Journal of Scientometric Research, 2023; 12(3):522-533.
https://www.jscires.org

Research Article

Mapping the Evolution of Sustainability Transitions Research: A Bibliometric Analysis

Sunny Dhiman[1], Rajbeer Singh[1,*], Vairaj Arjune[1], Raghvendra Singh Yadav[1], Mritunjay Singh Yadav[2], Albert Bansala[2]

[1]Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, New Delhi, INDIA.
[2]School of Computational and Integrative Sciences, Jawaharlal Nehru University, New Delhi, INDIA.

ABSTRACT
The Sustainability Transitions (ST) research has emerged as a promising approach to addressing climate change-led uncertainty. The ST research primarily emerged and concentrated in global north countries, but the global south has witnessed significant development. A gap in the bibliometric analysis of evolution ST research and its geography is addressed. The questions are, how has ST research evolved over the years (1994 to 2021), and how has ST research evolution reflected the dynamics of geographies? The ST literature is examined from the Scopus citation database (from 1994 to 2021). Results suggest that the ST research evolved in the Lag phase (1994 to 2002) and growth phase (2002 to 2021) as an S curve in Science Policy studies. The western geography of Europe is the origin and significant contributor to the location of authors, collaboration, and receiving the highest citation of publications. China, Brazil, India and South Africa are major non-OECD leading countries in ST research. The Dutch ST research has witnessed the highest impact. Most of the journals on ST research are published in the UK, out top 20 journals in the world. The research support and more numbers of researchers have led to the dominance of European countries in ST research. Finally, the study suggests that global sustainability issues necessitate an inclusive and diverse approach to ST research, incorporating knowledge from the global south.

Keywords: Evolution, Scopus, Bibliometrics, VOSviewer, Sustainability transitions, Socio-technical transitions.

Correspondence:
Rajbeer Singh
Centre for Studies in Science Policy, School of Social Sciences Building-I, Jawaharlal Nehru University, New Delhi-110067, INDIA.
Email: rajbasera16@gmail.com

Received: 01-06-2022;
Revised: 22-04-2023;
Accepted: 11-07-2023.

INTRODUCTION

Sustainability Transition (ST) research enables policymakers, academics, and practitioners to address climate change and socio-economic inequality by adopting dynamic technological and scientific options in diverse domains, such as agriculture, transportation, energy, health, construction, water, and communication. However, the current methods of societal function fulfilment are no longer viable. ST research is a promising framework for addressing sustainability-related challenges and anomalies in Western Europe.[1] The ST literature reflects on how socio-technical systems fulfil societal functions. Changes in institutions, culture, agents, actors, networks, technology, and knowledge denote the transition from one socio-technical state to another.[1,2]

Before the recent development in the framework of Sustainability transitions, it has four sub-framework – Multilevel Perspective (MLP), Strategic Niche Management (SNM), Transitions Management (TM) and Technology Innovation System (TIS).[3] The recent ST framework incorporates a systemic approach component comparable to the Innovation Systems approach, whereas ST treats actors, institutions, and technology as its core constituents. MLP includes three levels; first, the socio-technical regime at the middle level is a mainstream and dominant method of fulfilling societal functions that persists over time. The regime is a set of rules and procedures that govern how things are done. It drives stability, path dependency and lock-in, which prohibits the rise of radical innovations. The second level, the socio-technical landscape, is an exogenous environment or context beyond the reach of regime actors. Usually, the landscape creates pressure on the existing and dominant regime for change.

In addition, the transformation of regimes is contingent on the emergence of niches, which are novel and innovative ideas that require protection to thrive or coexist inside the current regime. The impetus for socio-technical transitions emerges from external forces within the socio-technical landscape, including issues the current regime fails to address, resulting in niche-based solutions. The path dependency of the regime inhibits radical innovations; landscape pressure pushes the regime to open up for innovation

DOI: 10.5530/jscires.12.3.050

developed in niches.[4] Strategic Niche Management (SNM) is a process that facilitates the emergence of strategic solutions or regime alternatives via the niche. In addition to the Multi-Level Perspective, SNM fosters and guides radical innovation within its niche. Under the SNM framework, it is critical to protect niche actors' learning, networking, and expectations in order to scale radical innovation.[5,6]

Further, Transitions Management emphasises navigating 'from the above' governance perspective.[4] Lastly, the Technological Innovation System (TIS) conceptualises transformation from the perspective of innovation studies and industrial economics and weighs more on knowledge of technological systems and entrepreneurs.[7,8]

Despite the rapidly expanding Sustainability Transitions (ST) literature, the vast majority of ST research has concentrated on developed or global north countries.[9,10] To understand the success or failure of transitions, however, it is necessary to explore political questions such as transitions by whom, for whom, and the what will be nature of transitions; thus, the question requires an in-depth analysis of Sustainability Transitions research.[11] Given the historical cultural and structural differences between the global south and global north nations, the global south is anticipated to undergo sustainable transitions differently than their northern counterparts.[12]

The concept of developed/global north and developing/global south is both theoretically and politically contested as a result of the contested meanings of "development" and "progress," as well as the lack of acknowledgement of the causes of "underdevelopment".[13] Consequently, this paper refers to OECD nations as so-called "developed" or "global north" nations and non-OECD nations as so-called "developing" or "global south" nations. Other studies analysed publication and collaboration patterns across disciplines using a similar classification scheme. Numerous previous studies have addressed the question of the geography of transitions towards sustainability. Wieczorek[10] provided a systematic review of 115 articles published on ST research in developing countries, but she placed greater emphasis on expectation and scaling. Ramos-Mejía *et al.*[9] uncovered the patterns of poverty alleviation in developing countries along with sustainability transitions. A bibliometrics study by[14] uses search query keywords 'transitions' and 'transformations' to compile the bibliometric data of 835 research articles. It infers that, until 2013, institutions and researchers from the Netherlands are predominately the leading ST research.

Similarly, Savaget *et al.*[15] conducted a bibliometric survey to conceptualise the linkages between sustainability and socio-technical systems change; however, the study focuses on 182 articles. Kern *et al.*[3] conducted a bibliometric analysis to comprehend the connections between policy mix and sustainability transitions research. However, bibliometric analyses of the distribution of literature on sustainability transitions in the context of the global north and global south are uncommon. This study addresses this deficiency by employing scientometric indicators and constructing a global view of ST research's geographical distribution.

The paper has addressed essential research questions, such as how ST research has evolved over different geographies and how ST research has reflected the dynamics of geographies.

The paper is divided into four sections. Section 2 discusses the research methodology used to answer the research questions, while Section 3 contains the results and discussion. Finally, section four is the conclusion.

METHODOLOGY

A quantitative approach, Bibliometrics, is deployed to study the patterns of publications in the area of the studies. It enables us to draw insights into the collaboration patterns in the intellectual landscape among sources, authors, institutions and countries.[16] This helps in understanding the performance of the country and how it performs in the intellectual landscape and publications. The term 'bibliometrics' first appeared in 1969; then, 'scientometrics' appeared as another synonym for bibliometrics. The bibliometrics methods have been applied in science policy as an important research methodology.[17] The bibliometric methods are systematically applied to explore the evolution of ST literature over different geographies and how collaboration has reflected the dynamics of geographies in the global south.

The bibliometric study opts for the parameters proposed[18] as follows;

- Research design,
- Compilation of bibliometric data,
- Analysis, Visualisation,
- Interpretation.

Bibliometric analysis tools

The Bibliometrics package of R from the University of Federico II, Italy, and Luigi Vanvitelli, Italy, is used. The R package Biblioshiny has different choices for analysing a research area's intellectual, conceptual, and social structure as tools.[19] With the help of the tools, co-citation analysis, co-word analysis and collaboration between countries and countries are drawn. Biblioshiny enables a coding-free platform for importing, analysing and plotting bibliometric data to bring out the analysis of the social, conceptual and intellectual structure of the given scientific field. Furthermore, the VOSviewer is used to develop vast network maps. Lastly, Microsoft Excel was applied to pre-process and correct the information, including authors, research journals, and countries.

Database selection

The information on publications of papers or articles on sustainability transitions is extracted through the Scopus database, published by Elsevier. Scopus is considered one of the largest sources of peer-reviewed scientific document information, with broad coverage in social science. It includes 75 million indexed items. Therefore, several studies have selected Scopus over other databases, such as Web of Science and Google Scholar.[20]

Search query

The search query is prepared to retrieve information from the Scopus database. The critical research by Markard,[21] Geels[22] and Wieczorek[10] is taken as a key reference. These researchers have explained the four major sub-fields of sustainability transitions. These are Multilevel Perspective, Strategic Niche Management, Transition Management, and Technological innovation system and take keywords. Socio-technical transitions, socio-technical regime and niche regime interaction, are also included in the search query after studying keywords and abstracts of leading research documents for 2019 and 2020.

The search query, as shown in Figure 1 was run in the advanced search interface of Scopus to extract the bibliographic data. The field type 'Article Title, Abstract, Keywords' were selected, and Boolean operators 'And' and 'OR', were used with keywords along with quote marks " to identify loose phrases, which instructs Scopus that words in " must come together and must be allowed for the wild card and lemmatisation. Further, the curly brackets '{}' were also employed to extract the exact phrases. The search was limited to documents published in English.

Data extraction

The initial search on Scopus found that many published documents generically mentioned search query keywords. Consequently, the study applied PRISMA guidelines proposed by Moher.[23] PRISMA approach offers four steps to clean, identify and retrieve the data for bibliometric analysis, see Figure 1. The study was executed on 25 January 2022. The documents are written in the English language only—the search query extracted information from 4034 documents.

"TITLE-ABS-KEY (("socio-technical transition" OR {multilevel perspective} OR "multilevel perspectiv" OR {sustainability transitions} OR {sustainability transition} OR "socio-technical transformation*" OR "sustainability transformation" OR "niche-regime interactio*" OR "socio-technical regim*" OR {strategic niche management} OR "socio-technical transitio*" OR {system innovatio*} OR "transition managemen*" OR "socio-technical transitio*" OR {technological innovation system})) AND (EXCLUDE (PUBYEAR,1976) OR EXCLUDE (PUBYEAR,1980) OR EXCLUDE (PUBYEAR,1981) OR EXCLUDE (PUBYEAR,1982) OR EXCLUDE (PUBYEAR,1988) OR EXCLUDE (PUBYEAR,1989) OR EXCLUDE (PUBYEAR,1990) OR EXCLUDE (PUBYEAR,1991) OR EXCLUDE (PUBYEAR,1993) OR EXCLUDE (PUBYEAR,1994) OR EXCLUDE (PUBYEAR,1995) OR EXCLUDE (PUBYEAR,1996) OR EXCLUDE (PUBYEAR,1997) OR EXCLUDE (PUBYEAR,1998) OR EXCLUDE (PUBYEAR,1999) OR EXCLUDE (PUBYEAR,2000) OR EXCLUDE (PUBYEAR,2001) OR EXCLUDE (PUBYEAR,2022) OR EXCLUDE (PUBYEAR,2023)) AND (LIMIT-TO (LANGUAGE,"English"))"*

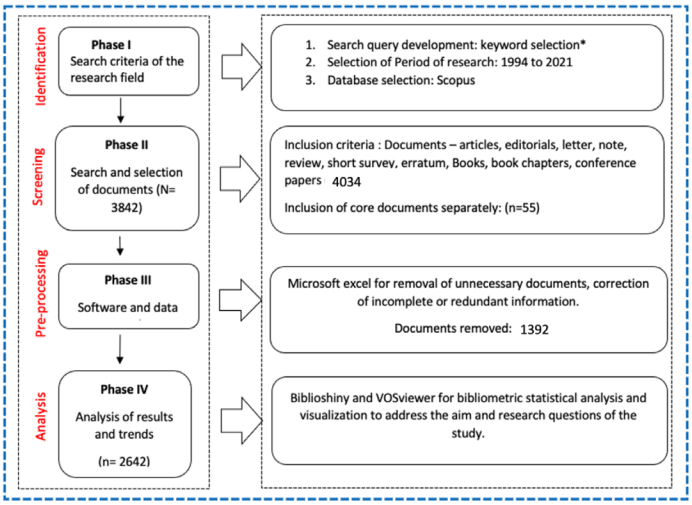

Figure 1: PRISMA diagram presents steps in identifying and selecting data sets for bibliometric study. (Adapted from Moher *et al.*, 2009).

Inclusion and exclusion criteria

Microsoft Excel is used to clean or pre-process the dataset drawn from the Scopus database. The titles and abstracts of the dataset of 4034 documents are evaluated. The irrelevant portion of the dataset is discarded after reading the abstracts of the publications. Some publications have mentioned keywords in a generic manner or other fields of study. Therefore, as a result of the process, a dataset of 2,587 documents on sustainability transitions was obtained. Table 1 has detailed bibliographic information for the refined dataset.

Furthermore, the dataset has omitted some core articles within of sustainability transitions field. In this regard, the paper used the source list of relevant documents prepared by Geels[22] to fill the gap. As a result, fifty-five (55) relevant documents of the sustainability transitions research were included in the dataset. Consequently, a final set of 2,642 documents is compiled. The 'cleansed' dataset is brought into the R environment by the R bibliometrics package. The Biblioshiny library is utilised to obtain the 'clean' data and analysis required to answer the research questions.

Table 1: General descriptive information of ST literature.

Description (DATA)	Results	Description (DATA)	Results
Timespan	1994:2021	DOCUMENT CONTENTS	
Sources (Journals, Books, etc.)	503	Author's Keywords (DE)	6011
Documents	2642	AUTHORS	
Average years from publication	4.75	Authors	5210
Average citations per document	37.97	Author Appearances	8014
Average citations per year per doc	4.256	Authors of single-authored documents	383
References	159378	Authors of multi-authored documents	4827
Citations	100308	AUTHORS COLLABORATION	
DOCUMENT TYPES		Single-authored documents	503
Article	2527	Documents per Author	0.507
Book	3	Authors per Document	1.97
Book chapter	13	Co-Authors per Documents	3.03
Conference paper	16	Collaboration Index	2.26
Editorial	4	Citations	100308
Erratum	4		
Letter	2		
Note	12		
Review	47		
Short survey	14		

Data analysis

A bibliometric approach by Zupic and Cater[18] is further used for the data analysis. A descriptive study is performed in the first step. The Biblioshiny and Excel are further used to draw basic analytics, including dynamics around publication sources, authors and documents. In the later phase, Biblioshiny and VOSviewer are applied to make the analysis and gather information to address research questions.

Further, in section 0, the questions of how ST literature has evolved over the years (1994 to 2021) and how collaboration has reflected the dynamics of geographies are addressed.

RESULTS AND DISCUSSION

Evolution

Sustainability literature

The sustainability transitions witnessed the beginning of publication in 1994. The first paper was authored by Kemp[24] in the year 1994. However, the growth of literature in this field remained embryonic until 2002, when Frank W. Geels produced significant articles that gained 215 citations per year. A dataset of 2,642 documents is identified as a group of literature on Sustainability Transitions, as shown in Table 1 between the years 1994 to 2021.

The data analysis indicates that the number of publications per year has increased dramatically from 2012 onwards. The evolution of ST literature over the past 18 years, beginning with the publication of the first paper in 1994, has been slow and steady. In science policy studies, this is known as the leg phase of the S curve. From 2012 until 2021, a period of expansion is observed. The highest share, i.e. 2527 in the dataset of 2642, is of articles. This accounts for 95.65% of the total dataset. The other sources included are 3 books, 13 book chapters, 16 conference papers, 47 reviews, 14 short surveys, 12 notes, 4 errata, 2 letters and 4 editorials published. The dataset has emerged from 503 sources and was published by 5,210 authors.

The dataset comprises 6,011 authors' keywords. The single-authored documents are 503, 8% of the total authored documents. The ST literature has evolved in collaborations through multiple authorships. The analysis clearly shows that the co-authorship for each document has reached 3.03 in the year 2021. This indicates that the ST literature field has intensified the exchange of knowledge and co-creation of literature among different authors across the institutes and geographies (Table 1).

Perhaps authors with single publications are switching between the various research fields, thus diversifying the ST research domain. The examination of the dataset exhibits a collaboration index of 2.26, indicating ST literature has an exemplary collaborative network. Moreover, 2,217 documents have gained a total citation

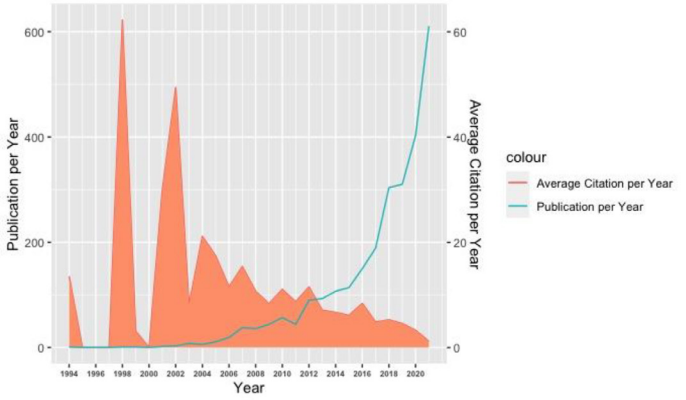

Figure 2: Annual scientific production.

of 100,308, where the average citation per document is 37.97. At the same time, 425 documents have yet to earn citations. Section 0. discusses how scientific publications evolved annually over the years from the year 1994.

Yearly Scientific Publication Evolution

It is worth noting that the growth rate of particular academic fields is proportional to the size of the published document dataset.[17] Figure 2 shows the annual growth dynamics of ST literature. The annual growth is 32.17%. The graph shows that Transitions literature has shown tremendous growth over the years. It can be suggested that 2021 is the most productive in the number of publications publishing 611 documents.

The COVID period and lockdowns across the world have not hampered the speed of publications in the ST field. The graph shows that from 1994 to 2002, one can conclude that this period is a kind of incubation period for ST research. The growth became visible in 2004 with the publication of a paper in a range of 5 to 10. The year 2006 has shown a strong thrust in the number of publications per year. The average yearly citation reflects an interesting pattern by showing that papers published in the year 1998 had got the maximum number of references.

On the other hand, articles published from 2001 to 2006 received the highest average citation per year compared to later years' publications. Overall, the evolution of scientific publications in ST literature indicates a dynamic, expanding field with a promising future. Further, the following section, 0 discusses how the significance of authors in ST research areas has evolved throughout the study.

Significance of authors

The top 10 ranked researchers were identified for their significant contribution to ST literature from 1994 to 2021. These authors have intensively published and shown leadership by earning very high citations for their publications, as shown in Table 2. The *h*-index of authors, along with the number of cited publications and total citations, are directly associated with the productivity of researchers.[25] The data analysis shows that Geels has the highest *h*-index (36), with 51 documents and 15,775 citations. Geels is considered one of the pioneering and leading authors in ST literature.

Table 2: Leading authors of ST.

Sl. No.	Authors	*h*-index	Total Citation	Number of cited documents	Publication started
1	Geels f	36	15775	51	2002
2	Raven r	32	5343	46	2004
3	Hekkert m	26	3779	35	2007
4	Truffer b	23	4615	31	2002
5	Loorbach d	22	4055	29	2005
6	Smith a	21	6501	24	2003
7	Kern f	19	2552	24	2008
8	Markard j	18	3410	26	2008
9	Sovacool bk	18	1946	35	2009
10	Kemp r	17	4904	21	1994

Rob Raven from the Netherlands has achieved second in the *h*-index. He started publications in the year 2004. Further, the leading Dutch authors, such as Raven, Markard, Hekkert, Truffer, and Loorbach, have contributed significantly to the expansion of ST research in the Global North. However, the absence of any authors from the Global South among the top 10 indicates the need for more inclusive and diverse research collaborations. Future research should focus on enabling collaboration and knowledge sharing between scholars from various geographic regions to promote a more inclusive and well-rounded development of ST literature.

Publications

The following sub-section reflects the top 10 most cited documents in the ST research field (Table 3). Of the top 20 cited documents, the articles by F. W. Geels have been the pioneering documents of the ST field.

The top ten most-cited documents in sustainability transitions research have significantly shaped the discipline. These articles, led by the pioneering works of F.W. Geels, have contributed to the establishment of the multilevel perspective, strategic niche management, and transition management as essential conceptual frameworks in ST research. Other influential articles have contributed to a body of socio-technical systems and governance of sustainable socio-technical transitions. These articles' high citation counts reflect their influence on the field and suggest that they will continue to shape ST research for years

Table 3: **The 10 most cited articles. (TC = total citation, TC per year = total citations per year, Norm. TC = normalised total citations).**

Sl.No.	Title, Authors, Year of publication	Source	TC	TC per Year
1	Technological transitions as evolutionary reconfiguration processes: A multilevel perspective and a case study. F. W. Geels, 2002.	Research policy	2759	131.4
2	Typology of sociotechnical transition pathways. F. W. Geels and Schot, 2007.	Research Policy	2153	134.6
3	From sectoral systems of innovation to socio-technical systems, F. W. Geels, 2004.	Research Policy	1719	90.47
4	Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management, Kemp *et al.*, 1998.	Technology Analysis And Strategic Management	1493	59.72
5	Sustainability transitions: An emerging field of research and its prospects, Markard *et al.*, 2012.	Research Policy	1302	118.4
6	Functions of innovation systems: A new approach for analysing technological change, Hekkert *et al.*, 2007.	Technological Forecasting And Social Change	1207	75.44
7	The governance of sustainable socio-technical transitions, Smith *et al.*, 2005.	Research Policy	1135	63.06
8	More evolution than revolution: Transition management in public policy, Rotmans *et al.*, 2001.	Foresight	1114	50.64
9	The multilevel perspective on sustainability transitions: Responses to seven criticisms, F. W. Geels, 2011.	Environmental Innovation And Societal Transitions	1070	89.17
10	Analysing the functional dynamics of technological innovation systems: A scheme of analysis, Bergek *et al.*, 2008.	Research Policy	973	64.87

Table 4: **Top cited sources (TC= total citations; NP= number of cited documents, PY= publication year).**

Sources	Rank (*h*-index)	TC	NP	PY	Country	Impact factor (2020)
Research Policy	1 (51)	21160	91	1999	United Kingdom	8.11
Technological Forecasting and Social Change	2 (50)	8014	146	2005	United States	8.59
Energy Policy	3 (41)	6565	101	2004	United Kingdom	6.142
Environmental Innovation and Societal Transitions	4 (40)	7366	220	2011	Netherlands	9.68
Journal Of Cleaner Production	5 (39)	5846	159	2007	United Kingdom	9.297
Energy Research and Social Science	6 (29)	3322	113	2014	United Kingdom	6.834
Technology Analysis and Strategic Management	7 (29)	7443	55	1998	United Kingdom	2.874
Sustainability (Switzerland)	8 (23)	2195	178	2009	Switzerland	3.251
Global Environmental Change	9 (20)	2181	25	2002	United Kingdom	9.523
Ecology And Society	10 (17)	1590	19	2007	Canada	4.403

to come. This analysis emphasises the significance of seminal works in driving the evolution of scientific publication and the need for continued research in a rapidly expanding field.

Section 0 address how ST research evolution has reflected the dynamics of geographies.

Dynamism of Geographies

Journal and Geographies

The ST literature is published from 503 sources during the study period from 1994 to 2020. The top 10 journals are selected from these sources according to the number of published papers.

Table 4 has listed the ranking of journals (based on *h*-indexed), numbers of citations, publishing countries and their impact factors (in 2021). The 1107 documents are published in these top journals. This represents 41.9% of the total publications. These publications have received 65,682 citations (65.4% of total citations).

6 of the top 10 journals are from the United Kingdom (UK). This shows a clear dominance of the UK over the other countries. The Netherlands, United States, Switzerland and Canada have 1 journal each. No journal from Asia and Africa indicates that Europeans dominate ST literature. Among Europeans, western Europe is a clear leader in this area.

UK-based journal Research Policy has published 91 cited articles (3.4% of the published documents); nevertheless, it received the highest citation (21%). However, an interesting fact emerged about the Journal from the Netherlands. *Environmental Innovation and Societal Transitions* journal has shown the highest impact factor at 9.68 among all the 10 top journals. It means the Netherlands has achieved this impact in 10 years of publication compared to the UK's journal, with an impact factor of 9.523 in 18 years.

The analysis of sources and their geographies reveals that the literature on sustainability transitions is dominated by European journals, with Western Europe in the lead. Research Policy, published in the United Kingdom, has received the most citations, but Environmental Innovation and Social Transitions, published in the Netherlands, has achieved the highest impact factor in a shorter time. Asia and Africa are underrepresented in the ST literature due to the absence of journals from these regions.

Further, section 0 discusses and analyses how geography contributed to ST literature

Corresponding author(s) and Geographic Analysis

The ST research emerged from OECD countries, as seen in Table 5. The relationship between the corresponding author of the publication is identified with their origin or geographical location. The top 5 nations hosting corresponding authors on ST are the United Kingdom (383), the Netherlands (382), Germany (226), Sweden (115) and the USA (140). Comparing OECD and non-OECD country contributions would be an interesting analysis to understand the dynamism across the geographies. A comparative analysis of Tables 5 and 6 suggests that the top 10 OECD nations hosting corresponding authors of ST have produced 66.8% of the total research. Out of 2642 documents, 2208 articles are from 35 OECD nations.[1] Most of the 50 cited articles are from OECD countries. This suggests that non-OECD countries do not contribute significantly compared to OECD geographies.

The non-OECD countries have very high disparity among themselves. China, Brazil, South Africa, India, and Iran, out of 31 non-OECD countries, have published 141 articles out of 204 articles published by non-OECD countries. China (72), Brazil (25), South Africa (17), India (16) and Iran (11) (see Table 6) have contributed in respective order.

The maxim citations are received by 35 OECD nations who have published 92% of documents and received 98% of citations. This demonstrates that OECD countries have the highest influence on ST literature. The non-OECD ST community has a too long way to increase its research impact.

1 It is also to be noted that in the ST dataset retrieved from Scopus, the meta-data of 226 documents are either incomplete or left blank. However, scrutiny of such documents shows that the majority of these documents were published by OECD countries (containing 6161 citations).

Table 5: OECD Country collaboration and productivity (SCP = Single country publication, MCP = Multi-country publication, TC = Total citation.

	OECD					
Sl.No.	Country	Articles	SCP	MCP	MCP Ratio	Citations
1	United Kingdom	383	255	128	0.334	26116
2	Netherlands	382	273	109	0.285	28982
3	Germany	226	149	77	0.341	5164
4	Sweden	155	113	42	0.271	5973
5	USA	140	108	31	0.223	3133
6	Australia	127	93	34	0.268	2856
7	Finland	124	95	29	0.234	1620
8	Switzerland	82	48	34	0.415	5244
9	Canada	76	52	24	0.316	2415
10	Italy	72	43	29	0.403	1231

Table 6: Non-OECD Country collaboration and productivity (SCP = Single Country publication, MCP = Multi-country publication, TC = Total citation).

	Non-OECD					
Sl. No.	Country	Articles	SCP	MCP	MCP Ratio	Citations
1	China	72	43	29	0.403	716
2	Brazil	25	21	4	0.16	124
3	South Africa	17	10	7	0.412	599
4	India	16	12	4	0.25	125
5	Iran	11	6	5	0.455	48
6	Hong Kong	9	5	4	0.444	78
7	Malaysia	7	3	4	0.571	32
8	Singapore	6	3	3	0.5	476
9	Russia	5	4	1	0.2	18
10	Pakistan	4	3	1	0.25	6

The citation analysis suggests that UK and Dutch authors receive 60% of citations. The major reason for the dominance of these countries is also because the ST approach originates in the UK and Netherlands. Therefore, their early publication and large-scale funding for research in ST have helped authors publish more journals, as most of the publications are generated from funded research in OECD countries. In contrast, non-OECD countries do not have enough research funds to support their ST research and publications.

Furthermore, it is observed that the Netherlands and the United Kingdom are the most productive countries in terms of frequency. Table 5 and Table 6 also indicate the productive countries based on the Multi-country Publication ratio (MCP ratio). The MCP ratio is MCP proportional to the total of all the research publications. According to,[18] countries with higher MCPR signify greater international collaboration.

Except for the United Kingdom and Germany, the top ten most productive countries have low MCP ratios, implying a moderate or low degree of collaboration between European countries and a low collaboration between Asian countries. Among developing countries, China and South Africa have scored relatively higher MCP ratios of 0.403 and 412, with 72 and 17 documents, respectively.

In conclusion, the majority of ST research originates in OECD nations, with the United Kingdom, the Netherlands, Germany, Sweden, and the United States having the highest number of corresponding authors. China, Brazil, South Africa, India, and Iran are the leading contributors to research output and influence among non-OECD nations. Further, this dominance of OECD countries is due to the origin of the ST approach in the United Kingdom and the Netherlands, as well as their early publications and substantial funding for ST research.

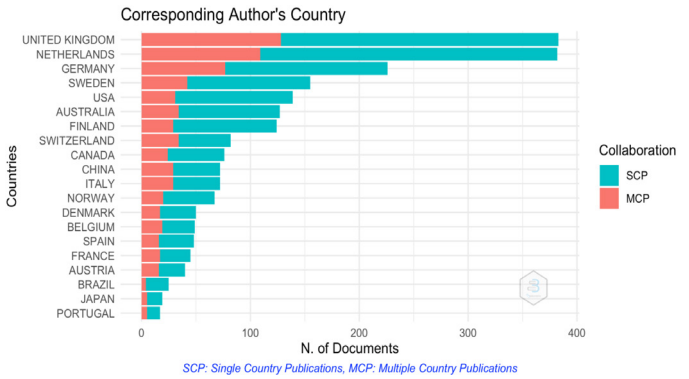

Figure 3: Corresponding author's country.

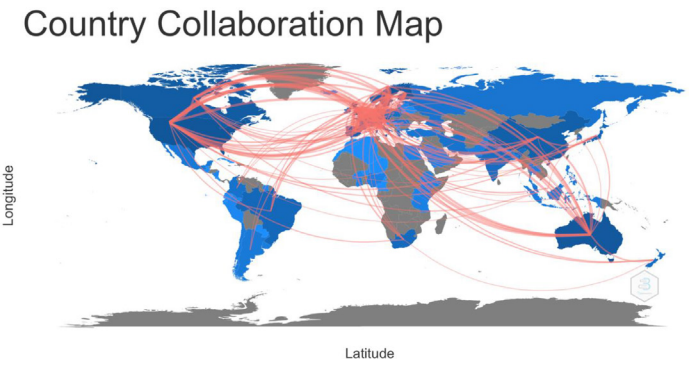

Figure 4: Country Collaboration Map.

Geography of Collaboration

The Western European countries are the most collaborative, as shown in the collaboration map in Figures 3 and 4. The Netherlands and the United Kingdom have higher MCP.

The Western European countries are the most collaborative, as shown in the collaboration map in Figure 3. The Netherlands and the United Kingdom have higher MCP.

Within Europe, the UK, the Netherlands, Germany, Sweden and Denmark are significant collaborators in ST research, as shown in Table 7. The Netherlands and the UK are the most collaborative countries in ST research globally, with the highest frequency 74.

No non-European country falls in the group of top 25 collaborators in ST research. This suggests that European countries heavily dominate ST research.

The analysis indicates that Western European nations are the most collaborative in ST research. The United Kingdom and the Netherlands have the highest MCP and are the most collaborative nations in the world. Moreover, European countries dominate the top 25 collaborators in ST research, indicating that Europe dominates ST research substantially. Future research should

Table 7: Collaboration between top 25 countries.

From	To	Frequency
Netherlands	United Kingdom	74
United Kingdom	Germany	62
Netherlands	Germany	54
Netherlands	Sweden	41
United Kingdom	Denmark	37
United Kingdom	Sweden	36
United Kingdom	USA	36
Netherlands	USA	33
Germany	Sweden	32
United Kingdom	Finland	30
Netherlands	Australia	28
Germany	USA	25
Netherlands	Belgium	21
United Kingdom	Italy	21
United Kingdom	Spain	21
United Kingdom	Australia	20
Germany	Finland	19
Germany	Switzerland	19
Netherlands	Austria	19
Sweden	USA	19
Netherlands	Switzerland	18
Sweden	Norway	18
United Kingdom	China	18
United Kingdom	Switzerland	18
Germany	Austria	17

identify the reasons for this trend and examine ways to promote global collaboration in the field.

Bibliographic coupling of Geographies

Bibliographic coupling occurs when two documents cite the same third research work in their respective bibliographies, indicating that the two works are likely to deal with a similar topic. If two publishing countries or geographies refer to the same third country or geography, the two countries or geographies are bibliographically coupled. The strength and degree of geographic coupling change as the number of citations they share increases.

In the bibliometric geographic coupling analysis (minimum number of documents from the country = 3), 61 countries were chosen from 116 countries in 5 clusters (minimum number of documents from the country = 3). The red cluster consists of twenty-one countries, including the United Kingdom, the Netherlands, and Sweden, which are the leading nations in this cluster, as well as Switzerland, Norway, China, Japan, Hong

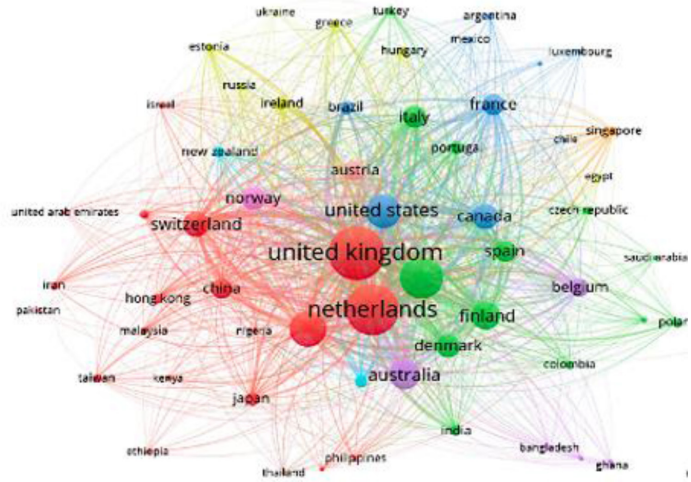

Figure 5: Bibliometric coupling of geographies and changes over the study period.

Kong, Indonesia, Iran, Israel, Japan, Kenya, Malaysia, Nigeria, Norway, Pakistan, Philippines, South Korea, Taiwan, Thailand, and the United Arab Emirates. The United States, Canada, and France anchor the blue cluster of 15 countries: Brazil, Argentina, Chile, Luxembourg, Mexico, New Zealand, South Africa, and Uruguay. Eight nations comprise Cluster 4 (Yellow): Austria, Egypt, Estonia, Hungary, Ireland, Russia, and Ukraine. Cluster 5 (Purple) comprises Australia, Bangladesh, Belgium, Ghana, Tanzania, and Uganda. There is a high degree of bibliometrically coupled geographies in Clusters 1, 2, and 3.

In addition, Figure 5 illustrates the strong coupling between a handful of nations, including the United Kingdom, Netherlands, Germany, Sweden, and the United States. In addition, the bibliographic coupling of countries indicates that the United Kingdom, the Netherlands, Germany, the United States, and Switzerland have demonstrated a higher degree of networking.

In conclusion, the bibliographic coupling by geography analysis has revealed substantial ties and collaborations between specific nations in ST research. Other nations have formed clusters based on their bibliometric coupling, whereas the United Kingdom, the Netherlands, Sweden, Germany, and the United States have demonstrated a greater degree of networking. These results indicate that geography plays a significant role in shaping collaborations in ST research and that certain nations have established themselves as key players in the global ST research landscape. Understanding these collaboration patterns can assist policymakers and researchers in identifying potential areas for collaboration and investment in ST research and foster the growth of a more inclusive and diverse research community.

Co-author visualisation of geographies

This section analyses ST literature based on co-author visualisation based on countries. The minimum number of

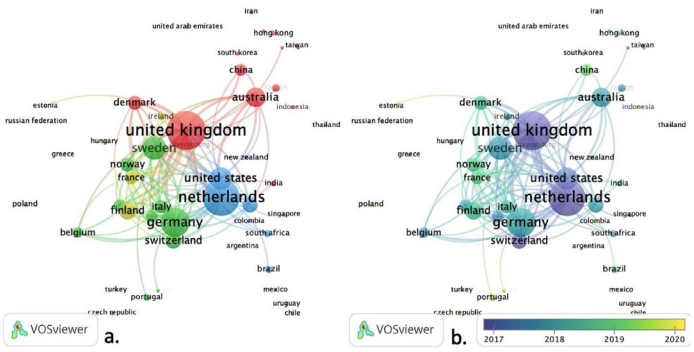

Figure 6: Co-author visualisation map of counties.[1]

1 The threshold was set to 10 documents and a fractional counting method was deployed to gain a clearer picture

documents required to analyse a country's co-authorship network visualisation map was set at 5. 50 of the 116 counties met the criteria. In the country collaboration visualisation map, the size of a given node represents the number of documents. On the map depicted in Figure 6 a, five clusters, each presented in a different colour, define the level of collaboration between authors from other countries on ST. The lines between the clusters represent their relationship, and their thickness indicates the number of citations. In VOSviewer Version 1.6.17 (0), Horizontal and vertical axes reflect nothing. Each cluster is assigned a unique colour.[26]

In Figure 6 a, the red cluster consists of 15 countries, where the United Kingdom emerges as a leading country (publications = 596; Total Link Strength (TLS) = 615), linked with Australia (publications = 193; TLS = 199), China (publications= 87; TLS = 76), Japan (publications = 42; TLS=50) and India (publications= 27; TLS= 38). The Green cluster consists of 12 countries, and it is anchored by the Netherlands (publication = 552; TLS = 531) with strong centrality, and the USA (publication = 244; TLS = 288) and Canada (publication=1309; TLS =159) are the major countries of this cluster. The blue cluster includes 9 countries and is anchored on Germany (publication=367; total link strength=440), Italy (publication = 107; TLS = 140) and Belgium (publication=73; TLS= 105). Further, the yellow cluster consists of 8 countries, anchored by Finland (publication=167; TLS = 141) and France (publication= 94; TLS = 159). The fifth cluster, purple, consists of 6 countries, Sweden (publication=272; TLS =340), Norway (publication=114; TLS = 129), and Switzerland (publication=137; TLS = 188) are the prominent ones.

Further, co-authorship network visualisation (Figure 6 b) indicates the concentration of collaborations amongst countries from the global north. However, it also reflects that new collaboration networks spread between developed and developing countries.

The co-author's analysis of geographies reveals the concentration of collaborations among countries from the global north and the emergence of collaboration networks between developed and developing nations. The analysis emphasises the centrality of countries such as the United Kingdom, the Netherlands, and the United States, as well as the significance of collaborations between these nations and Australia, China, and Japan. The results indicate that co-authorship networks in ST research are evolving toward more diverse collaborations as participation from countries in the global south has begun to increase.

Content Analysis of developing countries

In the following section, co-word analysis is provided to assess the nature of ST research in the global south. A co-word analysis was conducted using the text in the titles and abstracts of Non-OCED sample publications. For this analysis, an Excel file was created using the bibliographic information of publications where the corresponding author's affiliation was from a non-OECD country. After some experimenting, it was decided to limit the frequency of co-occurrences of phrases to at least ten times as this would yield the relevant terms deliberated by authors in the dataset. This analysis is also important to assess the topics emerging from the non-OECD countries and potentially outline research agendas crucial to developing countries in sustainability transitions. After performing the co-word analysis, 29 relevant key phrases were uncovered, and their centrality to the overall distribution was tabulated and given in Table 8.

Table 8: Top 15 most frequently occurring words relevant to ST research in corresponding authors from developing countries.

Sl. No.	Term	Occurrences	Relevance score
1	Urban sustainability transition	10	5.8121
2	City	24	3.3609
3	Tis	13	2.0485
4	Landscape	15	1.8332
5	Technological innovation system	36	1.2723
6	Innovation system	22	1.1491
7	Sustainability transition	63	1.0149
8	Diffusion	16	0.8734
9	Governance	23	0.8103
10	Renewable energy	17	0.6498
11	Barrier	13	0.6174
12	Energy transition	19	0.6077
13	Brazil	16	0.4092
14	Energy	18	0.3894
15	China	39	0.3874

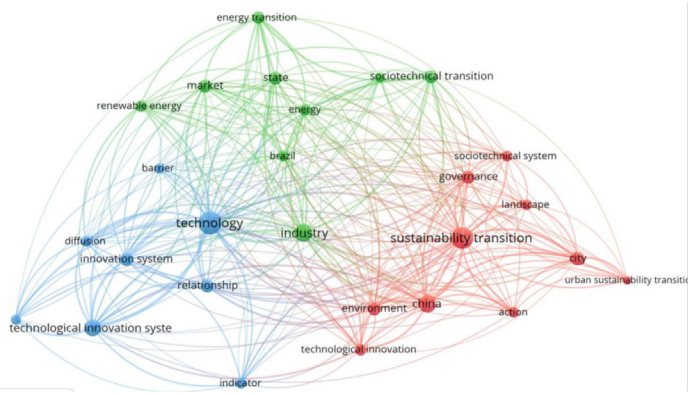

Figure 7: Textual co-occurrence analysis of titles and abstracts.

Error! Reference source not found.

In binary counting analysis (where two adjoining words are considered as co-word), the number of occurrences of words or phrases is not considered; instead, only the presence or absence of phrases or words counts. The linkages among the frequent terms are given in Figure 7. Each node in the figure represents a frequent term, with the size of the frame being proportional to the number of co-occurrences within the selected dataset. The term with the most frequency was "sustainability transition" which appeared 63 times, followed by "China" and "technological innovation system" which occurred 39 and 36 times, respectively.

The co-occurrence analysis reveals three clusters. The red cluster is tied with sustainability transitions, urban sustainability, governance, landscape, and China. At the same time, the green cluster is anchored by energy transitions, renewable energy, innovation system, Brazil, energy, and the state. Finally, the blue cluster is anchored by the Technological innovation system, this (technology innovation system), barrier, and diffusion.

It is evident from the analysis that research themes, including sustainability transitions in the urban context, governance of sustainability transitions, and China, are closely linked. Likewise, energy transitions, renewable energy, the role of the state in enabling and steering the transitions and Brazil are possibly related. Finally, the technological innovation system is a significant research sub-theme perused by leading developing countries, China and Brazil.

The content analysis of developing countries illuminates the emerging research themes and priorities in sustainability transitions. The analysis revealed three clusters, highlighting the interconnections between research themes such as urban sustainability transitions, governance, energy transitions, and technological innovation systems. The findings indicate that developing countries prioritise similar research topics as OECD nations, including the role of innovation systems and governance in sustainability transitions. However, the study also showed specific research priorities for developing countries, such as the transition to urban sustainability and the role of the state in promoting and governing transitions. Overall, the content analysis of developing countries provides essential insights for sustainability transition researchers and policymakers working in developing countries.

CONCLUSION

The ST research has evolved from 1994 with the first publication to the highest number of publications in 2021. The most interesting evolution of ST research has been witnessed in multiple phases in the form of an S curve. The first phase can be the incubation period from 1994 to 2002, called the leg phase. The next phase of the evolution of ST research is the Growth phase from 2002 to 2021. The origin of the ST research is attributed to Dutch and UK researchers. The geographical evolution of ST research and its dynamics suggests that the Dutch authors are leading research in the world on ST research with their highest numbers of publications and impact factors. This indicates that they consistently produced high impact creating research in the ST area. It can also be concluded that the reason for such a higher number of publications and research outcomes from Dutch research is the higher availability of funding and emerging ecology within the country. This conclusion is evident from SCP from the Netherlands.

Similarly, the UK, too, has shown a high impact next to the Netherlands. The Western geographical locations of Europe are major contributors and creators of ST literature, evident from the results of MCP, where maximum publications are from this region. The global north has dominated the ST research during the study period. Moreover, diversity and inclusion in research on sustainability transitions are essential due to the global and systemic nature of sustainability issues. Therefore, ST theory must incorporate experiences and knowledge from the global south to ensure a better understanding and more effective solutions to global sustainability challenges.

ACKNOWLEDGEMENT

We would like to express our gratitude to the Indian Council of Medical Research (ICMR) for their unwavering support throughout this research. Their provision of a Junior Research Fellowship (JRF) to the first author was critical to the completion of this project. This work would not have been possible without their generous support, and we extend our deepest appreciation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Elzen B, Geels F, Green K, editors. System innovation and the transition to sustainability: theory, evidence and policy. Cheltenham: Elgar; 2004.

2. Geels FW. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research policy. 2004;33(6-7):897-920.
3. Köhler J, Geels FW, Kern F, Markard J, Onsongo E, Wieczorek A, Alkemade F, Avelino F, Bergek A, Boons F, Fünfschilling L. An agenda for sustainability transitions research: State of the art and future directions. Environmental innovation and societal transitions. 2019;31:1-32.
4. Grin J, Rotmans J, Schot J, Geels FW, Loorbach D. Transitions to sustainable development: new directions in the study of long term transformative change. First issued in paperback. Routledge; 2011.
5. Kemp R, Schot J, Hoogma R. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis and Strategic Management. 1998;10(2):175-98.
6. Schot J, Geels FW. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technology Analysis and Strategic Management. 2008;20(5):537-54.
7. 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.
8. Hekkert MP, Suurs RAA, Negro SO, Kuhlmann S. Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change. 2007;74(4):413-32.
9. Ramos-Mejía M, Franco-Garcia ML, Jauregui-Becker JM. Sustainability transitions in the developing world: Challenges of socio-technical transformations unfolding in contexts of poverty. Environmental Science and Policy. 2018;84:217-23.
10. Wieczorek AJ. Sustainability transitions in developing countries: Major insights and their implications for research and policy. Environmental Science and Policy. 2018;84:204-16.
11. Scoones I, Newell P, Leach M. The politics of green transformations. Routledge; 2015.
12. Lundvall BÅ, Joseph K, Chaminade C, Vang J. Handbook of Innovation Systems and Developing Countries Edward Elgar Publishing; 2009. ISBN: 9781847206091.
13. Escobar A. Encountering development: the making and unmaking of the Third World. Princeton, N.J: Princeton University Press; 1995.
14. Chappin EJL, Ligtvoet A. Transition and transformation: A bibliometric analysis of two scientific networks researching socio-technical change. Renewable and Sustainable Energy Reviews 2014;30:715-23.
15. Savaget P, Geissdoerfer M, Kharrazi A, Evans S. The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review. Journal of Cleaner Production. 2019;206:878-92.
16. Broadus RN. Toward a definition of "bibliometrics". Scientometrics. 1987;12(5-6):373-9.
17. Andrés A. Author production. In: Measuring Academic Research: How to undertake a bibliometric study. Chandos Publishing; 2009:23-30.
18. Zupic I, Čater T. Bibliometric Methods in Management and Organization. Organizational Research Methods. 2015;18(3):429-72.
19. Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of InformetricsInformetrics. 2017;11(4):959-75.
20. Mongeon P, Paul-Hus A. The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics. 2016;106(1):213-28.
21. Markard J, Raven R, Truffer B. Sustainability transitions: An emerging field of research and its prospects. ResearchPolicy. 2012;41(6):955-67.
22. Geels FW. Reference list to transition publications. 2013. Available from: http://www.transitionsnetwork.org
23. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS medicine 2009;6(7):e1000097.
24. Kemp R. Technology and the transition to environmental sustainability: the problem of technological regime shifts. Futures 1994;26(10):1023-46.
25. De Bellis N. Bibliometrics and citation analysis: from the science citation index to cybermetrics. Scarecrow Press; 2009.
26. van Eck NJ, Waltman L. Visualizing Bibliometric Networks. In: Measuring scholarly impact: Methods and practice. 2014; 285-320. Springer Publishing.

Cite this article: Dhiman S, Singh R, Arjune V, Yadav RS, Yadav MS, Bansala A. Mapping the Evolution of Sustainability Transitions Research: A Bibliometric Analysis. J Scientometric Res. 2023;12(3):522-33.