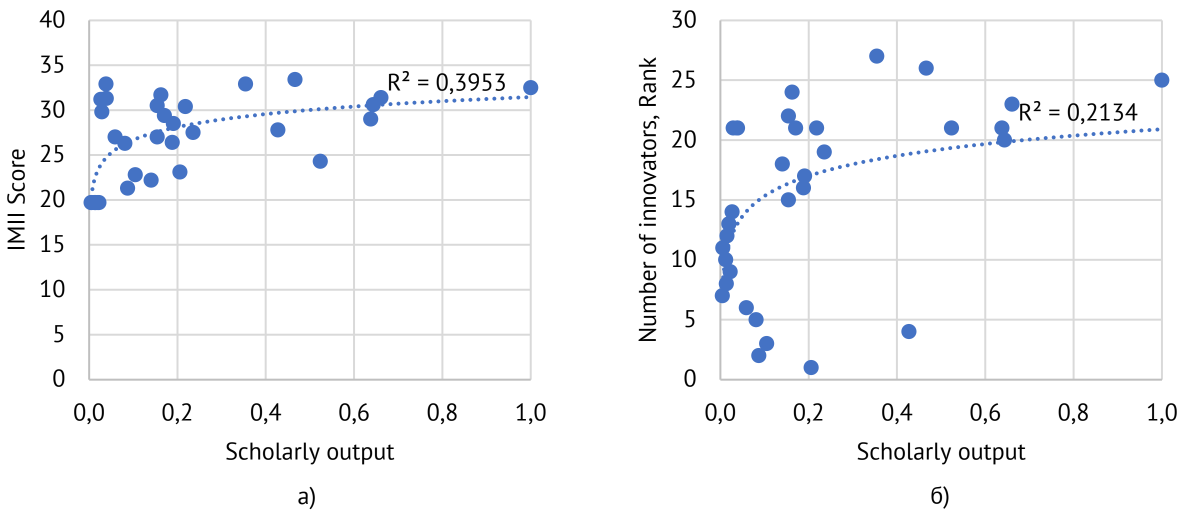

Fig. 8. *Correlation of innovation activity and scholarly output*

Note: R2 reflects the logarithmic trendline

Source: developed by the author based on Scopus data and India Manufacturing Innovation Index (IMII)

Table 2.

Relationship between research subject areas and innovation activity

	Arts & Humanities	Engineering & Technology	Life Sciences & Medicine	Natural Sciences	Social Sciences & Management	Total
	by IMII score					
Rank	5	4	1	3	2	
Correlation	0.443	0.462	0.522	0.485	0.501	0.498
R-squared	0.197	0.214	0.273	0.235	0.251	0.395
	by number of innovative firms					
Rank	5	3	1	4	2	
Correlation	0.402	0.459	0.496	0.443	0.461	0.508
R-squared	0.161	0.211	0.246	0.197	0.212	0.213

Source: developed by the author based on Scopus data and India Manufacturing Innovation Index (IMII)

(see Figure 8b). The regression analysis yields relatively low *R*-squared values, indicating limited predictive power.

An analysis of regional research focus across five broad subject fields shows a strong correlation between publication activity and the IMII score in Life Sciences & Medicine (r = 0.522) and Social Sciences & Management (r = 0.501). Similarly, the number of innovative firms is strongly associated with publication output in Life Sciences & Medicine (r = 0.496), Social Sciences & Management (r = 0.461), and Engineering & Technology (r = 0.459). In contrast, publication activity in Arts & Humanities shows the weakest connection to knowledge commercialization (see Table 2).

Discussion

The national innovation system of a country is a complex, non-linear process involving the generation, transformation, and commercialization of knowledge. Each stage of this process can be assessed using distinct indicators: scholarly publications reflect knowledge production, patents (including applications) represent knowledge processing, and innovation activity indicates the commercialization of knowledge.

Bibliometric analysis—including its spatial dimension (spatial bibliometrics or spatial scientometrics)—is commonly used to assess the “scientific strength” (Matthiessen & Schwarz, 1999) and “basic research capacities” (Hennemann et al., 2011) of cities, regions, and countries. Previous studies have identified noteworthy links between scientific output and broader measures of regional development (Acosta et al., 2010), as well as with specific indicators like R&D spending (Zhou et al., 2009). These findings suggest that bibliometric indicators may serve as valuable supplements to traditional innovation statistics, or even as proxies for the overall development of regional innovation systems.

While some prior studies have touched on this idea (e.g., Mikhaylov, 2019; 2020), a more targeted analysis is needed to explore the extent to which scholarly output correlates with key innovation metrics such as patenting and innovation activity. This article addresses two core hypotheses:

H1: The volume of scholarly output correlates with the volume of patenting and innovation activity.

H2: Natural sciences and technical fields of science are more correlated with patenting and innovation activity.

The correlation between publication activity (knowledge production) and patent applications (knowledge processing) is strong, with a coefficient of 0.865 and a high predictive capacity across regions (R^2 = 0.75). This relationship might have been even stronger if not for outlier regions with atypical patterns. For example, Karnataka performs exceptionally well in patenting—ranking 3rd in patent applications but only 6th in publications. In contrast, Dadra and Nagar Haveli and Daman and Diu rank 24th in publications but drop to 32nd in patenting.

Only three regions report fewer than 1,000 publications: Arunachal Pradesh (991), Ladakh (191), and Lakshadweep (20). In contrast, patenting activity shows a much wider disparity, as 11 regions have fewer than 100 patent applications and 20 regions fall below the 1,000 mark. As shown in Figure 2, different region types—major states, union territories and city states, and hill states—exhibit significant variation and could be analysed separately in future studies for greater consistency and insight.

Overall, these findings are consistent with earlier research that examined the relationship between publications and patents (e.g., Inglesi-Lotz et al., 2018; Meyer, 2000; Wang & Ye, 2021), although prior studies have rarely focused on regional-level analysis.

The correlation between publication activity and innovation data (knowledge commercialization) is moderate. It is slightly stronger when measured against the number of innovative firms (0.508) than with the Indian Manufacturing Innovation Index (IMII) score (0.498). The lower correlation with IMII may stem from the index's broader scope: it includes 80 indicators such as state policies and investment levels, which may be less directly tied to publication volume. To better capture the relationship between knowledge production and commercialization, future research should consider primary data—such as the number of new innovative products introduced to the market.

The first hypothesis is confirmed: the volume of publications produced in a region correlates with its volume of patenting and innovation activity. Among these indicators, patenting, which reflects the knowledge processing stage, is more closely connected to knowledge production, measured by publication activity, than to innovation activity. This relationship is influenced by the fact that many innovations result not from internal R&D but from the adoption of foreign technologies. In India, this pattern is reflected in the dependence on foreign technologies (Sharma, 2016) and an emphasis on adaptive innovations instead of original inventions (Jyoti et al., 2010; Khachoo & Sharma, 2017; Krishnan & Prashantham, 2018).

The second hypothesis—that patenting and innovation activity have a stronger correlation with publications in natural sciences and technical fields—finds partial support. Patenting activity is most strongly linked with Natural Sciences (NS) and Life Sciences & Medicine (LS&M). Engineering & Technology (E&T) shows only a slightly stronger correlation than Social Sciences & Management (SS&M), while Arts & Humanities (A&H) has the weakest correlation, with a value of 0.733 compared to 0.865 for total publication volume.

The relatively lower correlation for E&T is somewhat surprising given the emphasis on engineering and computer science research and the large volume of patents in computer science and electronics. Research on India's ICT sector suggests that IT companies primarily focus on product development and tend to adapt existing foreign technologies rather than conduct original research (Aoyama & Parthasarathy, 2012). Conversely, India's pharmaceutical industry stands out as one of the most science-intensive sectors, emphasizing original scientific research (Krishnan & Prashantham, 2018; Shivdas & Ray, 2021).

Conclusion

Recent advances in scientometrics have broadened its applications, ranging from benchmarking research areas and evaluating centres of excellence to mapping corporate R&D activities and assessing regional STI performance. Studies focusing on geographic units, such as cities, regions, and countries, fall under the field of spatial scientometrics (also called spatial bibliometrics). In recent years, scientometric data have been widely used to analyse territories by measuring the development of science and technology, levels of inter-regional and international research collaboration, and clustering of field-specific centres of excellence.

Publications, as the primary indicator of knowledge production, also serve as an indirect measure of the overall development level of a territorial innovation system, including its intellectual capital.

This article tests the hypothesis that publication activity, representing knowledge production, reflects subsequent stages in the non-linear innovation process at the regional level—specifically, knowledge processing and knowledge commercialization. Knowledge processing is measured by patent applications, while knowledge commercialization is assessed through innovation activity, captured by the Indian Manufacturing Innovation Index (IMII) and the number of innovative companies in each region.

The findings confirm the initial assumption that the volume of publication activity is positively related to patenting and innovation activity, with a particularly strong connection in the hard sciences. Regions performing well in knowledge production are, generally, strong in the subsequent stages of knowledge processing and commercialization. Differences occur due to considerable divergence between Indian states (Dwivedi, Arora, 2020), suggesting that future studies could apply a smaller scale of analysis — the districts or cities, or evaluated in groups by the state types — Major states, UT & city states, Hill states. Narrowing the analysis to particular research fields does not change the general findings significantly. For India, publications in Natural Sciences (NS) and Life Sciences & Medicine (LS&M) are most related to patenting and innovation activity. Social Sciences & Management (SS&M) research area is found to be highly related to innovation activity. This is an interesting finding, as numerous papers suggest limiting the sample by "hard sciences", while excluding "soft sciences". This observation should be further tested using other innovation indicators and other geographies.

The findings presented in this research paper confirm the overall strong analytical capacity of the big geocoded datasets sourced from various abstract and citations databases and processed using the spatial scientometric approach. The availability and uniformity of the data is an undeniable advantage, making it ideal complementary data source at numerous hierarchical levels where conventional statistical information is scarce or of limited access.

References

Acosta, M., Coronado, D., Ferrándiz, E., & León, M. D. (2010). Factors affecting inter-regional academic scientific collaboration within Europe: The role of economic distance. *Scientometrics, 87*(1), 63–74. http://dx.doi.org/10.1007/s11192-010-0305-6

Aoyama, Y., & Parthasarathy, B. (2012). Research and development facilities of multinational enterprises in India. *Eurasian Geography and Economics, 53*(6), 713730. https://doi.org/10.2747/1539–7216.53.6.713

Arana Barbier, P. J. (2023). The Relationship Between Scientific Production and Economic Growth Through R&D Investment: A Bibliometric Approach. *Journal of Scientometric Research, 12*(3), 596–602. https://doi.org/10.5530/jscires.12.3.057

Badran, A., & Badran, S. (2022). *Ups and Downs of Science and Technology Indicators in Arab Countries. In A. Badran*, E. Baydoun, J. R. Hillman (Eds.), *Higher Education in the Arab World: Research and Development*. Cham. https://doi.org/10.1007/978-3-030-80122-9_6

Bhardwaj, M., Sandhu, A., & Ghumman, N. (2021). Patents Commercialization Profile of Universities and Higher Education Institutes in India. *Journal of Intellectual Property Rights, 26*(4), 199–207. https://doi.org/10.56042/jipr.v26i4.49278

Bielecka, E., & Burek, E. (2019). Spatial data quality and uncertainty publication patterns and trends by bibliometric analysis. *Open Geosciences, 11*(1), 219–235. https://doi.org/10.1515/geo-2019–0018

Bonitz, M. (2001). About the Nalimov Memorial Issue of the Journal Scientometrics. *Scientometrics, 52*(2), 107–109. https://doi.org/10.1023/A:1017986917073

Bornmann, L., & de Moya-Anegón, F. (2019). Spatial bibliometrics on the city level. *Journal of Information Science, 45*(3), 416–425. https://doi.org/10.1177/0165551518806119

Bornmann, L., & Waltman, L. (2011). The detection of "hot regions" in the geography of science — A visualization approach by using density maps. *Journal of Informetrics, 5*(4), 547–553.

Bornmann, L., Leydesdorff, L., Walch-Solimena, C., & Ettl, C. (2011). Mapping excellence in the geography of science: An approach based on Scopus data. *Journal of Informetrics, 5*(4), 537–546. http://dx.doi.org/10.1016/j.joi.2011.05.005

Brooks, H. (1994). The relationship between science and technology. *Research Policy, 23*(5), 477–486. https://doi.org/10.1016/0048–7333(94)01001-3

Chakrabarti, K., & Mondal, D. (2022). India's Research Collaboration Trend with the Selected African Countries: An Exploratory Study. *Journal of Scientometric Research, 10*(3), 412–422. https://doi.org/10.5530/jscires.10.3.59

Csomós, G. (2017). Mapping spatial and temporal changes of global corporate research and development activities by conducting a bibliometric analysis. *Quaestiones Geographicae, 36*(1), 67–79. http://dx.doi.org/10.1515/quageo-2017–0005

Csomós, G., & Tóth, G. (2016). Exploring the position of cities in global corporate research and development: A bibliometric analysis by two different geographical approaches. *Journal of Informetrics, 10*(2), 516–532. http://dx.doi.org/10.1016/j.joi.2016.02.004

de Queiroz, A. P. (2021). Spatial analysis: A bibliometric approach (1950–2019). *Earth Science Informatics, 14*(1), 277–289. https://doi.org/10.1007/s12145-020-00546-6

De Solla Price, D. (1951). Quantitative measures of the development of science. *Archives Internationales d'Histoire des Sciences,* (14), 85–93.

De Solla Price, D. (1965). Networks of Scientific Papers: The pattern of bibliographic references indicates the nature of the scientific research front. *Science, 149*(3683), 510–515.

De Solla Price, D. (1975). *Science Since Babylon.* (2nd ed.). Yale University Press, New Haven.

Desai, P. N. (2013). Export innovation system: Changing structure of India's technology-intensive exports. *Institutions and Economies, 5*(3), 21–51.

Dwivedi, A., & Arora, A. (2020). Economic geography of innovation in India: an empirical investigation. *Innovation and Development, 10*(3), 395–412. https://doi.org/10.1080/2157930X.2019.1679952

Gao, S. (2015). Towards a frontier of spatial scientometric studies. SIGWEB Newsl., 5, 1–9. https://doi.org/10.1145/2749279.2749284

Garg, K. C. (2019). Whither Scientometrics in India. *Journal of Scientometric Research, 7*(3), 215–218. https://doi.org/10.5530/jscires.7.3.34

Godin, B. (2006). On the origins of bibliometrics. *Scientometrics, 68*(1), 109–133. https://doi.org/10.1007/s11192-006-0086-0

Grafield, E. (1964). Science Citation Index — a New Dimension in Indexing. *Science, 144,* 649–654. https://doi.org/10.1126/science.144.3619.649

Hennemann, S., Wang, T., & Liefner, I. (2011). Measuring regional science networks in China: A comparison of international and domestic bibliographic data sources. *Scientometrics, 88*(2), 535–554. https://doi.org/10.1007/s11192-011-0410-1

Inglesi-Lotz, R., Hakimi, A., & Pouris, A. (2018). Patents vs publications and R&D: three sides of the same coin? Panel Smooth Transition Regression (PSTR) for OECD and BRICS countries. *Applied Economics, 50*(45), 4912–4923. https://doi.org/10.1080/00036846.2018.1468556

Ivanova, N.I., & Mamedyarov, Z. A. (2019). R&D and innovation: Competition is growing. *World Economy and International Relations, 63*(5), 47–56. https://doi.org/10.20542/0131–2227-2019-63-5-47-56

Jain, P. & Roy, A. (2024). Catalysts of Innovation: Advancing India's Future Through Investments in Basic Science. In S. Trivedi, V. Grover, B. Balusamy, A. Ganguly (Eds.), *Unleashing the Power of Basic Science in Business* (pp. 91–117). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693–5503-9.ch006

Javed, S., Rong, Y., Zafeer, H.M. I., Maqbool, S., & Abbasi, B. N. (2024). Unleashing the potential: a quest to understand and examine the factors enriching research and innovation productivities of South Asian universities. *Humanities and Social Sciences Communications, 11,* 1147. https://doi.org/10.1057/s41599-024-03674-2

Jiang, L., Zhu, N., Yang, Z., Xu, S., & Jun, M. (2018). The relationships between distance factors and international collaborative research outcomes: A bibliometric examination. *Journal of Informetrics, 12*(3), 618-630. https://doi.org/10.1016/j.joi.2018.04.004

Jyoti, Banwet, D.K., & Deshmukh, S. G. (2010). Modelling the success factors for national R&D organizations: a case of India. *Journal of Modelling in Management, 5*(2), 158–175. https://doi.org/10.1108/17465661011061005

Kalachikhin, P.A. (2020). Forecasting Basic Research Using Scientometric Data. *Scientific and Technical Information Processing, 47*, 126–132. https://doi.org/10.3103/S0147688220020100

Khachoo, Q., & Sharma, R. (2017). FDI and incumbent R&D behavior: Evidence from Indian manufacturing sector. *Journal of Economic Studies, 44*(3), 380–399. https://doi.org/10.1108/JES-10-2015–0188

Kopala, M.R., Ashta, A., Mor, S., & Parekh, N. (2023). The Co-Evolution of India's Policy on Science, Technology, and Innovation with University Education: The Need for Innovation in Higher Educational Institutions. *Space and Culture, India, 11*(2), 6–17. https://doi.org/10.20896/saci.v11i2.1333

Krishna, V. V. (2019). Universities in the national innovation systems: Emerging innovation landscapes in Asia-Pacific. *Journal of Open Innovation: Technology, Market, and Complexity, 5*(3), 43. https://doi.org/10.3390/joitmc5030043

Krishnan, R.T., & Prashantham, S. (2018). Innovation in and from India: The who, where, what, and when. *Global Strategy Journal, 9*(3), 357–377. https://doi.org/10.1002/gsj.1207

Kumar, A. (2021). Comparing scientific productivity using Scopus and Web of Science (WoS): a case of Indian R&D laboratories. *Asian Journal of Technology Innovation, 29*(3), 414–426. https://doi.org/10.1080/19761597.2020.1816837

Mammen, J.T., & A. K., N. (2024). Evolution of Science Technology and Innovation policies of India: Assessing the role of the domestic and international milieu. *Comparative Strategy, 43*(2), 118–136. https://doi.org/10.1080/01495933.2024.2317253

Matthiessen, C.N.W., & Schwarz, A.W. (1999). Scientific centres in Europe: An analysis of research strength and patterns of specialisation based on bibliometric indicators. *Urban Studies, 36*(3), 453–477. https://doi.org/10.1080/0042098993475

Mehta, S. (2018). National Innovation System of India: An Empirical Analysis. *Millennial Asia, 9*(2), 203–224. https://doi.org/10.1177/0976399618786343

Mesropyan, V.R., & Ovsyannikov, M. V. (2014). Prospects for the application of scientometric methods for forecasting. *Scientific and Technical Information Processing, 41*(1), 38–46. https://doi.org/10.3103/S0147688214010080

Meyer, M. (2000). Does science push technology? Patents citing scientific literature. *Research Policy, 29*(3), 409–434. https://doi.org/10.1016/S0048–7333(99)00040-2

Mikhaylov, A.S., Hvaley, D.V., Singh, P. & Singh, V. K. (2020). Potential of Russian-Indian scientific cooperation (the case of western border regions of Russia). *IKBFU's Vestnik. Series: Humanities and social science,* (3), 103–117. (In Russ.)

Mikhaylov, A.S., Kuznetsova, T.Yu., & Peker, I. Yu. (2019). Methods of spatial scientometrics in assessing the heterogeneity of the innovation space of Russia. *Perspektivy Nauki i Obrazovania [Perspectives of science and education],* (5), 549–563. https://doi.org/10.32744/pse.2019.5.39 (In Russ.)

Mikhaylov, A.S., Mikhaylova, A. A., Singh, V. K., & Hvaley, D. V. (2020). Knowledge geography for measuring the divergence in intellectual capital of Russia. *Electronic Journal of Knowledge Management, 18*(2), 121–135. https://doi.org/10.34190/EJKM.18.02.003

Mondal, D., Chakrabarti, K., Banerjee, S., & Lal, D. D. (2021). Publication output with citation-based performance of selected DBT institutes in India. *DESIDOC Journal of Library and Information Technology, 41*(2), 157–165. https://doi.org/10.14429/djlit.41.02.16547

Mueller, C. E. (2016). Accurate forecast of countries' research output by macro-level indicators. *Scientometrics, 109*(2), 1307–1328. https://doi.org/10.1007/s11192-016-2084-1

Nalimov, V. V. (1966). Quantitative methods of research of scientific evolution. *Voprosy Filisofii,* (12), 38–47. (In Russ.)

Nalimov, V.V., & Mul'chenko, Z. M. (1969). *Naukometriya. Izucheniye razvitiya nauki kak informatsionnogoprotsessa [Naukometriya, the Study of the Development of Science as an Information Process]*. Moscow: Nauka Publ. (In Russ.)

Narin, F., & Carpenter, M. P. (1975). National publication and citation comparisons. *Journal of the American Society for Information Science, 26*(2), 80–93. https://doi.org/10.1002/asi.4630260203

Pan, R. K., Kaski, K., & Fortunato, S. (2012). World citation and collaboration networks: Uncovering the role of geography in science. *Scientific Reports, 2,* 902.

Pogodina, T. V., Udaltsova, N.L., & Filushina, A. V. (2019). Paradigm shift in technological development of socio-economic system in the context of digital transformation. *Journal of Advanced Research in Law and Economics, 10*(2), 653–662.

Popp, D. (2017). From science to technology: The value of knowledge from different energy research institutions. *Research Policy, 46*(9), 1580–1594, https://doi.org/10.1016/j.respol.2017.07.011

Pritchard, A. (1969). Statistical Bibliography or Bibliometrics? *Journal of Documentation, 25*(4), 348–349.

Rakshit, S., & Moitra, S. (2024). Innovation and Progress: An Insight into the Indian Business Start- Ups and the Promotion of Scientific Temper for Socio-Economic Advancement. *Indian Journal of Law and Justice, 15*(1), 377–399.

Régnier, P. (2023). Innovation, Appropriate Technologies and Entrepreneurship for Global Sustainability Development: A Review Until the Early Twenty-first Century. *Journal of Entrepreneurship, 32*(2_suppl), S12–S26. https://doi.org/10.1177/09713557231201115

Salisbury, L., Tian, Y., & Smith, J. (2021). Showcasing Innovation by Analyzing the Characteristics of Patents Granted to Researchers at a Research University. *Science & Technology Libraries, 41*(1), 73–89. https://doi.org/10.1080/0194262X.2021.1939835

Sattiraju, V. K., & Janodia, M. D. (2024). Analysis of science, technology and innovation (STI) policies of India from 1958 to 2020. *Journal of Science and Technology Policy Management, 15*(6), 1691–1708. https://doi.org/10.1108/JSTPM-02-2022–0030

Shapira, P., & Youtie, J. (2006). Measures for knowledge-based economic development: Introducing data mining techniques to economic developers in the state of Georgia and the US South. *Technological Forecasting and Social Change, 73*(8), 950–965. https://doi.org/10.1016/j.techfore.2006.05.017

Sharma, C. (2016). R&D, technology transfer and productivity in the Indian pharmaceutical industry. *International Journal of Innovation Management, 20*(1), 1650010. https://doi.org/10.1142/S1363919616500109

Sharma, G., & Haldar, S. (2020). India's S&T indicators 2019-20: what it reveals and what remains hidden. *Journal of Scientometric Research, 9*(3), 352–355. https://doi.org/10.5530/JSCIRES.9.3.43

Sharma, P., Tripathi, R., Singh, V., & Tripathi, R.C. (2016). Assessing the ICT innovative position of India based on patent data and research publications. *Queen Mary Journal of Intellectual Property, 6*(4), 514–533. https://doi.org/10.4337/qmjip.2016.04.07

Sharma, R., & Jain, A. (2014). Research and patenting in Indian universities and technical institutes: An exploratory study. *World Patent Information, 38,* 62–66. https://doi.org/10.1016/j.wpi.2014.04.002

Shivdas, A., & Ray, S. (2021). Research and development efforts in Indian pharmaceutical industry: How much does it matter? *International Journal of Pharmaceutical and Healthcare Marketing, 15*(4), 534–549. https://doi.org/10.1108/IJPHM-01-2020–0004

Srinivasaiah, R., Renuka, S. D., & Prasad, U. K. (2021). Impact of DST-FIST Funding on Research Publications in India (2000–2020) — A Bibliometric Investigation. *Journal of Scientometric Research, 10*(2), 135–147. https://doi.org/10.5530/jscires.10.2.28

Venkata, S. K., I Narayan, A., Chogtu, B., & Janodia, M. (2021). A bibliometric study on the research outcome of Brazil, Russia, India, China, and South Africa. *F1000Research, 10.* https://doi.org/10.12688/f1000research.51337.1

Veugelers, R., & Wang, J. (2019). Scientific novelty and technological impact. *Research Policy, 48*(6), 1362–1372, https://doi.org/10.1016/j.respol.2019.01.019

Wang, J. J. & Ye, F. Y. (2021). Probing into the interactions between papers and patents of new CRISPR/CAS9 technology: A citation comparison. *Journal of Informetrics, 15*(4), 101189. https://doi.org/10.1016/j.joi.2021.101189

Wong, C.-Y., & Wang, L. (2015). Trajectories of science and technology and their co-evolution in BRICS: Insights from publication and patent analysis. *Journal of Informetrics, 9*(1), 90–101. https://doi.org/10.1016/j.joi.2014.11.006

Zhou, P., Thijs, B., & Glänzel, W. (2009). Regional analysis on Chinese scientific output. *Scientometrics, 81*(3), 839–857. https://doi.org/10.1007/s11192-008-2255-9

About the author

Andrey Mikhaylov — Cand. Sci. (Geography), Head of the Laboratory of Geography of Innovations, Immanuel Kant Baltic Federal University; Senior Research Associate, Institute of Geography of the RAS; Scopus Author ID: 57214075325; http://orcid.org/0000-0002-5155-2628 (14, A. Nevskogo St. Kaliningrad, 235014, Russian Federation; building 4, 29, Staromonetniy Pereulok, Moscow, 119017, Russian Federation; e-mail: mikhailov.andrey@yahoo.com).

Информация об авторе

Михайлов Андрей Сергеевич — кандидат географических наук, заведующий Лабораторией географии инноваций, Балтийский федеральный университет им. И. Канта; старший научный сотрудник, Институт географии РАН; Scopus Author ID: 57214075325; http://orcid.org/0000-0002-5155-2628 (Российская Федерация, 235014, г. Калининград, ул. А. Невского, 14; Российская Федерация, 119017, г. Москва, Старомонетный переулок, д. 29, стр. 4; e-mail: mikhailov.andrey@yahoo.com).

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