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Trends in science and technology research: literature review

Nadim Akhtar Khan, Sumaira Jan and Iram Amin
Library & Information Science, University of Kashmir, Jammu and Kashmir, India

Abstract

Purpose – The paper aims to explore and identify the contributions to the literature available about trends in science and technology research at various levels.

Design/methodology/approach – A deep scan of literature was carried out in an attempt to identify considerable works that have been published concerning various facets related to science and technology research. Varied search terms like "research", "research and research output", "science and technology research", "research collaboration", "research in universities", "importance of science and technology research", "issues in research", etc. were used for retrieving the literature from a range of online scholarly databases, search engines and allied web sources.

Findings – The literature review reveals that a considerable amount of literature has been published related to science and technology research. However, keeping in view immense advancements and innovations in science and technology, scholarly output is still in its emergent phase.

Practical implications – It is apparent from the study of existing literature that there is still vast scope for advanced exploration on the topic and the study paves the way for the concerned organizations and institutions (like universities, libraries and publishers) at national and international level to take substantial measures to boost research in the field of science and technology.

Originality/value – The paper is the first ordered and makes an endeavour to review the literature and provides a summary of emerging trends in science and technology research.

Keywords Research, Science and technology research, Collaborative research, University research, Research issues, Research work, Research methods, Sciences

Paper type Literature review

Research and research output

It is far and wide accepted that research, as the most significant source of knowledge generation, occupies a critical position in promoting a nation's prosperity and its citizens' well-being in the knowledge-based era (Etzkowitz *et al.*, 2000). The aim of research is discovering and development of methods and systems for advancement of human knowledge. The outcome and the extent of the functions of the academics in creating new knowledge and innovation are forms of research output (Okafor, 2011). Research output is a means by which academics contribute their own knowledge to the existing body of knowledge. This can be in form of journal articles, technical reports, books, chapters in a book, supervision and training of students, etc. (Okafor and Dike, 2010). Another study conducted by Ochai and Nwafor (1990) to highlight the importance of research and publication, revealed that research and publication occupy such a core position in academic circle that they are not only a key determinant of industrial prestige, but also the pivot on which an individual advancement revolves. Yamamoto (2001) in his study highlighted the role of basic research in the knowledge-based society with particular reference to Japan, the study revealed that the country is not only capable to barely advance the intellectual assets of human kind but also increases its own intellectual presence by leading basic research in the world society and opening new intellectuals frontier, further the study revealed that it is imperative

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to maintain a good research balance between the curiosity drive research and nationally targeted research or strategy research for achieving optimal production of the knowledge. Although government and private institutions have set up their own research centers and started their own research in recent years, but universities as centers of knowledge continue to play a prominent role in knowledge production, particularly in the pure or basic research fields (Conroy, 1989; Geuna, 1998; Loon, 2005). Furthermore, academic research is one of the most significant facets of research activities conducted in a country (SESRIC, n.d.). Pavitt (1998) summed up the benefits of academic research as follows: "the main practical benefits of academic research are not easily transmissible information, ideas and discoveries available on equal terms to anyone in the world. Instead, they are various elements of problem solving capacity, involving the transmission of often tacit knowledge through personal mobility and face-to-face contacts. The benefits therefore tend to be geographically and linguistically localized." Moreover, the academic research that is most likely to have an impact on the local economy is research that directly influences industrial innovation, Yale and Carnegie melon surveys (as cited in Hill, 2006) revealed factors useful in determining which industries are closest to university science and which academic fields are most important to industrial research, which includes: new industries are more reliant on university research than are mature industries, and research in applied academic fields is more directly relevant to industrial innovation than is research in basic fields. However, to a certain extent, the performance in academic research can be well reflected by means of the number of scientific articles published in indexed journals. In this regard, the quantity and growth of the research output, i.e. articles are indicators commonly used to measure the research performance of a given institution or a country (SESRIC, n.d.). Indeed such bibliometric indicators have been extensively used in national science and technology (S&T) statistics publication to measure the scientific capacity and linkage to world science and particularly national and international rankings of universities (UNESCO Institute for Statistics, 2005). Furthermore, the analysis by Okafor (2011) revealed that bibliometrics could involve counting of articles or citation analysis, however, at the same time it also highlighted that citation analysis is not sustainable for developing countries because of the fact that researchers from developed countries are not well represented in most international databases and science citation index. Moreover, a study by Sudhier (n.d.) to highlight the importance of evaluating research output explored that among the productivity indicators, one well known productivity indicator of research and development (R&D) is number of publications produced by the scientists, institutions and the country as analysis of publications provide some insight into complex dynamics of research activities and enables framing policies and directions in which R&D has to be conducted. Leydesdorff and Wagner (2008) in his study revealed that one of the best methods of measuring research output is by making use of S&T indicators like impact factor, which are clearly defined, but for other purposes. Another study by Rao and Suma (1999) highlighted some of science indicators which could be applied to measure the impact of the S&T and to compare output at national and international levels includes number of papers published by individuals and also by institutions, number of papers per author, number of authors per paper; male, female, qualified scientists at different levels, impact factor, collaboration factor, etc. Furthermore, King (1987) conducted a study to highlight different types of science indicators used for research evaluation; the author found out those most widely applied indicators for research evaluation includes publication

count and citation analysis. However, the author stressed for the need to develop reliable field independent indicators.

S&T research

Research in S&T is of enormous importance as well as key to advancement toward a knowledge-based, or an innovation-driven economy, as it promotes enhanced understanding on different aspects of life and helps to advance the standard of living by means of creating new knowledge and technological innovations (SESRIC, n.d.). The ability to generate new knowledge and new ideas that are then embodied in products and organizations has always served to fuel development (David and Foray, 2002). The key elements of the knowledge society are ICT use, highly educated and skilled people and progress in S&T research and innovation (Hafkin, 2008). Research entails the application of intellectual endeavor in exploration of matter of either natural or human origin as well as intend of research is breakthrough and development of methods and systems for advancement of human knowledge (Okafor and Dike, 2010). A study by Ahmed and Stein (2004) revealed that S&T research is well thought-out among the most effective means to enhance growth and socio-economic development of nations as the technological development has a profound and long-term impact on income distribution, economic growth, employment, trade, environment, industrial structure and defense and security matters. Furthermore, Yale survey (1983) analyzed by Nelson (1986), Rosenberg and Nelson (1994) and Kelvorick *et al.* (1995, as cited in Hill, 2006) revealed that science is important to industrial R&D in that it provides a pool of knowledge and research techniques which industrial researchers used to solve particular research problems. Moreover, productivity in scientific and technological information of a country determines its overall development (Sudhier, n.d.).

S&T is widely recognized as an important tool for fostering and strengthening the economic and social development of the country. India has made significant progress in various spheres of S&T over the years and has developed a strong network of S&T institutions, trained work force and an innovative knowledge base (Glanzel and Gupta, 2008). A study by Anand (2008) based on the findings of INFLIBNET revealed that the research output of teachers and students of top 50 universities in the country has increased manifold over last years. In his study, the author also highlighted that easy access to web available because of automation as a fundamental reason behind the spurt in research activities. A multifaceted study on the status of S&T conducted by Gupta and Dhawan (2006) to report the status of S&T research in India revealed following important findings, which include: S&T activities in India is picking up both in terms of growth rate and quantity of publications output during the time period of (1985-2005); India's publication in international subject database has also shown improvement during (1994-2003); India along with China leads developing countries in S&T majority of subject fields. Furthermore, Gupta and Dhawan (2008) performed an analysis of research publication output data for India in S&T for (1997-2007) to provide current position of S&T. Based on analysis study revealed following important findings: India's scientific activities are on rise and is growing at an average rate of 7.76 percent pa; India's global publication has shown rise in S&T from the year (1997-2007) with most significant rise in the field of pharmacology, toxicology and pharmaceutics followed by chemistry, dentistry, immunology and microbiology, environmental science, biochemistry, genetics, microbiology, material science, etc.; India ranks at 12th position among the top 20 productive countries in the world in the field of S&T; top priority areas of S&T in India are physical science followed by life science, engineering

science and health science; chemistry, physics and engineering are the high-productive areas of S&T research. However, agriculture, biology, basic life science, earth and environmental science have been the medium productive areas while as mathematics and computer science have been the low-productive areas of S&T research; the study further revealed that despite the significant rise in India's average growth rate, it's global publication share (1997-2007) is still very small compared to the leading world economies especially China. Moreover, Kumar and Garg (2005) conducted an analysis of Chinese and Indian publications in the field of computer sciences during (1991-2000) which revealed India's output is significantly higher than Chinese output, study further revealed that Chinese researchers prefer to publish the research results in domestic journals while Indian researchers prefer to publish their research results in journals published in advanced countries of west. Furthermore, Bala and Gupta (2010) analyzed the research profile of biochemistry, genetics and molecular biology research and the share of intellectual collaborative papers in India's research output during (1998-2007). The analysis revealed that India was tenth among the top 30 productive countries of the world in biochemistry and molecular biology. The analysis further revealed that India witnessed rise in global from 1.77 percent in 1998 to 3.07 percent in 2007 and it's world ranking improved from 14th in 1998 to 9th in 2007. Moreover, Sevukan and Sharma (2008) conducted an analysis to explore the research performance of biotechnology faculties in central universities of India from (1997 to 2006). The findings of the analysis indicated that the contribution to the literature on the subject from the universities has been steadily growing. It was 15 articles in 1997 and 43 in 2006.The articles contributed by the faculties appeared in journals published from 16 different countries with a maximum from the Netherlands followed by the USA. Only 0.32 percent articles were published from India.

Collaborative research

Amabile *et al.* (2001) describe collaboration as individuals that differ in notable ways sharing information and working toward a particular purpose "citing in particular the definition by Jassawalla and Sashittal (1998) the coming together of diverse interests and people to achieve a common purpose via interactions, information sharing, and coordination of activities." Lee and Bozeman (2003) conducted a survey to highlight and reveal the impact of collaboration on scientific productivity in terms of publication. They developed a "collaboration cosmopolitanism" scale to measure collaboration outside one's own work group. The findings revealed that physicist tend to be the most cosmopolitan in pattern. They also tested a number of regression models and in each model, number of collaborators remains the strongest predictor of productivity measured by fraction and round count. Beaver (2004) conducted a study to explore the impact of research collaborations. The author found out that collaborative research is having greater commanding authority than research performed by individual scientists alone; moreover single authored papers are slightly more liable never to be cited than collaborative. Moreover, Gupta and Dhawan (2006) conducted a study to highlight about research in collaboration and patterns of collaborative research, the findings of the study revealed that there has been a significant growth of collaborative research output in India and the country's share of papers through national collaboration is greater than its share through international collaboration. Frame and Carpenter (1979) in their study investigated the international collaboration behavior among scientists. The major findings of their study revealed: the more basic the fields, the greater the portion of international co-authorship; the larger the national scientific

enterprise, the smaller the portion of international co-authorship; international co-authorship occurs along clearly discriminable geographic lines which suggested that extra-scientific factor (e.g. geographic, political and language) plays a strong role in determining who collaborate with whom in the international scientific community. Moreover, a study by Gupta and Dhawan (2008) to highlight international collaborative fields of research in S&T revealed that international collaborative publications are highest in the physics followed by biochemistry, genetics and molecular biology, material science, engineering, chemistry, agriculture and biological science and medicine. Another study by Bala and Gupta (2010) revealed that India's collaboration share of internationally collaborative papers increased from 16.81 percent during (1998-2000) to 18.38 percent during (2005-2007). Okafor (2011) conducted a study to explore the impact of collaborative research, the findings of the study revealed that coordination between universities, researchers and industries will lead to maximum output from different faculties, and this will lead to creation of new knowledge, which the academics pass to other through publishing their findings for the economic and social welfare of society. Furthermore, Cummings and Kireler (2005) conducted a study to investigate scientific collaboration across disciplines and university boundaries to determine the needs for coordination in these collaborations and how different levels of collaboration predicted success, they found out that multi-university projects were problematic rather than disciplinary projects, further projects with principle investigators from more universities were significantly less well coordinated and reported fewer positive outcomes than projects with project investors from fewer universities. Godin and Gingras (2000) conducted a study to assess the extent to which collaborative research in Canada influences the nature of scientific production and the level of international scientific collaboration for the years (1980, 1985, 1990, 1995), they found out that during the period under study the proportion of inter-sectorial collaboration grew by 155.2 percent from 1,732 to 44,420 publications, but this trend showed fluctuations and went from 50 percent during (1980-1985) to 34.3 percent in (1986-1990) and to 26.6 percent in 1991-1995, the study further revealed that during the period (1980-1995), publication written in international collaboration grew by 237.2 percent which highlighted that international collaboration has grown more than sectorial collaboration and also the research undertaken in collaboration is more applied than research undertaken solely between university researchers. Furthermore, Bukvova (2010) conducted a review of literature to study the various aspects of collaborative research. The findings of the study revealed that the collaborative research has potentials as well as risks, among the potentials the author highlight the following, access to expertise, access to resources, exchange of ideas, especially across disciplines, pooling expertise for complex problems, keeping own activities focussed, learning new skills, higher quality of results, access to funding, fun and pleasure and the risks include stress caused by uncertainties about credit which can have adverse effect on the researchers' motivation and it is often undecided, who has responsibility for the results of a collaboration.

Role of universities in research

The role of universities in the innovation process has increased continuously over time because the development of new products or technologies depends increasingly on the findings of university (scientific) research (Narin *et al.*, 1997; Rosenberg and Nelson, 1994; Tijssen, 2002). Loon (2005) conducted a study revealing that universities make very large contribution to country's economy and society as well university research or

patent licensing has significant impact on social and economic life of people. Another study conducted by Mowery and Sampat (n.d.) explored the importance of universities in knowledge-based economies. The findings of the study revealed that universities play an important role in the knowledge-based economies of modern industrial and industrializing states as a source of trained "knowledge workers" and ideas flowing from both basic and applied research activities, the study further revealed about the functions that universities perform directly or indirectly, which help in overall development of a society and nation as a whole, includes: first, production of trained personnel's (scientists/researchers), the movement of whom into industrial and other occupations, helps in the diffusion of scientific research that can ultimately strengthen the links between the academic research agenda and the needs of society; second, production of different forms of economically important outputs of research which include scientific and technological information that increases the efficiency of R&D in industry. Moreover, Klevorick *et al.* (1995) finds that the results of university research are particularly relevant for firms in R&D intensive industries, such as the computer industry, aircraft industry and the pharmaceutical industry. Firms in these industries mainly utilize findings from applied sciences (mechanical engineering, electrical engineering, chemical engineering) while new findings from basic research in physics and mathematics are of lower relevance for industrial innovation. Li, *et al.* (2008) conducted review of literature on role of universities and academics in research, the study revealed that emphasis on research in higher educational institutions across the world is a product of combined forces operating nationally and institutionally, the study further revealed that national university research is a key indicator of the overall national competence and has been given a significant attention, further institutionally these institutions are motivated by the desire to win international and national recognition, which are closely associated with the research performance of their academic staff. A study by Gupta and Dhawn (2006) to highlight the significant progress of S&T in Indian universities revealed that chemistry, physics, engineering and clinical medicine had been the high-productivity areas of research in universities. Hill (2006) in his study highlighted the role of universities in economic development of a nation. The findings of the study revealed that universities have played a key role in the process of economic growth, both as a source of nascent knowledge and trainer of scientists and engineers who work in industrial laboratories, the study further revealed that universities with the greatest economic impact are generally those with the highest quality research programmers. Another study by Abbott and Doucouliagos (2004) conducted within Australian universities to highlight the association between research output and characteristic of universities, revealed that research income, academic staff and post-graduates are all associated positively with research output, the study further revealed that the newer universities are lagging in research performance as compared to older ones. Furthermore, Florida *et al.* (2006) conducted a study to observe the task of the university in the 3Ts of economic growth i.e. technology, talent and tolerance. The findings of the study recommended that the role of the university go far beyond the "engine of innovation" perspective. First, in terms of technology: universities as major recipients of both public and private research and as sources of innovations and spin-off companies, they are time and again at the cutting edge of technological innovation. Second, universities play a dominant role in generating, attracting and retaining talent. On one hand, they directly attract top faculty, researchers and students. On the other hand, they can also act as magnets for other talent, attracting

talented people, research laboratories and even companies to establish near them to access their research and amenities.

Challenges in research

A study conducted by Harris and Kaine (1994) explored relationship between individual productivity in research, their preferences and perceptions about research relate issues. The authors in their study highlighted the items/things, which the researchers felt constrained their research. The findings of the study revealed that there is relationship between the hurdles and group membership and therefore productivity; the study also revealed that productive researchers made deliberate choice about the type of research and enjoyed freedom and challenges of their position that in turn revealed that research performance is more a function of individual motivation than resource support. Sudhier (n.d.) conducted a study to highlight the factors that hinders the growth of advanced research in India, which includes the research institutions and programmers finding difficulty in attracting good students in sufficient number, lack of encouraging research environment that necessarily includes reasonably good incentives for research and professional monitoring of their research progress. Another study by Geuna (1998) to reveal the factors that had an impact on quality of research in knowledge centers/universities includes; first a center of excellence attracts high-quality researchers who will, most probably do valuable research, in turn increasing the quality of the center and therefore, attracting additional talented scientists. Second, a high level of human and physical capital implies a better chance of achieving important results; further the study revealed that the high-quality research increases the probability of attracting new research funds and therefore expansion in the investment of human and physical capital. Moreover, Leydesdorff and Wagner (2008) revealed that among the funded and rejected authors, rejected authors have significantly higher publication and citation rates than funded ones, because of the reason like peer review. Furthermore, Waworuntu and Holsinger (1989) analyzed the factors influencing the research productivity of faculty in higher education, the analysis revealed that these factors can be divided into three broad categories/variables: ascriptive, achievemental, organizational variables, among the three variables ascriptive variable which is to assign quality has least association with all dependent variables, the analysis further revealed that it is the research capacity building, the building of nations capacity to generate knowledge that is of central importance to countries all over the world.

Conclusion

The survey of current literature reveals that research plays a vital role in development and prosperity of every nation especially in the field of S&T, as it has been recognized as a tool for strengthening the economic as well as social development of nation. Moreover, the developing nations like India are paying more attention toward S&T research, which is evident from the facts revealed in the review of literature. In this context, the study highlights that the universities act as hub of research activities by fostering R&D processes. However, despite of advancement in S&T research there are still many challenges that are being faced by the researchers.

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About the authors

Nadim Akhtar Khan is working as an Assistant Professor in the Department of Library and Information Science, University of Kashmir, India. He has done Master's in Library and Information Science (Gold Medallist), NET and PGDCA. His research interests include open

source software, metadata harvesting and interoperability, institutional repositories, digital libraries, multilingual interfaces and cultural heritage. He has attended and presented papers in many national and international seminars including ICDL 2010, ETTLIS 2010, ICDK 2011, ICLAM 2011, etc. He bagged Best Poster Award for his Conference Poster entitled "Harvesting capabilities of Google Scholar: a comparative study of three major journal lists-DOAJ, Highwire and Biomedcentral" in the Third International Conference on Digital Libraries (ICDL-2010). Besides, he has authored a number of papers in many national and international journals and also contributed book chapters to various book series. He is also Deputy Administrator for Knowledge Repository Open Network (KNoor), an open access repository which aims at harvesting and aggregating the scholarly products emanating from research and scientific institutions of Jammu & Kashmir (viz. S.K. Institute of Medical Sciences, S.K. University of Agricultural Science & Technology and University of Kashmir). He has coordinated a number of national workshops and seminars. For further details please visit http://lis.uok.edu.in/faculty5.aspx Nadim Akhtar Khan is the corresponding author and can be contacted at: khannadim2007@gmail.com

Sumaira Jan is a PhD research scholar in the Department of Library and Information Science, University of Kashmir, India. She has done Master's in Library and Information Science. Her research interests include open access repositories, cultural heritage and digital preservation. She has presented research papers in several national seminars.

Iram Amin has done Master's in Library and Information Science and Post-Graduation Diploma in Computer Applications. Her areas of research interest include open access repositories, cultural heritage and digital preservation. She has presented research papers in several national seminars.