Journal of Scientometric Res. 2021; 10(2):212-224
http://www.jscires.org

Research Article

A Scientometric Analysis of the Evolution and Changing Structure in Systems of Innovation Approaches

Vairaj Arjune*, Rajbeer Singh, Pranav N Desai, Krishna Tripathi

Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, New Delhi, INDIA.

ABSTRACT
The present study was conducted to investigate new emerging directions and identify literature by depicting and analysing the historical origins, contemporary research fields and intellectual authors in the domain of Innovation Systems. Using the ISI WoS database, we deployed a systematic review of the literature using scientometric approaches for delineating the various innovation systems in STS literature and conduct a specific analysis of each system. Publications in the WoS database were filtered using the search string "innovat* NEAR/2 syst*" in the publication title for the period 1990 to 2017. A total of 692 innovation-related publications with contributions from 1651 authors were processed article by article, and as a result, 7 innovation clusters were reviewed using highly frequent cited papers. After constructing a co-citation network map to derive the structure and origins in the innovation systems field, we found that 330 (47.68%) of all publications were published in only 12 (5.71%) journals in research areas of business economics, public administration, environmental sciences ecology, geography and science technology. In mapping the evolution and salient features of the innovation systems approach, we performed a keyword co-occurrence textual analysis which reveals important characteristics about each innovation cluster. More so, topics like "policy", "technology" and "knowledge" continues to be dominant research topics in all periods of the study. However, emerging topics are moving away from the theories and processes of innovation. The paper aims to be a potential guide to science policy researchers and newcomers to become familiar with this field of study as it examines the salient features and evolution in the field of innovation studies.

Keywords: Co-citation, Co-occurrence, Innovation systems, Interactive learning, Networks.

Correspondence
Vairaj Arjune
Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, New Delhi-110067, INDIA.
Email id: varjune24@gmail.com
ORCID ID: 0000-0002-4057-2164

Received: 20-03-2021
Revised: 25-07-2021
Accepted: 02-09-2021
DOI: 10.5530/jscires.10.2.35

INTRODUCTION

During recent decades, science policy scholars have devoted significant efforts in identifying new trends and directions in the STS domain, particularly in innovation and competitiveness. The spread of the internet and information and communication technologies have significantly spiked the level of international collaboration[1] thus triggering new heights of research and innovation potential. Even policymakers are keen on the investment in research and innovation as a key contributor to economic growth and the development of a market-based economy.[2] Emerging technologies like ICT, biotechnology, and new materials that rapidly diffused in the 1970s and 1980s have shown to intensify the science-technology interface and enhance the importance of networking systems for achieving innovative success.[3] New technologies are seen as enablers of scientific exchange of information by the 'shrinking' of the globe that has considerably reduced the effects of geography on scientific activity and has given rise to the emergence of the 'global village'.[4] Thus, many scholars[2,5] point to a close connection in science and technology infrastructure and economic development and enhanced societal welfare.

Innovation has therefore, become the new world language that will contribute both to competitiveness and economic development.[3,5] The concept of innovation is conceived by many scholars differently. Schumpeterian view of entrepreneurial innovation consider it to be a "critical dimension of economic change"[6] while defining it as "carrying out of new combinations"[7] which may be in the form of new products or a new species of existing products, new methods of production or sales of a product, new markets, new sources of supply of raw material or semi-finished goods and new industrial structures.[8] Nelson and Rosenberg[9] have considered innovation as a "processes which firms master and get into practice product design and manufacturing processes that are new to them"[10] by adopting the process aspect of the innovation. West and Anderson[11] have considered both the product and process aspect of innovations in terms of the practicality of their introduction. The definition of

innovation suggested by the Oslo manual considers it to be "the implementation of new or significantly improved product (good and service) or a process, or a new marketing method or a new organisational method in business practice, work place organisation or external relations".[12] As these elements often originate from different actors, innovation following Schumpeter is, as a result, interactive learning. Through interactions in the economy, various pieces of knowledge or elements get combined in new ways to create new knowledge or new products and processes.[5] These interactions and linkages that occur on different levels between and among firms, universities and government institutions are best understood through the innovation systems approach.

Work on the idea innovation systems appear in the late 1980s and were only documents that emerge as alternative models to the predominant macro-economic theories that tend to focus on market mechanisms and neglect institutional mechanisms, a focal point for the former in understanding and mapping technological competitiveness of economies. The first published literature on innovation system was by Freeman[13] in his book on technology policy and economic performance in Japan. Since then emerging social structure of economic and technological globalisation, has given rise to the formation of networks comprising of different players – producers, consumers, among others – across which flow knowledge and innovation.[14] As such, economies are getting integrated not just by economic and financial means but through knowledge-based institutions and innovation systems that are dispersed geographically. This led many scholars to the conceptualization of various innovation system approaches like technology systems, national systems, international systems and responsible innovation. Admittedly, these perspectives can be clustered as variants of a single generic 'systems of innovation' (SI) approach.[5] The SI approach is useful in the analysis of innovation which has found its way in many national, regional as well as international organisations such as the OECD, the European Union, UNCTAD, and UNIDO.[15] More so, the SI is an interactive learning system comprising of the determinants of innovations (social, economic, political and environmental factors), organisations (formal structures), institutions (rules, norms and practices) and relationships among them to develop, diffuse and use innovations.[15]

Despite developments in the literature of innovation system (IS) in recent years, there still remains limited documented research on the historical origins, evolutions and structure of the scientific field.[16] An analysis and understanding of the changing structure and research trends of a scientific discipline is useful for anyone to coherently understand the various scales, magnitude and level of innovation systems existing either at the country level, sub-country or international level.[17] For science policy researchers, it helps in positioning their investigations within the field and identifies new emerging directions and key literature in the field of study by delineating the various innovation systems in STS and conduct a specific analysis of each system deterrent and unit of analysis. In this context, the paper attempts to map the literature on systems of innovation using scientometric methods. Thus, we intend to answer the following questions in the field of systems of innovation: What are different innovation system approaches and how do they differ from one another? What are the key issues addressed in the different innovation system approaches? And what are the research areas, sources of publications and contributing authors?.

Most studies have analysed the structure and evolution of SI approaches from the standpoint of either qualitative and bibliometric methods. For example, Sharif[18] interviewed prominent contributing authors in the field of innovation systems to determine the history and emergence of the SI approach using the social constructive perspective. The study explored themes of social controversies that shaped the development of the NIS concept which could help explain certain features (actors in the system) of the varying innovation systems approach. However, analysis of expert judgements may contain subjective elements and provide limited cognitive horizons, thereby creating a coalesce of selective individuals (and their research) and overshadowing new comers to the field of innovation studies.[19] Martin[20] performed a citation analysis to uncover the origins and evolution in the field of innovation studies using highly cited publications and core journals. His analysis points to various timelines in the development of the field and showed that SI approaches comprises of National, Regional, Sectoral, Triple Helix and Technological systems of innovation. The problem with focusing on journals as an indicator for defining a particular field is that low impact journals with low impact publications will get similar score as high impact journals having high publications.[21] Also, the selection of high impact documents has limitations on identifying frameworks that are weakly developed or have potential links with other fields of innovation systems. Uriona-Maldonado, dos Santos[22] used bibliometrics to analyse 773 articles published in the Science Citation Index Expanded database from 1975 to 2009. Using words such as, "Innovation Systems", "Innovation System", "System of Innovation" and "Systems of Innovation" they found that Lundvall (1992), Nelson (1993), Freeman (1987), Edquist (1997), and Porter (1990) were the top five cited references in the field on innovation systems. Their results were confined to identifying routine scientometric indicators such as important authors in the field, journals where the publications are published and the co-citation network among authors with limited analysis on the interpretation of the different innovation systems approach. Improving on this study through similar search selections in the SCI-Expanded, SSCI, and AHCI

databases, Liu, Yin[16] analysed co-citation and co-occurrence pattern of 1,364 articles. The results were much similar to the findings of Uriona-Maldonado study but with the addition of highlighting turning points at which new directions emerged in the IS literature. However, the use of narrow search string fails to highlight emerging fields of research like open innovation and responsible innovation. A more recent and robust analysis by Kashani and Roshani[23] used co-citation and centrality to map the network of new concepts, their connections and citations from a database of 2600 articles on innovation systems literature. The study added pioneering work of Nelson and winter (1982) and Cohen and Levinthal (1990) among the top five cited references shaping the evolution of the IS literature but did not venture beyond author analysis in depicting the intellectual structure and evolution of literature in IS field.

As mentioned, the previous studies examined the field of innovation studies from different perspectives using scientometric analysis to identify publication outputs, citation count and important contributing works in the field. However, they do not provide adequate information beyond their analysis relating to the salient features of each of the different innovation systems uncovered in the studies. The central problem arises from the fact that selective IS taxonomy does not provide a comprehensive knowledge structure and emerging direction of the scientific field. This research gap is highlighted in the following aspects: 1) Inadequate search string eliminates key studies which could provide new concepts and emerging frameworks in the field of SI such as open innovation, responsible innovation among others. 2) Lacking the analysis on the different SI approaches and their respective features and contributing authors. 3) The data analysis of existing studies does not highlight core contents of publications, intellectual structure and research trends from the perspective of scientometrics. To fill this gap, we use a Boolean expression of systems of innovation which has similar taxonomy with studies[16,23] but with the potential to complement these studies further by including documents where the words "innovation/s" and "system/s" or vice versa are separated within 2 words from each other. This method provides emphasis on the categories of research using systems of innovation approach, though careful selection of relevant publication is required. The methodology used for the scientometric analysis is presented in Section 2. As research is published in many journals and databases, it is always useful to have a consolidated scientific citation database like Scopus or Web of Science where rigorous guidelines are implemented for indexing journal. Thus, the science citation database acts as central information hubs for extracting and analysing any domain or field of literature by researchers. Application of these indicators would allow examining innovation systems research field to map their intellectual structure and evolution. Thus, we aim to fulfil the following objectives in this paper:

a) What are different innovation system approaches and how do they differ from one another?

b) What are the key issues addressed in the different innovation system approaches?

c) What are the emerging research areas, sources of publications and contributing authors?

The paper achieves these objectives by deploying a coherent and rigorous systematic review of the literature using scientometric approaches to map and analyse key documents describing the historical origins and evolution in the domain of innovation studies. Systematic reviews provide for a transparent, replicable and rigorous methodology for understanding a given body of literature.[24-28] Thus, this provides the opportunity to explore and identify concepts in the SI literature more deeply through a comprehensive analysis of carefully curated publications. Secondly, the paper goes beyond traditional citation counts and employs VOSviewer to identify and visualize the intellectual structure, new emerging fields, and leading authors in innovation studies through a timeline perspective. A study by Wei and Zhang[17] showed that dividing publication dataset into periods helps to better identify intellectual structure and evolution of a discipline. Thirdly, this paper aims to be a potential guide to science policy researchers to become familiar with this field of study by delineating the various innovation systems in STS literature and conduct specific analysis of each system deterrent, unit of analysis and magnitude.

METHODOLOGY

The source of data for performing bibliometric analysis and visualising the intellectual structure was collected from the online version of Social Science Citation Index (SSCI)[1] produced by the former Institute for Scientific Information (ISI), known now as the Web of Science. Bibliometric analysis has gained acceptance in the evaluation of researchers' contributions to the scientific community. The benefits and drawbacks of using the bibliometric approach are well documented in the literature of[29-31] and continue to be standard practice to measure research output. A simple search on the innovation system on the online scientific citation platform shows the tremendous research being conducted on systems of innovation. For example, we inputted the search string, "*innovat* syst**" in publication titles by querying the Web of Science Core

1 The WoS Social Science Citation Index provides access to bibliographic information relating to author, affiliations, and citations among others for the period covering 1988 to the present. For more information, see https://library.maastrichtuniversity.nl/collections/databases/ssci/

databases and found 3,621 publications for the period 1990–2017, see Figure 1.

The flowchart adopted for searching for the innovation system-related papers is shown in Figure 2. The analysis is multi-fold. Firstly, we used the Boolean expression "*innovat* NEAR/2 syst**" in the publication title of Web of Science for the period 1990–2017 and found 1,959 documents where the terms *innovat* and syst** or vice versa were separated within 2 words from each other. Within this sample, we selected those publications written in English from the Web of Science SSCI database in the domain of research articles, proceeding papers, review articles, and book chapters, thus reducing the sample to 942 documents.

We then proceed to read the abstracts of the publications and access the full text of these studies where necessary to identify additional documents from the list of cited references and exclude publications that are not related to our objectives. Accordingly, a total of 692 systems of innovation-related articles were published in the SSCI between the years 1992 – 2017. The general characteristics of the selected publications are depicted in Table 1.

Secondly, from our refined dataset, we split the publications into different periods, from 1990–2000, 2000–2010 and 2010–2017 to identify various keywords, contributing author and cited references that help shape the evolution of innovation system approaches throughout the selected period. So, breaking

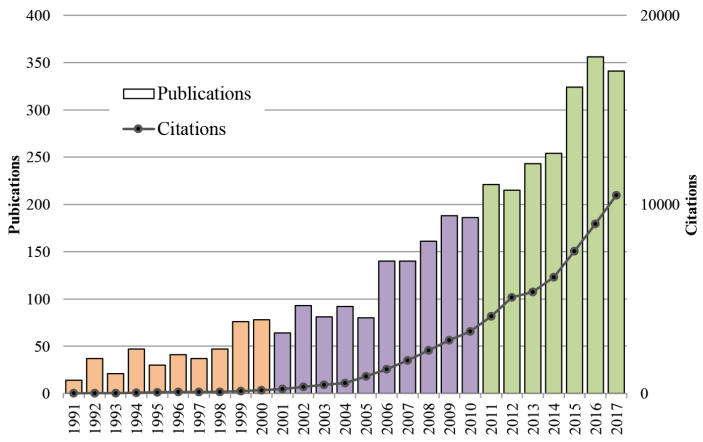

Figure 1: Distribution of publications and citations in the field of innovation studies by year for the period 1990 – 2017.

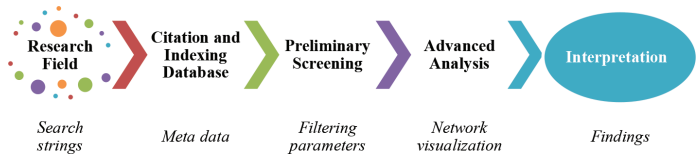

Figure 2: Research Methodology adopted in the study.
Source: Adapted from.[32]

Table 1: Cross-section of preliminary results by WoS criterions.

Key Identifiers	Records
Total Publications	692
Number of Authors	1651
Single Authors	191
Multiple Authors	1460
Number of Journals	209
Research Area	41
Citations	37205
Cited References	40114

the dataset into parts would locate emerging turning points in the literature and allow for closer analysis on how innovation system discourse (particular approaches, their scope and magnitude) travel from one time space to another. Thirdly, using network mapping software tool – VOSviewer version 1.6.11 – we generated a network map based on bibliographic data of the 692 publications to analyse the frequently cited publications that appeared in the field of innovation systems using the co-citation analysis of VOSviewer. This analysis given in Section 3 deviates from previous scientometric studies[16,23,33] on highly cited documents where there is a tendency to depict the impact of author/s writing on innovation systems without much emphasis on the purpose, research space and implications of innovation systems approaches. Co-citation analysis has always found its place in academic research and is considered a powerful methodological tool in mapping predominant research areas in any particular field or discipline.[34-36] The method is widely used to identify key literature, especially in trans-disciplinary research, as it enables the identification of intellectual structure and evolution in relevant literature too often overshadow by standard approaches to literature searching.[16,17,37,38] Co-citation generally refers to the number of times two publications have been cited together in other publications or where a source document is cited by at least two different documents in a group of publications. Finally, we performed a clustering analysis on the refined dataset to extract the high-frequency keywords related to each innovation system approach. The larger dataset would allow for the inclusion of low impact publications from authors who may have something to propose on innovation systems literature, thereby providing a better approach in further mapping the salient features of innovation systems approaches.

Systematic Analysis on Innovation Systems from Co-Citation

The dataset in the previous section is used to generate a co-citation network to review the theoretical and historical origins of the innovation systems literature. Using VOSviewer,[39] the publications in our dataset after processing contained 26,377 co-cited references of which about 15 per cent were

cited two or more times with at least one other document. 793 of the cited references were co-cited five or more times, and 271 references were co-cited ten or more times. After some experimenting, we decided to limit the citation threshold to documents that were co-cited at least twenty times, thus bringing the most frequently co-cited documents to 97[2]. See Figure 3 for the network of co-cited references. The publication titles and author names are provided in[16] where a similar approach was taken to map the structure, dynamics and paradigm shifts in the IS field. Careful analysis of the dataset suggested that supplementary studies were needed as some articles were not analytical[40-42] in their approach. Accordingly, certain innovation-based approaches and models which were non-matching to the cited references were included in the analysis as they represent important historical roots and emerging research to the field of innovation. This provided us with a satisfactory level of details that turned out to yield important characteristics on the theoretical origins and influential publications and authors in innovation systems.

Systems of Innovation Approaches

The process through which technological innovations emerge depends to a large extent on the diffusion and absorption of scientific and technical knowledge as well as the conversion of these into new products and production processes. This paints an interactive and complex system involving science, technology, learning, policy, and demand.[5] The use of the systems of innovation approach to the study of technological change is not new.[43] The systems of innovation approach is compatible with the notion that processes of innovation, in a large part, are a result of interactive learning.[5] The fact that successful innovations are not isolated events[44] but occur in collaboration and interdependence with other organisation gives rise to the emergence of Edquist,[15] Systems of Innovation (SI) approach. Organisations and institutions are the two most important constituents in the SI approach. Given the systemic nature of the SI approach; it can transcend the traditional linear view of technological change.[5] Myriad theories of systems of innovation such as the national system of innovation,[45-49] regional innovation system,[50-55] a sectoral system of innovation,[56-58] a technological system of innovation,[43,59] international system of innovation,[1,60-63] multilevel perspective[64,65] and recently the approach of open innovation[66,67] and responsible innovation[68-73] have attempted to discuss the process of innovation and its underlying assumptions.

2 Initially, 100 documents were co-cited twenty or more times, but after preliminary analysis, only 97 documents were found relevant. For example, the list of authors for edited books was referenced differently causing multiple duplications.

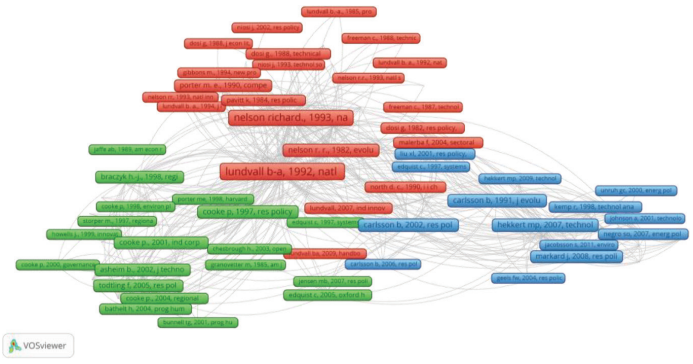

Figure 3: Mapping the network of highly co-cited publications, (tags are given by author name, year of publication and journal abbreviation)

National System of Innovation (NSI)

The first published literature on innovation system was by Freeman[13] in his book on technology policy and economic performance in Japan. Freeman[45] used the expression 'national system of innovation' to understand different actors, institutions and networks as well as an interactive process between economic, social and political factors which brought a thorough understanding of the innovation process, historical insight and wisdom to collaboration.[62] The NSI framework[13,46] has been a pioneer in broadening the sphere of the innovation process as it includes industries and firms alongside other actors and organisations. It considers the research and development activities performed by research institutions, universities, governing agencies and policy dimensions as a constituent of a single entity/system and carries out analysis of the R&D activities at the national level as a comprehensive whole. The basic intention of NSI is to change the analytical perspective away from allocation to innovation and from making choices to learning.[48] This is reflected in Freeman[13] definition of national innovation systems as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies'.[74] Overall, the NSI pertains to analysis at the national level reflecting the available resources and institutions endowed in a given country that domestic firms can leverage to support their innovations.[75]

Regional Innovation Systems (RIS)

The concept of a regional innovation system has been evolved from the bedrock of NSI and is aimed at unifying the significant considerations of R&D, termed as 'the new regional science'.[50] It focuses on the significance of regions as the loci for global economic competitiveness across firms, the institutional settings and organisational support infrastructure for regional economic competitiveness.[76] More so, it pays due consideration to the networks, both formal and informal, as instruments for sustaining mutual trust relationships between firms.[77] It also aims at the re-evaluation of the importance of the 'geographical proximity or agglomeration characteristics'

for aiding tacit knowledge exchange and recognises the significance of institutional and organisational learning tendencies towards regional economic performances.[50] Hence, the regions within countries or parts of different countries delineate the geographical boundaries of RIS.

Technological Innovation Systems (TIS)

Before the emergence of the regional innovation system, a group of Swedish scholars focused on 'technological systems' in a particular technology field such as factory automation, electronics and computers, pharmaceuticals, and powder technology.[5,60] This was one of the first innovation systems that advocate openly cross-border interactions beyond the national system of innovation framework. According to Carlsson, Jacobsson,[43] technological systems involve three types of network that may include market and non-market interaction: buyer to supplier relationships, problem-solving networks, and informal networks. Instead of focusing on the geographical boundaries of a system, it focuses on the constituent entrusted for the development of a 'generic technology'[78] and its complementary constituents influencing the innovation process thereof.[43] TIS encompasses an interactive and systemic nature of innovation processes and emphasises the need to create policy instruments that can aid the formation of technological innovation systems for increasing the chances of successful diffusion of new technology and innovation.[79-81]

Sectoral Innovation Systems (SIS)

In 1997 the notion of 'sectoral innovation system' emerged. The term sectoral innovation system (SIS) is defined, according to Breschi and Malerba,[82] "as that system (group) of firms active in developing and making a sectors' products and in generating and utilising a sector's technologies; such a system of firms is related in two different ways: through processes of interaction and cooperation in artifact-technology development and through processes of competition and selection in innovative and market activities." The sectoral innovation system[56] focuses on different technology fields or product areas[5,83] and the system has been defined based on an industry or sector.[84] The approach stems out from the idea that various industries or sectors function under different 'technological regimes' which are composed of a particular set of opportunities and technological knowledge.[43] The systemic configuration of the sectoral innovation system involves products, agents, knowledge, technologies and their dynamics and changes and the co-evolution of these constituents choose the directions of the changes and transformation of the sectoral system temporally.[56,85,86]

Multilevel Perspective (MLP)

Multilevel perspective delineates three levels i.e., meso, micro and macro which are 'analytical and heuristic concepts' for understanding system innovations.[87] The meso level is composed of socio-technical regimes which attribute to the broader category of rule sets or precepts engrossed in institutions and infrastructure of system innovation using engineering procedures, product and process technologies and characteristics, skills and ways of defining problems.[87] The micro-level comprises of technological niche which is the locus of radical innovation. Radical innovation, due to its novelty, has a lower level of performance.[88] Hence, the technological niches work as 'incubation rooms' which provide these radical novelties with a protected space to screen them from the upfront selections by the market. These protected spaces can be provided in different forms for instance by strategic R&D investment by companies and also by subsidies by the government.[87,89] The macro-level is made up of a socio-technical landscape referring to the 'wider exogenous environment' which influence socio-technical development i.e., cultural transformations, environmental challenges and globalisation.[90] The relationship between the three concepts can be understood as a 'nested hierarchy' embedding niche within regimes and regimes within landscapes.[87]

Open Innovation Model (OI)

Chesbrough defines open innovation as 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively'. It combines internal and external ideas into layouts and systems utilising business models in identifying the needs thereof.[67,91,92] These business models may employ external and internal ideas to produce values. Open innovation presumes that internal ideas, to create value, can also be introduced in the market using external channels outside the prevailing businesses of the companies. The open innovation model considers R&D as an open system. It advocates that productive ideas can emerge from in and outside of a company and can approach markets in the same ways.[66]

International System of Innovation (ISI)

Like any other innovation system approach, the ISI also follows the System of Innovation approach comprising of actors, institutions and interactions[5] but goes a step further in linking international actors and organisations as well as their influence to capture the international dimension of innovation. A precise definition of the international system of innovation is difficult, but previous work on India's and the OECD countries innovation systems[61,62,93-96] have provided assumptions as an extended national innovation system that captures the interactions of global regimes on the policies and development of a country. The dimension of global regimes

– global environmental movements, multinational and transnational corporations, global telecommunication networks – has a tremendous impact on the national policies and development of a country which is rarely reflected upon in the innovation process.[96,97] Desai[61] in dissecting international technology transfer channels in developing Asian countries generated three underpinnings of the international system of innovation – historically structured process, hierarchical, and power dimension. These three descriptive foundations of the ISI can be captured visually by an inverted triangle depicting the hierarchical S&T resource chain where countries try to harness and acquire technological capabilities. Moreover, this system generates multiplying effects in favour of those countries or regions where the S&T resources and innovation capabilities are concentrated. This historically structured process is a changing and only slowly changing system.[98] More importantly, this approach raises issues of interactions between the unequal partners and socioeconomic justice.

Responsible Innovation (RI)

The RI framework provided by Owen, Stilgoe[99] suggests that for an innovation to be responsible requires it to be anticipatory (describing and analysing intended and potentially unintended impacts), reflective (on underlying purposes, motivations, and potential impacts), deliberative (processes of dialogue, engagement, and debate) and responsive (effective mechanisms of participatory and anticipatory governance). The framework has since been expounded by Singh and Kroesen (2012) where various conceptual components for the framework of responsible innovation represent an integral part of the innovation process - being caring, ensuring care and certain values - which include universal and culture-specific values, along with five dimensions (anticipation, deliberation, participation, reflexivity, and responsiveness) of responsible innovation. The focal point of the framework suggests for innovation and the processes thereof to be present to the values for social desirability, economic viability and environmental sustainability of innovation, thereby leading to the goal of sustainability of innovation.[71-73] By following the five dimensions, the innovation process enables the embedding of the values (universal and culture-specific) in new and emerging innovation. These dimensions of RI are lateral in nature and not sequential and address both sustainability and responsibility in the innovation process ecosystems by creating conditions for deliberations, participation and anticipation from all stakeholders from the onset of research and innovation.[100] It also brings in the approach of open innovations in the picture by ensuring the effectiveness and relevance of the products, processes, organisations and markets.

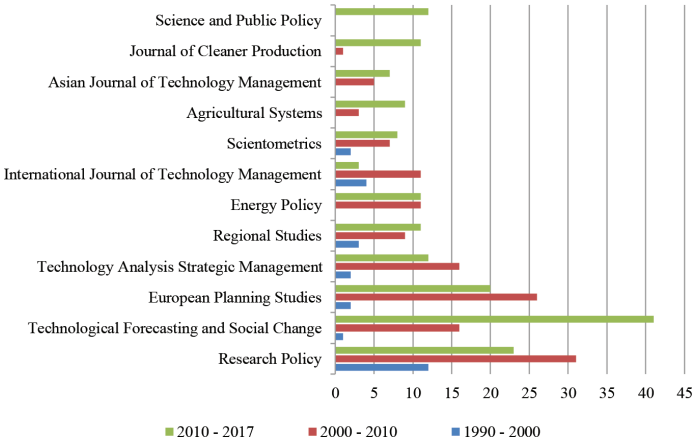

Figure 4: Distribution of publications in journals for 1990 to 2017.

RESULTS AND DISCUSSION

The sample database consisting of 692 publications is used to create a journal citation map based on document frequency for the three periods. The top influential journals in the field of innovation systems are shown in Figure 4. Out of the 692 papers published across 209 journals, only 330 (47.68%) were published in 12 (5.74%) journals, indicating an intellectual base of journals that guide the direction and impact of innovation systems research. *Research Policy* and *Technological Forecasting and Social Change* remained the most influential journals throughout most periods but emerging journals like 'Science and Public Policy' and 'Journal of Cleaner Production' are showing tremendous attention to studies covering innovation systems approaches, particularly in business economics and engineering disciplines respectively. This gradual shift in marked by the maturing of the innovation systems field both from a theoretical and planning tool to include sustainability in innovation processes that would alleviate the social, economic and environmental burdens of society.

The period 2010–2017 with 419 papers had the largest number of publications in the search period with the last five years accounting for over 65% of all publications during the period. Management (110), environmental studies (95), regional urban planning (89), economics (87) and business (77) categories derive from WoS, comprise the most published domains in the field of innovation systems. Business economics (239), public administration (115), environmental sciences ecology (108), geography (51), and science technology (45) are the top 5 research areas during the same period. In other words, publications on innovation systems added over 780 per cent point during the period 1990–2000 to 2010–2017. These insights indicate that the number of studies on innovation systems related research is growing at an exponential rate, especially in selected journals over the last decade. Considering that IS emerge in "Business Economics" and "Social Issues" research area during the first five years, representing 5% of

total citations, the field has immensely been distributed which signifies the acceptance of innovation systems approaches in other closely allied disciplines.

Conceptual Structure Map

We proceeded to show the top influential authors in the field of innovation systems based on co-citation analysis, as this helps in identifying the structure of a discipline. Here, we decided to set the citation threshold to five to identify the structure and relationship among authors who contribute to the field of innovation studies. Out of the list, 1171 top co-cited authors were selected and mapped into 7 clusters from high-frequency words extracted from each publication record, see Figure 5. The first cluster (C1), deals extensively on research related to advancing the concept and development of the national system of innovation, with leading contributions from *Freeman, C; Lundvall, B A; OECD, Nelson, R R;* and *Porter, M E*. As the NSI was the first documented innovation system being explicit about the networking of different actors for enhancing technological performance, this bracket had the most influential authors. The second cluster (C2) corresponds to the regional innovation system, with particular reference to firms operating in the national and international innovation systems. The leading authors in this cluster are from *Cooke, P; Asheim, B; Doloreux, D; Todtling, F;* and *Storper, M.* The third cluster (C3) includes studies on technological innovation system and the functions of the innovation system. Prominent contributions in this field are found to be from *Edquist, C; Carlsson, B; Jacobsson, S; Bergek, A;* and *Geels, F W.* The fourth (C4) and fifth (C5) clusters deal with technical change and sectoral systems of innovation, and the triple helix model respectively. Leading contributions in the field of SSI and TC are from *Nelson, R R; Malerba, F; Dosi, G; Mowery, D;* and *Pavitt, K* while studies on the triple helix model had contributions from *Nelson, R R; Etzkowitz, H; Leydesdorff, L; Cohen, WM;* and *Fritsch, M.* In C6, 69 publications cover

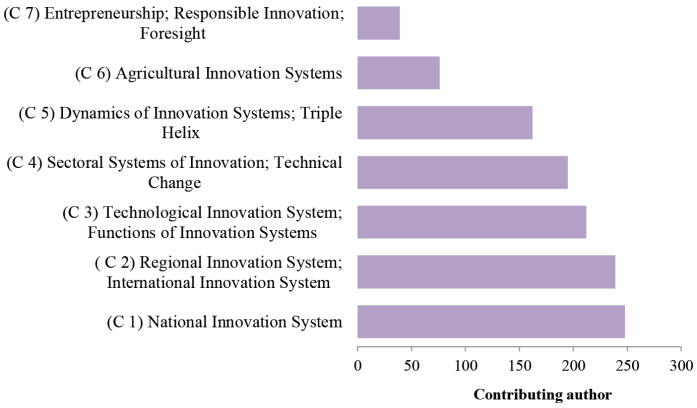

Figure 5: Clusters of relevant research themes related to systems of innovation by co-citation for 1990 to 2017.

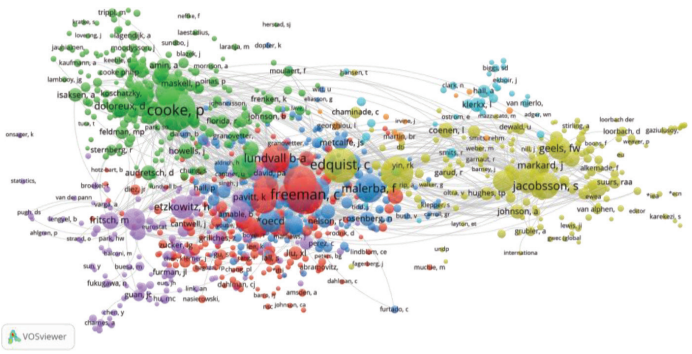

Figure 6: Map of author co-citation network for all three periods. Publications are labelled with the name of the first author and the colours are used to indicate clusters.

agricultural innovation systems with contributions from *World Bank; North, DC; Klerkx, L; Hall, A;* and *Metcalfe, S*. The remaining cluster (C7) consisted of about 15 publications that are related to open innovation, responsible innovation and foresight studies of innovation systems and had publications from *Lundvall, B A; OECD; Smith, K; Kline, S J;* and *Sharif, N.*

Interestingly enough, the contributing authors by co-citation reveals the evolution and relationship of authors and their work through clustering. This relationship and structure of co-cited authors for all periods in shown in Figure 6. The size of the nodes has particular importance as it indicates strong linkages and citation of an author who is likely a prominent researcher.[35] Names such as *Chris Freeman, Charles Edquist, Philip Cooke, Staffan Jacobsson, Bengt*-Åke *Lundvall, Bo Carlsson, Richard Nelson, and Franco Malerba* hold significant positions as they are connected by different authors in the map. A more in-depth analysis into the author names through the different time periods is given in Table 2.

Evolution Trend Map

Journal Co-citation

For extracting the journal co-citation information, we identify the original source where the cited publications appeared. In examining patterns of journal rankings by citation frequency during the three periods, it can reveal the key journals that form the evolution of the intellectual knowledge base for research on innovation systems.[16] As shown in Table 3, the top 10 highly cited source journals are led by "Research Policy", "Technological Forecasting and Social Change", "Energy Policy", "Regional Studies", "Industrial and Corporate Change", "Oxford University Press", "Pinter Publishers", "Technology Analysis and Strategic Management", "Technovation" and "European Planning Studies". The period 2000–2017 contains many recurring journals that suggest continuing research focus on important themes in innovation systems over several years.

Table 2: Ranking of 10 most productive authors by co-citation for 1990 to 2017.

1990 -2000		2000 - 2010		2000 - 2010	
Contributing authors	Citations	Contributing authors	Citations	Contributing authors	Citations
Nelson, R R	61	Cooke, P	268	Cooke, P	306
Freeman, C	52	Lundvall, B A	261	Freeman, C	232
OECD	35	Freeman, C	217	Edquist, C	225
Lundvall, B A	34	Nelson, R R	212	Nelson, R R	225
Mowery, D	28	Edquist, C	170	OECD	217
Dosi, G	24	OECD	168	Jacobsson, S	169
Cooke, P	24	Carlsson, B	118	Lundvall, B A	165
Rosenberg, N	24	Malerba, F	101	Bergek, A	164
Edquist, C	23	Asheim, B	78	Malerba, F	156
Pavitt, K	21	Porter, M E	74	Carlsson, B	128

Table 3: Top 10 most co-cited source journals for 1990 to 2017.

1990 - 2000			2000 - 2010			2010 - 2017		
Source of Publications	Category	Citations	Source of Publications	Category	Citations	Source of Publications	Category	Citations
Research Policy	Article	125	Research Policy	Article	882	Research Policy	Article	2039
Cambridge Journal of Economics	Article	61	Routledge	Book	262	Technological Forecasting and Social Change	Article	517
Oxford University Press	Book	61	Industrial and Corporate Change	Article	184	Energy Policy	Article	441
Routledge	Book	48	Regional Studies	Article	175	Regional Studies	Article	356
Pinter Publishers	Book	42	Oxford University Press	Book	165	European Planning Studies	Article	265
Harvard Business Review	Article	18	Pinter Publishers	Book	163	Technovation	Article	264
Journal of Economic Literature	Article	18	Technology Analysis and Strategic Management	Article	106	Technology Analysis and Strategic Management	Article	242
The American Economic Review	Article	18	Energy Policy	Article	105	Industrial and Corporate Change	Article	205
European Planning Studies	Article	17	Cambridge Journal of Economics	Article	102	Journal of Cleaner Production	Article	188
Regional Studies	Article	16	European Planning Studies	Article	85	Industry and Innovation	Article	169

Keyword Co-occurrence

From the clustering analysis in Section 4.1, we attempt to extract the high-frequency terms related to innovation systems, thus helping to explain the key features of the different innovation clusters. In doing so, we created an excel file of the bibliographic information of the refined dataset. The publication titles were query and grouped into the 7 clusters identified in the previous subsection. We then extracted the frequent terms from the abstract of publications corresponding to the cluster group. This analysis is shown in Table 4 along with the relevance score of each term used to describe the innovation approaches. For example, the NIS is specific at the country level and focuses on university as the driver of innovation potential along with firms and government. At the regional level, innovative activities operate within country borders but emphasis is on stimulating different regions through the interaction of universities, firms and policy infrastructure. Notably, in this cluster that also represents international innovation system, not many terms were extrapolated to define the system. The sparse research in the sub-cluster is related to emerging research (from the late 2000s onwards) on the globalisation of innovation and international actors in the innovation process. Nevertheless, the textual analysis was able to identified emerging innovation frameworks not earlier mentioned in previous scientometric studies on innovation systems. These include agricultural innovation system, open innovation system, responsible innovation and

Table 4: Salient features of the different innovation systems approaches based on textual analysis.

Cluster Name	Doc.	High-Frequency Terms (Relevance)	Top Source Journals
(C 1) NIS	180	University (3.82), Firm (2.45), Government (2.15), Innovation (0.98), Country (0.93), Industry (0.84), Science (0.76), Economy (0.68), Technology (0.67), Impact (0.33)	RES POLICY (28), TECHNOL FORECAST SOC (12), INT J TECHNOL MANAGE (6), SCI PUBL POLICY (5), EUR PLAN STUD (5)
(C 2) RIS; ISI	189	Country (1.52), Region (1.25), Industry (1.17), University (1.11), Innovation (1.11), Firm (1.01), Knowledge (0.86), Policy (0.79), Development (0.66), Interaction (0.65)	EUR PLAN STUD (39), REG STUD (20), RES POLICY (11), TECHNOL FORECAST SOC (9), ENVIRON PLANN C (6)
(C 3) TIS; Functions of IS	130	Innovation (1.47), Network (1.43), Technology (1.25), Diffusion (1.22), Interaction (1.20), Development (1.01), Country (0.83), Process (0.82), Function (0.81), Actor (0.80)	TECHNOL FORECAST SOC (18), TECHNOL ANAL STRATEG (14), RES POLICY (13), ENERG POLICY (13), ENVIRON INNOV SOC TR (9)
(C 4) SSI; TC	58	Intermediary (5.85), Role (2.93), Sector (1.68), Firm (1.42), Research (0.85), Institution (0.81), Policy (0.77), Development (0.67), Government (0.56), Actor (0.49)	RES POLICY (5), TECHNOL FORECAST SOC (5), ASIAN J TECHNOL INNO (5), IND INNOV (4), ENERG POLICY (4)
(C 5) Dynamics of IS; Triple Helix	57	Design (6.34), System innovation (6.18), Sustainability (5.28), University (1.05), Research (0.81), Organisation (0.73), Dynamic (0.66), Actor (0.55), Knowledge (0.48), Technology (0.34)	INT J TECHNOL MANAGE (5), TECHNOL FORECAST SOC (5), TECHNOL ANAL STRATEG (5), RES POLICY (4), J CLEAN PROD (3)
(C 6) AIS	37	Adoption (4.17), Network (2.33), Farmer (2.04), Intervention (1.76), Knowledge (1.64), Technology (1.20), Innovation process (1.18), Actor (1.15), Agricultural innovation (0.81), Country (0.61)	AGR SYST (7), AGR HUM VALUES (3), RES POLICY (2), IDS BULL-I DEV STUD (2), OUTLOOK AGR (2)
(C 7) Entrepreneurship; OI, RI; Foresight	41	Foresight (5.29), University (3.89), Practice (2.05), Sustainability (1.15), Open innovation (1.00), Entrepreneur (0.96), Government (0.93), Firm (0.83), Model (0.75), Research (0.66)	TECHNOL FORECAST SOC (7), RES POLICY (3), ENVIRON PLANN C (3), MINERVA (2), RES EVALUAT (2)

Note: Relevance of high-frequency terms are shown in brackets. The relevance score is determined based on the comparison of the overall distribution of co-occurrences words with each frequent term. See[104] for the technique on selecting the most relevant terms.

innovation foresight. Clusters 5-7 and sub-clusters 2-3 in Table 4 represent a break from the core terms of innovation systems particularly system boundaries and scales. Emerging frameworks recognised that innovation is collaborative and with contemporary globalisation, domestic actors are transformed into international actors thus creating bridging scales across various innovation systems and stakeholders.

Additionally, we created a co-word occurrence map based on author keywords as well as KeyWords Plus appearing at least one (1) time in the sample database for the different periods. This helps to highlight information about the core contents of the publications and thus allows for monitoring past and present areas of research. We standardised similar words by eliminating redundancies, for example, absorptive capacity and absorptive-capacity were listed under one heading; resulting in a total of 2019 (out of 2108) keywords. As keywords help in the discovery of new topics and evolution process of a research domain,[101] we used a keyword co-occurrence network map to link and highlight the change in keywords frequency during the three periods. Figures 7-9 illustrates the clusters of keywords relating to the field of innovation systems. Each node represents an author keyword (either their own or KeyWords Plus) with the size of the node being proportional to the number of co-occurrence with the sample database. In 1990-2000, the keyword with the highest frequency of occurrence was "technology," which appeared 9 times, followed by "policy" that appeared 8 times. In 2000-2010, the themes continue to be the dominant research topics in the field of innovation studies with the word "knowledge" occupying second spot, while "network" and "dynamics" began to appear. From 2010-2017, widespread attention was attracted to emerging topics like "dynamics", "framework" and "performance." This development illustrates that academic communities began to focus on the functions and performance of innovation systems, suggesting that the SI approach is moving away from theories and process of innovation and towards more heuristics tools.

CONCLUSION

Studies on innovation systems showed a noticeable increased during the search period from 1990-2017, with more than 60 per cent of studies being published in the last seven years.

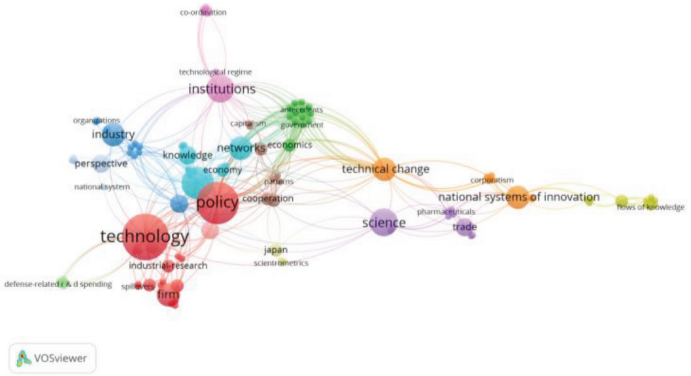

Figure 7: Keywords co-occurrence network map for 1990 to 2000.

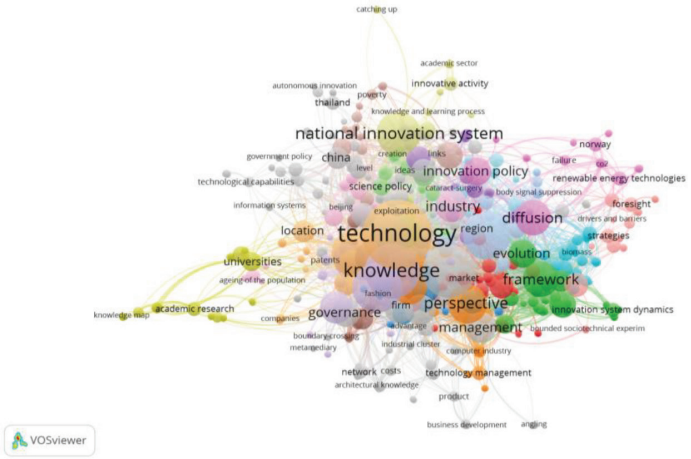

Figure 8: Keywords co-occurrence network map for 2000 to 2010.

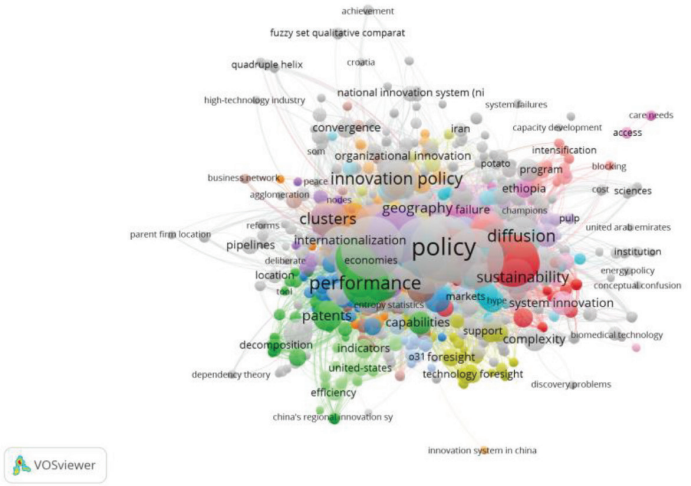

Figure 9: Keywords co-occurrence network map for 2010 to 2017.

The paper examines the theoretical origins and structure in the field of innovation systems as this represents an important domain of STS research for science policy researchers and other newcomers. Using a rigorous systematic literature process of highly cited articles, we uncovered seven clusters (national systems of innovation; regional innovation system and international innovation systems; technological innovation systems and systems function; technical change and sectoral systems of innovation; triple helix model; agricultural innovation system; and responsible innovation and foresight) of innovation systems approaches and theories in mainstream innovation studies. Most notably, the study identified emerging innovation frameworks that have been missing from earlier studies on the evolution and structure of the field, particularly, open innovation, responsible innovation and innovation foresight. This set the grounds for explaining the different SI approaches with particular reference to the unit of analysis and historical origins.

In terms of the structure and evolution of IS research, we utilised scientometric approaches such as co-citation analysis and keywords co-occurrence network map respectively. We firstly map the impactful journals and influential authors in the field of innovation systems as this reflects the relationships of journals and distribution of publications over the search period. The execution of co-citation analysis is commonly used to evaluate a growing body of literature by analysing academic papers to reveal the conceptual structure of the discipline. Secondly, we performed a textual analysis of publication abstracts to identify relevant terms associated with defining the features and components of the different innovation system clusters. We found that emerging frameworks are moving away from theoretical aspects to more heuristic tools that bridge innovation scales and system boundaries with relevant terms focusing on sustainability, actors and knowledge networks. We also combined similar keywords for standardisation purposes and generated a keyword co-occurrence temporal map. The keyword analysis helps to reveal what a topic deals with, without consulting the full text in addition to providing a thematic overview of the research.[103] Not surprising, "policy", "technology", "knowledge", "dynamics" and "networks" were the top five research topics as these represent key components of the SI approach. The findings of the study provide a better understanding of the different innovation systems approaches and research areas scholars are actively pursuing which can be used to influence future studies, partnerships and publications.

ACKNOWLEDGEMENT

The first author (VA) and fourth author (KT) gratefully acknowledge support provided by the Indian Council of Social Science Research (ICSSR), India through the ICSSR-Doctoral Fellowship awarded them at the Jawaharlal Nehru University under the file number [RFD/Short-Term/19-20/GEN/SOC/6] and [RFD/2019-20/GEN/SOC/104] respectively. The authors are grateful to two anonymous reviewers for their excellent suggestions on improving various aspects of our study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Desai PN. India's S&T cooperation with the developing countries. World Journal of Science, Technology and Sustainable Development. 2012;9(1):28-37. doi: 10.1108/20425941211223606.
2. Wagner CS, Brahmakulam I, Jackson B, Wong A, Yoda T. Science and Technology Collaboration. Building capacity in developing countries? RAND Science and Technology. 2001. Contract No.: MR-1357.0-WB.
3. Freeman C. The economics of technical change. Cambridge Journal of Economics. 1994;18(5):463-514. doi: 10.1093/oxfordjournals.cje.a035286.
4. Scholte JA. Globalization: A critical introduction. Macmillan International Higher Education; 2005.
5. Edquist C. Systems of innovation approaches: their emergence and characteristics. Mothe Jdl, editor. UK: Routledge; 1997.
6. Ziemnowicz C, Joseph A. Schumpeter and innovation. New York: Springer New York; 2013;1171-6.
7. Schumpeter JA. The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle. Routledge. 1934/2017.
8. Sledzik K. Schumpeter's view on innovation and entrepreneurship. In:Management Trends in Theory and Practice. 2013; pp 89-95.
9. Nelson RR, Rosenberg N. Technical innovation and national systems. In:National innovation systems: a comparative analysis. Oxford University Press; 1993.
10. Nelson RR. National innovation systems: A retrospective on a study. Industrial and Corporate Change. 1992;1(2):347-74. doi: 10.1093/icc/1.2.347.
11. West MA, Anderson NR. Innovation in top management teams. Journal of Applied Psychology. 1996;81(6):680-93. doi: 10.1037/0021-9010.81.6.680.
12. Hall BH, Rosenberg N. Handbook of the economics of innovation. Elsevier/Elsevier; 2010.
13. Freeman C. Technology policy and economic performance: lessons from Japan. London: Pinter Publishers; 1987.
14. Albornoz M, Estébanez M. What do we mean by networking? Selected Latin American experiences in cooperation. New approaches to science and technology cooperation and capacity building. 1998:75-112.
15. Edquist C. Reflections on the systems of innovation approach. Science and Public Policy. 2004;31(6):485-9. doi: 10.3152/147154304781779741.
16. Liu ZG, Yin YM, Liu WD, Dunford M. Visualizing the intellectual structure and evolution of innovation systems research: a bibliometric analysis. Scientometrics. 2015;103(1):135-58. doi: 10.1007/s11192-014-1517-y.
17. Wei F, Zhang G. Exploring the intellectual structure and evolution of 24 top business journals: a scientometric analysis. The Electronic Library. 2020;38(3):493-511. doi: 10.1108/EL-12-2019-0279.
18. Sharif N. Emergence and development of the National Innovation Systems concept. Research Policy. 2006;35(5):745-66. doi: 10.1016/j.respol.2006.04.001.
19. Van Raan A. The use of bibliometric analysis in research performance assessment and monitoring of interdisciplinary scientific developments. TATuP-Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis. 2003;12(1):20-9. doi: 10.14512/tatup.12.1.20.
20. Martin BR. The evolution of science policy and innovation studies. Research Policy. 2012;41(7):1219-39. doi: 10.1016/j.respol.2012.03.012.
21. van Leeuwen TN. The Holy Grail of science policy: Exploring and combining bibliometric tools in search of scientific excellence. Scientometrics. 2003;57(2):257-80. doi: 10.1023/A:1024141819302.
22. Uriona-Maldonado M, Dos Santos RNM, Varvakis G. State of the art on the Systems of Innovation research: a bibliometrics study up to 2009. Scientometrics. 2012;91(3):977-96. doi: 10.1007/s11192-012-0653-5.
23. Souzanchi Kashani ES, Roshani S. Evolution of innovation system literature: intellectual bases and emerging trends. Technological Forecasting and Social Change. 2019;146:68-80. doi: 10.1016/j.techfore.2019.05.010.
24. Greenhalgh T, Robert G, Macfarlane F, Bate P, Kyriakidou O. Diffusion of innovations in service organizations: systematic review and recommendations. The Milbank Quarterly. 2004;82(4):581-629. doi: 10.1111/j.0887-378X.2004.00325.x, PMID 15595944.
25. Becheikh N, Landry R, Amara N. Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993-2003. Technovation. 2006;26(5-6):644-64. doi: 10.1016/j.technovation.2005.06.016.
26. Mann K, Gordon J, MacLeod A. Reflection and reflective practice in health professions education: a systematic review. Advances in Health Sciences Education Theory Practice. 2009;14(4):595-621. doi: 10.1007/s10459-007-9090-2, PMID 18034364.
27. Pittaway L, Robertson M, Munir K, Denyer D, Neely A. Networking and innovation: A systematic review of the evidence. International Journal of Management Reviews. 2004;5-6(3-4):137-68. doi: 10.1111/j.1460-8545.2004.00101.x.
28. Crossan MM, Apaydin M. A multi-dimensional framework of organizational innovation: A systematic review of the literature. Journal of Management Studies. 2010;47(6):1154-91. doi: 10.1111/j.1467-6486.2009.00880.x.
29. Katz JS, Martin BR. What is research collaboration? Research Policy. 1997;26(1):1-18. doi: 10.1016/S0048-7333(96)00917-1.
30. Kim KW. Measuring international research collaboration of peripheral countries: taking the context into consideration. Scientometrics. 2006;66(2):231-40. doi: 10.1007/s11192-006-0017-0.
31. Glänzel W, Schubert A, Czerwon HJ. A bibliometric analysis of international scientific cooperation of the European Union (1985-1995). Scientometrics. 1999;45(2):185-202. doi: 10.1007/BF02458432.
32. Zupic I, Cater T. Bibliometric methods in management and organization. Organizational Research Methods. 2015;18(3):429-72. doi: 10.1177/1094428114562629.
33. Gao P, Zhao J, Li X. Visualizing the intellectual structure in innovation system studies: A Journal Co-citation Analysis. Economic Management Journal. 2019;8(2):144-150.
34. Braam RR, Moed HF, Van Raan AFJ. Mapping of science by combined co-citation and word analysis. I. Structural aspects. Journal of the American Society for Information Science. 1991;42(4):233-51. doi: 10.1002/(SICI)1097-4571(199105)42:4<233::AID-ASI1>3.0.CO;2-I.
35. Chen C. Visualising semantic spaces and author co-citation networks in digital libraries. Information Processing and Management. 1999;35(3):401-20. doi: 10.1016/S0306-4573(98)00068-5.
36. White HD, Griffith BC. Author cocitation: A literature measure of intellectual structure. Journal of the American Society for information Science. 1981;32(3):163-71. doi: 10.1002/asi.4630320302.
37. Trujillo CM, Long TM. Document co-citation analysis to enhance transdisciplinary research. Science Advances. 2018;4(1):e1701130. doi: 10.1126/sciadv.1701130, PMID 29308433.
38. Casillas J, Acedo F. Evolution of the intellectual structure of family business literature: A bibliometric study of FBR. Fam Bus Rev. 2007;20(2):141-62. doi: 10.1111/j.1741-6248.2007.00092.x.
39. Van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523-38. doi: 10.1007/s11192-009-0146-3, PMID 20585380.
40. Asheim BT, Coenen L. Knowledge bases and regional innovation systems: comparing Nordic clusters. Research Policy. 2005;34(8):1173-90. doi: 10.1016/j.respol.2005.03.013.
41. Asheim BT, Smith HL, Oughton C. Regional innovation systems: theory, empirics and policy. Regional Studies. 2011;45(7):875-91. doi: 10.1080/00343404.2011.596701.
42. Asheim BT, Isaksen A. Location, agglomeration and innovation: towards regional innovation systems in Norway? European Planning Studies. 1997;5(3):299-330. doi: 10.1080/09654319708720402.
43. Carlsson B, Jacobsson S, Holmén M, Rickne A. Innovation systems: analytical and methodological issues. Research Policy. 2002;31(2):233-45. doi: 10.1016/S0048-7333(01)00138-X.
44. Schumpeter JA. Business cycles. New York: McGraw-Hill; 1939.
45. Freeman C. The National System of Innovation in historical perspective. Cambridge Journal of Economics . 1995;19(1):5-24.
46. Lundvall BÅ. National innovation systems: Analytical concept and development tool. Industry and Innovation. 2007;14(1):95-119.
47. Johnson B, Lundvall BA. The learning economy. Journal of Industry Studies. 1994;1(2):23-42. doi: 10.1080/13662719400000002.
48. Lundvall BA. Why study national systems and national styles of innovation?. Technology Analysis and Strategic Management. 1998;10(4):403-22. doi: 10.1080/09537329808524324.
49. Lundvall BA, Johnson B, Andersen ES, Dalum B. National systems of production, innovation and competence building. Research Policy. 2002;31(2):213-31. doi: 10.1016/S0048-7333(01)00137-8.
50. Cooke P, Uranga MG, Etxebarria G. Regional systems of innovation: An evolutionary perspective. Environ Plan A. 1998;30(9):1563-84. doi: 10.1068/a301563.
51. Cooke P. Regional innovation systems: competitive regulation in the new Europe. Geoforum. 1992;23(3):365-82. doi: 10.1016/0016-7185(92)90048-9.
52. Cooke P, Gomez Uranga MG, Etxebarria G. Regional innovation systems: institutional and organisational dimensions. Research Policy. 1997;26(4-5):475-91. doi: 10.1016/S0048-7333(97)00025-5.
53. Cooke P. The role of research in regional innovation systems: new models meeting knowledge economy demands. International Journal of Technology Management. 2004;28(3/4/5/6):507-33. doi: 10.1504/IJTM.2004.005307.
54. Doloreux D, Parto S. Regional innovation systems: current discourse and unresolved issues. Technology in Society. 2005;27(2):133-53. doi: 10.1016/j.techsoc.2005.01.002.
55. Doloreux D. What we should know about regional systems of innovation. Technology in Society. 2002;24(3):243-63. doi: 10.1016/S0160-791X(02)00007-6.
56. Malerba F, editor. Sectoral systems of innovation and production. Research Policy. 2002;31(2):247-64. doi: 10.1016/S0048-7333(01)00139-1.
57. Pavitt K. Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy. 1984;13(6):343-73. doi: 10.1016/0048-7333(84)90018-0.

58. Malerba F. Sectoral systems of innovation: concepts, issues and analyses of six major sectors in Europe. Cambridge University Press; 2004.
59. Carlsson B, Stankiewicz R. On the nature, function and composition of technological systems. Journal of Evolutionary Economics. 1991;1(2):93-118. doi: 10.1007/BF01224915.
60. Carlsson B. Internationalization of innovation systems: A survey of the literature. Research Policy. 2006;35(1):56-67. doi: 10.1016/j.respol.2005.08.003.
61. Desai PN. Globalization of innovations: Changing nature of India's science and technology cooperation policy. International Journal of Institutions and Economics. 2009;1(1):53-78.
62. Desai PN. Export innovation system: changing structure of India's technology-intensive exports. Institutions and Economies . 2013;5(3):21-52.
63. Asheim BT, Isaksen A. Regional innovation systems: the integration of local'sticky'and global 'ubiquitous' knowledge. The Journal of Technology Transfer. 2002;27(1):77-86. doi: 10.1023/A:1013100704794.
64. Genus A, Coles A-M. A critique of Geels' multi-level perspective of technological transition. Transforming the Energy System. 2007.
65. Weber KM, Rohracher H. Legitimizing research, technology and innovation policies for transformative change. Research Policy. 2012;41(6):1037-47. doi: 10.1016/j.respol.2011.10.015.
66. Chesbrough HW. Open innovation: A new paradigm for understanding industrial innovation. In:Open Innovation: Researching a New Paradigm. Oxford University Press; 2006.
67. Boschma R. Proximity and innovation: a critical assessment. Regional Studies. 2005;39(1):61-74. doi: 10.1080/0034340052000320887.
68. Schomberg RV. A vision of Responsible Research and Innovation. In:Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society. London: John Wiley; 2013;51-74.
69. Owen R, Macnaghten P, Stilgoe J. Responsible research and innovation: from science in society to science for society, with society. Science and Public Policy. 2012;39(6):751-60. doi: 10.1093/scipol/scs093.
70. Singh R, Kroesen O, editors. Understanding Responsible innovation developing countries perspectives. 2nd Conference on Responsible Innovation, The Hague. 2012.
71. Setiawan AD, Singh R, Romijn HA. Responsible innovation: moving towards a culturally sensitive approach. Studies in Asian Social Science. 2019;6(2):46-65. doi: 10.5430/sass.v6n2p46.
72. Chamuah A, Singh R. Securing sustainability in Indian agriculture through civilian UAV: a responsible innovation perspective. SN Applied Sciences. 2020;2(1):1-10.
73. Mishra S, Singh R. Responsible innovation: A new approach to address the theoretical gaps for innovating in emerging E-mobility sector. SpringerBriefs in Research and Innovation Governance. 2018:93-9. doi: 10.1007/978-3-319-73105-6_12.
74. OECD. National innovation systems. Organization for Economic Co-operation and Development; 1997.
75. Spencer JW. Firms' knowledge-sharing strategies in the global innovation system: empirical evidence from the flat panel display industry. Strategic Management Journal. 2003;24(3):217-33. doi: 10.1002/smj.290.
76. Cui X, Wu B. Regional innovation system based on industrial clusters. Lecture Notes in Electrical Engineering. 2013:221-8. doi: 10.1007/978-3-642-35398-7_28.
77. Andersson G. Rethinking regional innovation. Systemic Practice and Action Research. 2013;26(1):99-110. doi: 10.1007/s11213-012-9265-5.
78. Bergek A, Jacobsson S, Carlsson B, Lindmark S, Rickne A. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy. 2008;37(3):407-29. doi: 10.1016/j.respol.2007.12.003.
79. Ruiz AZ. Responsible innovation at the firm-level: tracing in car industry. Retrieved from https://upcommons.upc.edu/bitstream/handle/2117/96212/TAZ-R1de1.pdf
80. Diaconu M. Technological innovation: Concept, process, typology and implications in the economy. Theoretical and Applied Economics. 2011;XVIII(10563):127-44.
81. Bauer F, Coenen L, Hansen T, McCormick K, Palgan YV. Technological innovation systems for biorefineries: a review of the literature. Biofuels, bioproducts and biorefining. 2017;11(3):534-48.
82. Breschi S, Malerba F. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. Systems of Innovation: Technologies, Institutions and Organizations. 1997;1:130-56.
83. Singh R. LED technologies, a way to create sustainability in Energy Sectoral System of Innovation of NICs: A case of India. 2010. Retrieved from www.dime-eu.org/files/active/0/Singh_DIME2010_Ettlingen.pdf
84. Savory C, Fortune J. From translational research to open technology innovation systems. Journal of Health Organization and Management. 2015;29(2):200-20. doi: 10.1108/JHOM-01-2013-0021, PMID 25800333.
85. Andersen PD, Andersen AD, Jensen PA, Rasmussen B. Sectoral innovation system foresight in practice: Nordic facilities management foresight. Futures. 2014;61:33-44. doi: 10.1016/j.futures.2014.04.012.
86. Liu Z, Jongsma MA, Huang C, Dons JH, Omta SO. The sectoral innovation system of the Dutch vegetable breeding industry. NJAS-Wageningen Journal of Life Sciences. 2015;74:27-39.
87. Geels FW. Multi-level perspective on system innovation: relevance for industrial transformation. In:Understanding industrial transformation. Springer; 2006; pp. 163-186.
88. John E. Technological innovation. Butterworth: Heinemann; 2006.
89. Popa IL, Preda G, Boldea M. A theoretical approach of the concept of innovation. In:Managerial Challenges of the Contemporary Society proceedings. 2010.
90. Bessant J. Innovation in the twenty-first century. In:Responsible innovation: Managing the responsible emergence of science and innovation in society. Chichester, UK: John Wiley and Sons; 2013;1-25.
91. Huff AS, Möslein KM, Reichwald R. Leading open innovation. MIT Press; 2013.
92. Nosyk OM. Open innovation systems: main characteristics and trends of internationalization. The Bull Dnipropetrovsk Univ S Manag Innov. 2016;24(6):103-.
93. Desai PN. Science, technology and international cooperation. New Delhi: Har-Anand Publications. 1997.
94. Kaiser R, Prange H. The Reconfiguration of National Innovation Systems in OECD Countries. In:SEGERA International Conference on Innovation in Europe: Dynamics, Institutions, and Values; 2003;8(9).
95. Fromhold-Eisebith M. Bridging scales in innovation policies: how to link regional, national and international innovation systems. Eur Plan Stud. 2007;15(2):217-33. doi: 10.1080/09654310601078754.
96. Kumar A, Desai PN. Mapping the Indian nanotechnology innovation system. World J Sci Technol Sustain Dev. 2014.
97. Chesnais F. National systems of innovation, foreign direct investment and the operations of Multinational Enterprises. In: Lundvall BA, editor. National systems of innovation: toward a theory of innovation and interactive learning. Anthem Press. 2010;259-92.
98. Desai PN. Africa's innovation dilemma: can South–South S&T collaboration transform innovation process? In: Emerie A, Mandefro F, Dessalegn A, editors. 12th Globelics International Conference on Partnerships for Innovation-Based Development. Addis Ababa: University Printing Press; 2015;385-406.
99. Owen R, Stilgoe J, Macnaghten P, Gorman M, Fisher E, Dave G. A framework for Responsible Innovation. Research Policy. 2013:27-50.
100. Setiawan AD, Singh R, Romijin H, editors. Embedding accountability throughout the innovation process in the green economy: the need for an innovative approach. The 2nd International Conference on Sustainable Innovation; Yogyarta, Indonesia. 2014.
101. Gu D, Li T, Wang X, Yang X, Yu Z. Visualizing the intellectual structure and evolution of electronic health and telemedicine research. International Journal of Medical Informatics. 2019;130:103947. doi: 10.1016/j.ijmedinf.2019.08.007.
102. Van Eck NJ, Waltman L. Text mining and visualization using VOSviewer. arXiv preprint arXiv:11092058. 2011.
103. Romo-Fernández LM, Guerrero-Bote VP, Moya-Anegón F. Co-word based thematic analysis of renewable energy (1990-2010). Scientometrics. 2013;97(3):743-65. doi: 10.1007/s11192-013-1009-5.