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A BIBLIOMETRIC ANALYSIS OF SECTORAL SYSTEMS OF INNOVATION

ABSTRACT

Purpose: The study aims to explore the dynamics of Sectoral Systems of Innovation (SSIs), emphasizing their role in linking innovation processes with sectoral dynamics. It investigates key contributors, thematic clusters, trends, and the interplay of institutions, technologies, and actors in fostering innovation across sectors.

Methodology/approach: A bibliometric analysis was conducted using data from the Web of Science database, focusing on 237 selected papers published between 2002 and 2024. Citation analysis and network mapping were employed to assess productivity, impact, and thematic interconnections. Tools like Bibexcel and VOSviewer were used to extract insights on authors, journals, institutions, and countries.

Findings: The research identifies significant trends in SSIs literature, with sustainability transitions emerging as a critical focus area. Thematic clusters reveal strong academic interest in "Innovation and Sustainability" and "Sectoral Systems and Catch-Up Dynamics". Key contributors, including leading authors, journals, and institutions, demonstrate varied research strategies balancing productivity and impact. The study also highlights gaps in existing research, particularly in niche areas such as forestry innovation systems.

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Originality/value: This study provides a comprehensive bibliometric perspective on SSIs, bridging gaps in qualitative research, and offering actionable insights into innovation systems' evolution. It contributes to the understanding of policy frameworks and strategies that can drive innovation and sustainability transitions across diverse sectors.

Keywords: sectoral innovation systems, bibliometrics, citations analysis

1. INTRODUCTION

Over the past two decades, sectoral systems of innovation (SSIs) have attracted considerable attention from researchers and policy makers worldwide, resulting in an increasing number of academic publications. The rationale for this growth lies at the heart of the SSI approach, which encompasses a wide range of factors that influence innovation and production in the sector, and a dynamic, process-oriented perspective (Malerba, 2005).

The sectoral system of innovation and production (SSI) can be defined as a set of new and established products for specific uses, along with the set of agents engaged in market and non-market interactions for the creation, production, and sale of those products. The sectoral system is characterized by a knowledge base, technologies, inputs, and an existing, emergent, and potential demand. The agents that comprise the sectoral system are organizations and individuals (e.g., consumers, entrepreneurs, scientists) (Malerba, 2002). The SSI approach provides a comprehensive framework for analyzing innovation across a range of sectors for both developed and developing countries (Malerba & Nelson, 2011), thereby highlighting the differences in innovation patterns and dynamics (Malerba, 2002; 2005). This methodology allows for an investigation of the international performance and competitiveness of firms and countries across a range of sectors (Malerba, 2018). By considering the co-evolutionary processes within sectors, the SSI approach offers insights into sector-specific innovation processes, industry dynamics, and the transformation of sectoral boundaries over time (Malerba, 2005; 2014). Furthermore, the SSI allows for the precise identification of the factors that impede and enable innovation, thus enabling the formulation of more effective policies and strategies to advance innovative development (Diercks et al., 2019). These policies and strategies are tailored to align with the specific needs and attributes of individual sectors (Intarakumnerd & Gerdsri, 2014). Despite the growing awareness of the significance of theoretical discourse on SSIs, there is a notable absence of qualitative, bibliometrically oriented studies exclusively dedicated to SSIs. Existing studies tend to encompass broader domains, including innovation systems (Rakas & Hain, 2019; Schlaile et al., 2017), national innovation systems (Sun & Grimes, 2015; Teixeira, 2014), and regional perspective (Cruz & Teixeira, 2010; Doloreux & Gomez, 2017).

The objective of this study is to identify the key contributors of SSIs research, including trends in the number of publications, the most cited publications, thematic clusters, their productivity, impact and interconnections, the most eminent authors, journals, institutions and countries by productivity, and citation impact. The study also seeks to determine the gaps in the scientific research on the subject. To this end, a bibliometric analysis was conducted, incorporating a citation analysis, utilizing the Web of Science database. The study is structured as follows: an introduction to the SSIs with its key characteristics and definitions; an overview of the methodology; and the results of the bibliometric analysis. The final section of the study presents the conclusions.

2. LITERATURE REVIEW

The concept of a sectoral system of innovation and production draws upon a range of relevant intellectual and theoretical traditions, including industry life cycle literature (Utterback, 1994; Klepper, 1996), the notion of development blocks introduced by Dahmén (1988), the innovation system approach (Lundvall, 1992) and evolutionary theory (Nelson & Winter, 1982). The SSI builds on the insights of other concepts, such as national systems of innovation (NSIs) (Lundvall, 1992). It extends the understanding of regional/local innovation systems (Cooke et al., 1997), and technological systems, in which the focus is on networks of agents for the generation, diffusion and utilization of specific technologies (Carlsson & Stankiewicz, 1991).

The concept of a Sectoral System of Innovation (SSI) has been defined in various ways. The most widely cited and foundational definition of a sectoral system of innovation (SSI) is that introduced by Malerba (2002): "An SSI is a set of products and the set of agents (individuals and organizations) that carry out market and non-market interactions for the creation, production, and sale of those products. These systems encompass knowledge, technologies, inputs, and demand specific to the sector, as well as the institutions and policies that shape innovation within that sector". This notion emphasizes the following core elements: knowledge and technologies, actors and networks, institutions, demand conditions, sectoral boundaries, and sectoral dynamics. Charles Edquist (2005) extends the concept by integrating systemic elements from national and regional innovation systems: "A sectoral innovation system includes all the major economic, social, political, organizational, and institutional factors that influence the development, diffusion, and use of innovations within a sector". Key components are knowledge flows, institutional frameworks, interactive learning, policy measures, and innovation processes.

The concept of technological regimes furnishes a framework for comprehending the technological milieu within which firms function (Malerba & Orsenigo, 1993). This environment exerts a significant influence on the innovation processes, competitive dynamics, and overall behavior of firms within a sector. The technological regimes that characterize these environments are defined by the following characteristics: (1) opportunities, defined as the potential for technological advancement and innovation within the sector; (2) appropriability, defined as the ability of firms to capture the economic benefits of their innovations; (3) cumulativeness, defined as the extent to which past technological developments influence future innovations; and (4) knowledge base, defined as the nature of knowledge (tacit vs. codified) and the degree of specialization within the sector (Malerba & Orsenigo, 1997).

Frank Geels (2004) incorporates insights from the multi-level perspective (MLP) theory to explain sectoral transformations. He defines a sectoral system of innovation as a set of technologies, institutions, and user practices that evolve together, influenced by broader socio-technical regimes and landscapes. The key components of this system are technological niches, socio-technical regimes, socio-technical landscapes, and co-evolutionary dynamics. While these definitions have some common elements, such as a focus on actors, networks, and institutions, they also highlight different aspects of sectoral systems. Malerba places emphasis on the comprehensive set of interactions and components that are intrinsic to a sector. In contrast, other scholars, such as Edquist and Geels, integrate a broader systemic and evolutionary perspective.

3. METHODOLOGY

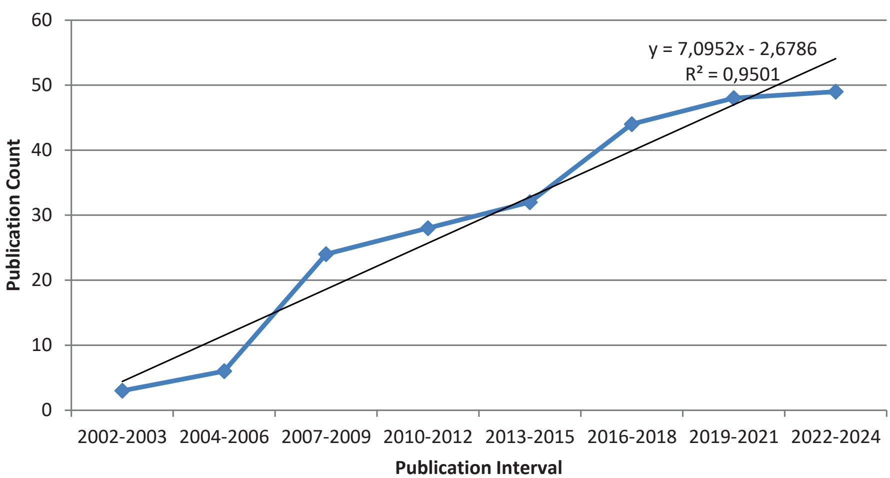
Bibliometric analysis uses a quantitative approach to describe, evaluate, and monitor published research (Small et al., 2014). Two key pillars of bibliometric analysis are performance analysis and science mapping. The first assesses the quantitative metrics such as citation counts, impact factor, and average citations per year. The second reveals structural and relational aspects of citation patterns, including connectivity, influence, and knowledge flow within a network (Cobo et al., 2011). Our study employs a Citation Analysis (CA) to evaluate research impact and productivity at an individual (publications and authors), journal, institutional, and country level. We use a Citation Network Analysis (CNA) to provide insights into the structure, dynamics, and influence of scientific literature within the SSIs. Thus, citations can be used to measure impact (van Raan, 2003), quantity, which measures productivity in terms of unites selected (e.g., the number of publications), and impact efficiency, which is defined as the quotient of the number of citations in relation to the number of publications (Leeuwen et al., 2003). The study draws upon 280 papers of research on SSIs published from 2002 to the end of 2024, retrieved from the Web of Science™ (WoS) Core Collection (CC). To identify papers in English relating to SSIs from Business Economics, we decided to search title, abstract, keyword plus, and author keywords. Hence, our query includes "sectoral innovation system*" (Topic) or "sectoral system of innovation*" (Topic) or "sectoral systems of innovation*" (Topic) or "sectoral system*" (Topic) and English (Languages) and Business Economics (Research Areas). In the subsequent stage, a selection of 237 papers was made on the basis of an in-depth analysis of titles, abstracts, and keywords, as well as shared references (minimum 1 reference), with the aim of identifying the most relevant and useful material. The process was carried out using Bibexcel (Persson et al., 2009) and Microsoft Excel. We opted to use the VOS algorithm to perform the CNA analysis, and mapping was conducted using the VOSviewer software (van Eck & Waltman, 2009).

4. RESULTS

4.1. GENERAL PERSPECTIVE

We identified 237 papers that deal with SSIs, prepared by 485 authors and published in 86 sources. The authors represented 333 research institutions from 47 countries. Figure 1 illustrates the trends in research output over successive three-year publication intervals, as measured by the Publication Count. The publication count increases steadily across the intervals, demonstrating a clear upward trend in research output over time. The R^2 value of 0.95 indicates a very strong linear relationship between the publication intervals and the publication count. This suggests that the growth in research output is consistent and predictable over time. Between the 2004–2006 and 2007–2009 intervals, there is a notable steep increase in publication count, indicating a period of accelerated research activity or increased academic focus in the subject area. After 2016–2018, the rate of growth appears to slightly slow down, with the publication count stabilizing near 50. The trend line predicts continuous growth in publication count if the trajectory persists, although the stabilization in recent intervals might indicate a potential shift in trends.

Figure 1.
Trends in publication count across successive intervals (2002–2024)



Source: own elaboration based on Web of Science Core Collection.

4.2. MOST CITED PUBLICATIONS

Table 2 offers a comprehensive overview of the top 10 most cited documents, providing valuable insights into their citation patterns. The ranking suggests that certain seminal works have gradually become more prominent over time. The most-cited document, Geels (2004), leads with 2,025 total citations, which demonstrates a sustained impact, particularly between 2017 and 2021 (918 citations). This suggests that it has an important role to play in integrating socio-technical systems with institutional theory. Markard et al. (2012) is a close second with 2,012 citations, gaining traction especially from 2012 onwards, which seems to reflect its relevance to the burgeoning field of sustainability transitions. Malerba (2002) and Bergek et al. (2008) also deserve a mention, ranking third and fourth, and indicating consistent influence over the years, particularly in the earlier and middle periods, with 1,336 and 1,220 citations, respectively. It is notable that Markard & Truffer (2008) and Weber & Rohracher (2012) demonstrate a more moderate influence.

Table 1
Top 10 most cited publications

Rank	Document	2002–2006	2007–2011	2012–2016	2017–2021	2022–2024	TC
1.	From sectoral systems of innovation to socio-technical systems – Insights about dynamics and change from sociology and institutional theory (Geels, 2004)	13	173	456	918	465	2025
2.	Sustainability transitions: An emerging field of research and its prospects (Markard et al., 2012)	0	0	280	1065	667	2012
3.	Sectoral systems of innovation and production (Malerba, 2002)	56	235	374	478	193	1336
4.	Analyzing the functional dynamics of technological innovation systems: A scheme of analysis (Bergek et al., 2008)	0	67	315	537	301	1220

Table 1 (continued)

Rank	Document	2002–2006	2007–2011	2012–2016	2017–2021	2022–2024	TC
5.	Technological innovation systems and the multi-level perspective: Towards an integrated framework (Markard & Truffer, 2008)	0	63	225	309	176	773
6.	Legitimizing research, technology and innovation policies for transformative change combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework (Weber & Rohracher, 2012)	0	0	70	322	277	669
7.	The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930) (Geels, 2005)	0	42	129	239	145	555
8.	Environmental Innovation and Sustainability Transitions in Regional Studies (Truffer & Coenen, 2012)	0	0	94	212	97	403
9.	Global Innovation Systems – A conceptual framework for innovation dynamics in transnational contexts (Binz et al., 2017a)	0	0	0	168	177	349
10.	Schumpeterian analysis of Economic Catch-up: Knowledge, Path-Creation, and the Middle-Income Trap (Lee, 2013)	0	0	53	181	101	335

Source: own elaboration based on Web of Science Core Collection.

4.3.THEMATIC CLUSTERS

The analysis of thematic clusters reveals diverse research focuses and varying levels of productivity, total citations (TC), and citation impact per document (TC/Doc Count) (see Table 2). "Innovation and Sustainability" cluster is the most influential in terms of total citations and citation impact per document. Its high TC/Doc Count indicates that the publications in this cluster are highly impactful, addressing critical issues at the intersection of innovation and sustainability. This suggests strong relevance to global challenges like climate change and sustainable development, making it a central focus of scholarly attention. "Exploring Patterns and Challenges" cluster has the highest productivity (document count) but a moderate citation impact per document. Its focus on understanding patterns and addressing challenges in various systems of innovation likely attracts a wide range of contributions, but the relatively lower TC/Doc Count suggests opportunities for enhancing the academic influence of individual studies. Sectoral "Systems and Catch-Up Dynamics" cluster highlights research on the dynamics of sectoral systems and the processes of technological and economic catch-up. While it is productive with a relatively high number of documents, its citation impact per document is similar to that of "Exploring Patterns and Challenges", suggesting comparable levels of influence per publication. It reflects the ongoing interest in sector-specific innovation and latecomer economies. The fourth cluster "Dynamics, Challenges, and Evolution" focuses on the evolutionary dynamics and challenges within innovation systems. Its moderate document count and TC/Doc Count suggest a niche but impactful research area. "Global Trends and Emerging Frameworks" cluster explores global innovation trends and the development of new frameworks. While its productivity is moderate, its lower TC/Doc Count indicates that its individual publications have had less academic impact. The last cluster concerning "Innovation in the Forestry Sector: Systems, Policies, and Global Networks" focuses on innovation in the forestry sector. Although it has the lowest productivity and total citations, its relatively high TC/Doc Count demonstrates significant impact for its small number of studies. This reflects the niche importance of forestry innovation systems, policies, and networks in academia.

Table 2
Thematic clusters by productivity and citation impact

Cluster Name	TC	Doc Count	TC/Doc Count
Exploring Patterns and Challenges	2302	61	37,7
Sectoral Systems and Catch-Up Dynamics	2094	56	37,4
Innovation and Sustainability	10394	54	192,5
Global Trends and Emerging Frameworks	1000	32	31,3
Dynamics, Challenges, and Evolution	1240	31	40

Table 2 (continued)

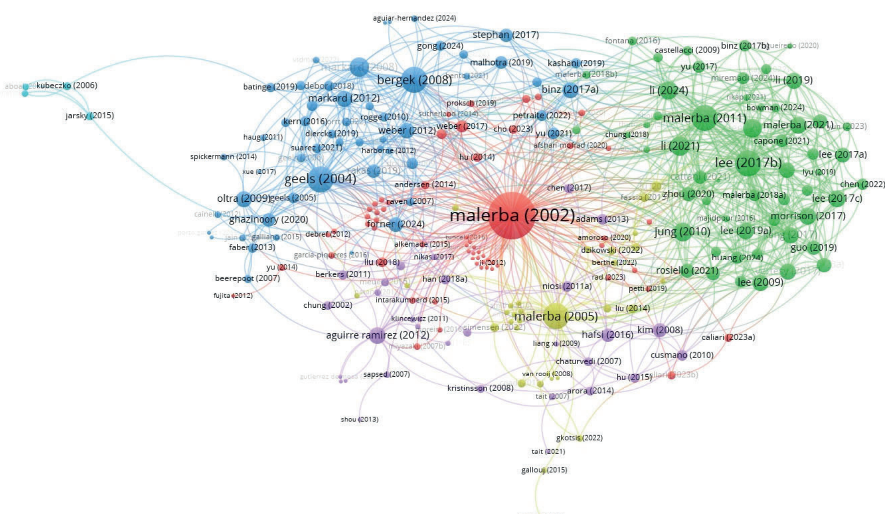
Cluster Name	TC	Doc Count	TC/Doc Count
Innovation in the Forestry Sector: Systems, Policies, and Global Networks	194	4	48,5

Source: own elaboration, TC – Total Citations; Doc Count – the number of documents.

Figure 2 shows a thematic cluster map based on citation analysis. The map visually represents how research topics are interconnected and the impact of various research themes. Clusters closer to one another share more conceptual overlap, while distant clusters represent distinct areas of research. Clusters are labeled based on the dominant theme, derived from keywords, titles, or abstract analysis of the documents within the cluster. In the subsequent stage, each identified cluster will be presented in depth.

Figure 2

The network of thematic clusters based on citation analysis



Source: own elaboration based on WoS & VosViewer.

EXPLORING PATTERNS AND CHALLENGES

Sectoral systems of innovation (SSIs) offer a framework for understanding the interplay of institutions, technologies, and actors within specific industries. Malerba (2002) introduces this concept as a means to link innovation processes with production dynamics, while McKelvey et al. (2003) emphasize the importance of co-location for fostering knowledge collaboration in industries like Swedish biotechnology. Fukugawa (2018) and Intarakumnerd & Chaoroenporn (2013b) extend the discussion by analyzing the role of intermediaries and policies in shaping sectoral systems in emerging economies. Case studies from Thailand's automotive sector (Intarakumnerd & Gerdsri, 2014) and Turkey's machinery industry (Tuncel & Polat, 2016) highlight the role of innovation policy and management in driving technological change. The globalized nature of innovation systems is evident in studies on healthcare services (Savory & Fortune, 2014), agriculture (Thitinunsomboon et al., 2008), and electric power industries (Turovets et al., 2021). Wangwe et al. (2022) underscore the significance of dynamic industrial deepening in health-related sectors in Tanzania, whereas Andrews-Speed et al. (2022) identify critical deficiencies in China's coal-bed methane innovation systems compared to the US At the intersection of digitalization and innovation, researchers like Proksch et al. (2019) and Kim & Flanagan (2024) explore challenges in the healthcare sector and machine learning in broadcasting, respectively. Emerging themes in global innovation systems include green digitalization (Turovets et al., 2021), sustainability transitions (Debref, 2012), and circular economy practices in Africa (Andersen et al., 2022).

SECTORAL SYSTEMS AND CATCH-UP DYNAMICS

Sectoral systems of innovation provide a critical lens for understanding how industries evolve and how firms and nations navigate challenges to achieve technological and economic leadership. Lee & Malerba (2017) explore the cycles of industrial leadership, identifying "windows of opportunity" and strategic responses by firms and countries to evolve within sectoral systems. Binz et al. (2017) furthers this discussion with insights into technology-sensitive catching-up policies in renewable energy, using China as a case study. The complexity of catch-up processes is evident in studies such as Lee (2019a), which identifies barriers, detours, and leapfrogging in innovation systems. Similarly, Li et al. (2019) presents a history-friendly model of China's mobile communications industry, emphasizing how institutional and market dynamics play critical roles. Figueiredo et al. (2020) focus on interactive learning in multinational subsidiaries, highlighting how local innovation capabilities are built through micro-level interactions. The role of policy and systems-level planning is underscored by Landini et al. (2020), who advocates for demand-led catch-up strategies in the global green economy, and by Rikap (2022), who examines the State Grid Corporation of China's use of national innovation systems to achieve intellectual monopoly. Capone et al. (2021) adds to this discourse by analyzing how Chinese firms in the mobile phone sector leverage entry strategies to address catch-up challenges. Sectoral systems are not only about technological leapfrogging but also about adapting to global shifts. Bowman & Chisoro (2024) emphasize inclusive development in agro-industrial systems in South Africa, while Xiong et al. (2022) discuss the development of China's energy-saving electric vehicle industry. Zhou et al. (2020) identify green windows of opportunity in the hydropower sector, showing how sustainability goals intersect with latecomer development. The interplay of knowledge-intensive entrepreneurship and sectoral innovation systems is highlighted in works such as Malerba & McKelvey (2019), which explores innovative entrepreneurship, and Fontana et al. (2015), which classifies entrepreneurship across sectoral systems.

INNOVATION AND SUSTAINABILITY

The study of sectoral and socio-technical systems provides a framework for understanding how industries and societies evolve through innovation, adaptability, and sustainability. Geels (2005; 2006) provides foundational analyses of transition pathways, exploring the multi-level dynamics in socio-technical transitions such as the shift from horse-drawn carriages to automobiles and the transformation of aviation from propeller to turbojet systems. These studies emphasize the importance of co-evolutionary processes and multi-level perspectives in guiding technological transitions. The role of energy transitions is further examined by Kern & Markard (2016) and Rogge & Hoffmann (2010), who assess policy impacts on energy systems, while Markard & Truffer (2008) integrates the multi-level perspective with technological innovation systems to offer a cohesive framework for understanding sustainability transitions. The exploration of global innovation systems by Binz & Truffer (2017) and the identification of transformative innovation policies by Diercks et al. (2019) highlight the importance of aligning local and global innovation goals. Sectoral systems of innovation provide insights into specific industries, as shown by Stephan et al. (2017) in the lithium-ion battery sector in Japan, and Grimm & Walz (2024), who explore the interplay of the automotive and ICT sectors in autonomous driving. These sector-specific studies illustrate how technological innovation relies on inter-sectoral learning, as Malhotra et al. (2019) demonstrate in the context of clean energy technologies. The socio-political environment also plays a pivotal role in shaping innovation systems. Aguiar-Hernandez & Breetz (2024) investigates the adverse effects of political instability on renewable energy in Mexico, while Magnusson & Berggren (2018) address sustainability transitions and the strategies of actors in hydrogen vehicle systems. By bridging sectoral systems, socio-technical perspectives, and global innovation frameworks, these studies provide a comprehensive roadmap for navigating the challenges of the 21st century.

GLOBAL TRENDS AND EMERGING FRAMEWORKS

The study of sectoral systems of innovation offers a nuanced understanding of how industries evolve by linking innovation to knowledge bases, structural changes, and sectoral dynamics. Malerba (2005) provides a foundational framework for understanding this connection, which has been expanded upon by later studies. Gallouj et al. (2015) investigates the service economy's future in Europe, utilizing foresight analysis to explore evolutionary changes. Similarly, Saritas & Nugroho (2012) employs scenario-based approaches to map out issues and envision futures, adding to the growing understanding of innovation pathways. Specific sectoral insights, such as those into oil and gas (Engen et al., 2018) and crude oil refining in India (Iyer, 2016), emphasize the role of entrepreneurs and sector-specific dynamics. Meanwhile, Van Rooij et al. (2008) examine how national systems facilitate international knowledge flows, as seen in the Netherlands. Agriculture and biogas systems also come under scrutiny. Berthe et al. (2022) highlights the diversity within agricultural biogas plants in France, while Damioli et al. (2021) questions how open policies affect growth across EU countries and sectors. Regional contexts further influence innovation systems. Smith & Romeo (2016) explore biotech development in Oxfordshire, and Kang & Choung (2023) analyze how institutional transitions in Korea shape innovation outcomes. The role of industrial policy is underscored by Hegerty & Weresa (2023), who study the medical sector in Central Europe, and Álvarez Scanniello & Menéndez (2024), who analyze productivity growth in agricultural systems across multiple countries.

DYNAMICS, CHALLENGES, AND EVOLUTION ACROSS INDUSTRIES

The study of sectoral innovation systems offers a lens to understand how industries evolve and adapt within national and regional frameworks. Chung (2002) highlights the importance of building national innovation systems through regional frameworks, emphasizing the layered and interconnected nature of these systems, as further explored by Meuer et al. (2015). The ability to manage stakeholder knowledge effectively in innovation systems is critical, especially in the face of global challenges like climate change (Nikas et al., 2017). In specific contexts, industrial users play a pivotal role in driving innovation within sectoral systems, as demonstrated by Adams et al. (2013) in the semiconductor industry. Historical cases, such as technological transitions in Dutch greenhouse horticulture (Berkers & Geels, 2011), reveal how stepwise reconfiguration drives innovation. However, complexity and path dependence often characterize these systems, particularly in high-tech sectors like biotechnology (Niosi, 2011b). Regional comparisons and cross-sectoral studies shed light on innovation patterns. For example, Patana et al. (2012) compare life science innovation systems in Finland and the San Francisco Bay Area, while Teh & Roos (2015) analyze regional innovation in South Australia through patent systems. Cusmano et al. (2010) take a different approach, examining trajectories of technological catch-up in the wine sectors of Chile, Italy, and South Africa. Sector-specific innovation challenges are explored in various industries. Kristinsson & Rao (2008) evaluate how technology transfer enables catch-up in renewable energy sectors such as wind energy in Denmark and India. Similarly, Kim & Lee (2008) examine technological catch-up in Korea's capital goods industry.

INNOVATION IN THE FORESTRY SECTOR: SYSTEMS, POLICIES, AND GLOBAL NETWORKS

Innovation in the forestry sector is a critical area of study, focusing on how systems and policies can support advancements in a traditionally resource-based industry. Rametsteiner & Weiss (2006) highlight the importance of linking innovation processes with systems models, offering a comprehensive framework for understanding how structured approaches can drive innovation in forestry. Building on this foundation, Kubeczko et al. (2006) emphasize the interconnectedness of regional policies and sectoral strategies, illustrating how local dynamics can foster broader innovation outcomes. In the context of the Czech Republic, Jarský (2015) raises important questions about the institutional and structural barriers that may impede the development of effective innovation systems in specific national contexts. On a global scale, Aboal et al. (2018) investigates the role of international collaboration and corporate strategies in fostering innovation, showcasing how knowledge transfer across borders can address sector-specific challenges.

MOST EMINENT AUTHORS

The analysis of the top 10 authors (see Table 3) provides insights into their academic productivity and influence, based on the number of documents published, total citations (TC), and citation impact per document (TC/Doc Count). Jochen Markard demonstrates an outstanding citation impact, indicating that his limited number of publications has made a significant impact on the academic community. Bernhard Truffer has the highest total citations among the authors, with an impressive citation impact per document, reflecting the broad influence of his research. Matthias Weber combines a decent number of publications with a high citation impact, showcasing strong recognition of his work. Roberta Rabellotti's work has consistent recognition, as reflected in her citation impact, although her total citation count is comparatively lower. Franco Malerba stands out for his productivity, leading in document count, though his citation impact per publication is moderate compared to others on the list. Keun Lee is highly productive, contributing a significant number of documents with a steady citation impact. Kumiko Miyazaki maintains consistent citation recognition across her publications, with a moderate citation impact.

Table 3
Top 10 authors by productivity and citation impact

Rank	Name of the Author	TC	Doc Count	TC/Doc Count
1	Markard, Jochen	2841	3	947,0
2	Truffer, Bernhard	3537	4	884,3
3	Weber, Matthias	868	4	217,0
4	Rabellotti, Roberta	213	3	71,0
5	Malerba, Franco	950	14	67,9
6	Lee, Keun	631	11	57,4
7	Miyazaki, Kumiko	137	4	34,3
8	Li, Daitian	91	5	18,2
9	Niosi, Jorge	43	3	14,3

Table 3 (continued)

Rank	Name of the Author	TC	Doc Count	TC/Doc Count
10	Intarakumnerd, Patarapong	48	4	12,0

TC – Total Citations; Doc Count – Number of Documents

Source: own elaboration based on Web of Science Core Collection.

4.5. MOST INFLUENTIAL JOURNALS

The superiority of *Research Policy* in terms of productivity and impact is manifest in its attainment of the highest ranking, with its TC per article (TC/Doc Count) and article count (TC) demonstrating exceptional productivity, indicating a high impact of citations per publication. The category of journals with high impact factor and moderate productivity includes *Technovation*, and *Technological Forecasting and Social Change*, which has the highest Impact Factor on the list, and the number of papers shows high productivity. The group of journals with moderate citation productivity includes *Technology Analysis & Strategic Management*, *Economics of Innovation and New Technology*. The Energy and Environmental Focus Journals group consists of *Energy Policy* representing a solid performance with moderate productivity, *Forest Policy and Economics* and *Energy Policy*. The final group includes journals with a lower TC/Doc Count, but with notable contributions such as *Industrial and Corporate Change* and *Journal of Evolutionary Economics*.

Table 4
Top 10 journals by productivity and citation impact

Rank	Name of Journal	IF (2023)	PHEJL (2024)	Doc Count	TC	TC/Doc Count
1	Research Policy	7,5	200	35	10801	308,6
2	Technovation	11,1	140	6	470	78,3
3	Technology Analysis & Strategic Management	2,9	70	10	714	71,4
4	Economics of Innovation and New Technology	3,2	70	4	257	64,3

Table 4 (continued)

Rank	Name of Journal	IF (2023)	PHEJL (2024)	Doc Count	TC	TC/Doc Count
5	Energy Policy	9,3	140	9	463	51,4
6	Forest Policy and Economics	4,0	100	4	194	48,5
7	Technological Forecasting and Social Change	12,9	140	25	1170	46,8
8	Industry and Innovation	3,4	100	9	380	42,2
9	Journal of Evolutionary Economics	1,3	70	4	145	36,3
10	Industrial and Corporate Change	2,8	140	19	564	29,7

IF – Impact Factor; PHEJL – Polish Higher Education Journals List

Source: own elaboration based on Web of Science Core Collection.

4.6. MOST INFLUENTIAL INSTITUTIONS

Eindhoven University of Technology (Netherlands) is the clear leader in citation impact (TC/Doc Count), indicating that its publications are highly influential and frequently cited. It sets a benchmark for research quality and impact. Lund University (Sweden) demonstrates high-quality research with a significant citation impact, despite its moderate document count. On the other side, Bocconi University leads in productivity but has a relatively lower citation impact compared to Eindhoven and Lund. This suggests a broader publication strategy but lower average influence per paper. Utrecht University exhibits moderate productivity and citation impact, positioning itself as a solid contributor to the field. In contrast, Swiss Federal Institute of Technology (Switzerland) has a relatively low document count but still manages to maintain a decent citation impact per document. Moderate productivity with lower citation impact represents Seoul National University (South Korea) and European Commission. Institutions with Niche Contributions include University of Sussex (Great Britain), University of Pavia (Italy), and Aalborg University (Denmark), the productivity and citation impact of which are the lowest among the top 10, but their inclusion highlights consistent contributions to the academic field. Table 5 includes Top 10 institutions by productivity and citation impact.

Table 5
Top 10 institutions by productivity and citation impact

Rank	Name of Organization	Doc Count	TC	TC/Doc Count
1	Eindhoven University of Technology (Netherlands)	11	5277	479,7
2	Lund University (Sweden)	7	2134	304,9
3	Bocconi University (Italy)	17	2293	134,9
4	Utrecht University (Netherlands)	8	703	87,9
5	Swiss Federal Institute of Technology (Swiss)	4	272	68,0
6	Seoul National University (South Korea)	12	677	56,4
7	European Commission	5	274	54,8
8	University of Sussex (Great Britain)	4	186	46,5
9	University of Pavia (Italy)	4	169	42,3
10	Aalborg University (Denmark)	5	180	36,0

TC – Total Citations; Doc Count – Number of Documents

Source: own elaboration based on Web of Science Core Collection.

4.7. MOST INFLUENTIAL COUNTRIES

Switzerland has been found to demonstrate a high level of influence and wide citation of its publications, despite a relatively modest number of documents. The Netherlands combines high productivity with significant citation impact, reflecting its prominence in the global research community. Sweden achieves a strong balance between productivity and citation impact, showcasing its quality-focused research output. The cluster of moderate citation impact countries includes Austria, which has a selective publication approach, Italy, which focuses on a high volume of publications but has a comparatively lower citation impact, suggesting broader but less concentrated influence, and the USA, which exhibits strong productivity with moderate citation impact, indicating its diversified research contributions. The lowest citation impact concerns Norway, Spain, France, and Denmark which has also the lowest citation impact among the top 10, suggesting limited influence relative to its document count. Table 5 shows Top 10 countries by productivity and citation impact.

Table 6
Top 10 countries by productivity and citation impact

Rank	Name of Country	Doc Count	TC	TC/Doc Count
1	Switzerland	13	4115	316,5
2	Netherlands	27	6185	229,1
3	Sweden	13	2379	183,0
4	Austria	8	1161	145,1
5	Italy	32	3096	96,8
6	Usa	21	1809	86,1
7	Norway	7	572	81,7
8	Spain	14	818	58,4
9	France	18	1011	56,2
10	Denmark	13	606	46,6

Source: own elaboration based on Web of Science Core Collection.

5. CONCLUSIONS

Our analysis reveals that the present interest among researchers and policymakers in SSIs is driven by the need to understand how innovation is influenced by the interplay of knowledge, technologies, actors, networks, and institutions within specific sectors. However, the analysis of the most cited publications suggests that there has been a dynamic evolution of citation patterns, indicating a potential shift in research priorities and the consolidation of sustainability transitions as a critical research field. "Innovation and Sustainability" cluster appears to play a central role as a hub of research that is connected to various other topics, which indicates the foundational applicable nature of the theme. Overall, this body of research demonstrates the complex interplay between technological innovation, institutional dynamics, and policy frameworks in fostering sustainable development. In contrast, "Innovation in the Forestry Sector" cluster appears on the periphery, reflecting its niche focus. The most interconnected themes are "Sectoral Systems and Catch-Up Dynamics" and "Exploring Patterns and Challenges" clusters, which have strong connections as they address overlapping topics related to innovation systems and economic development. The first underscores the importance of aligning national innovation policies, firm-level strategies, and global market dynamics to address the multifaceted challenges of sectoral innovation and economic catch-up, whereas the other one emphasizes the importance of adaptive strategies, collaborative networks, and tailored policies in fostering innovation and overcoming structural challenges across industries. On the other side, "Global Trends and Emerging Frameworks" cluster highlights interdisciplinary approaches, thus offering opportunities to pioneer research in emerging fields. Furthermore, it demonstrates the interplay of policy, technology, and sector-specific dynamics, featuring the importance of tailored strategies to drive innovation across diverse systems. Jochen Markard and Bernhard Truffer lead in terms of citation impact per document, highlighting the significant influence of their research despite moderate productivity. On the other side, Franco Malerba and Keun Lee excel in the volume of publications, though their citation impact per document is moderate. Research Policy stands out as the most influential journal in terms of both productivity and impact. Journals such as *Technovation* and *Technological Forecasting* demonstrate a high level of influence, but lower level of productivity compared to *Research Policy*. Journals that focus on specific sectors, such as *Energy Policy* and *Forest Policy*, tend to exhibit moderate productivity and consistent citation impact. Eindhoven University of Technology is the standout institution, combining moderate productivity with exceptional citation impact. Lund University also performs impressively in terms of influence. Institutions such as Bocconi and Seoul National University prioritize quantity, while others, like Utrecht and the Swiss Federal Institute of Technology, focus on high-quality contributions. Overall, this analysis highlights varying strategies in academic research and the impact among leading institutions. Switzerland, the Netherlands, and Sweden emerge as leaders in citation impact, with Switzerland demonstrating exceptional influence. Italy and the USA dominate in productivity but require a stronger focus on citation efficiency to enhance their impact. Meanwhile, Austria showcases quality-driven research with high per-document influence despite lower output. Altogether, this analysis illustrates the different strategies adopted by countries to balance productivity and impact in academic research.

REFERENCES

Aboal, D., Rovira, F., & Veneri, F. (2018). Knowledge networks for innovation in the forestry sector: Multinational companies in Uruguay. *Forest Policy and Economics*, *97*, 9–20. https://doi.org/10.1016/j.forpol.2018.08.013

Adams, P., Fontana, R., & Malerba, F. (2013). The magnitude of innovation by demand in a sectoral system: The role of industrial users in semiconductors. *Research Policy*, *42*(1), 1–14. https://doi.org/10.1016/j.respol.2012.05.011

Aguiar-Hernandez, C., & Breetz, H. L. (2024). The adverse effects of political instability on innovation systems: The case of Mexico's wind and solar sector. *Technovation*, *136*, 103083. https://doi.org/10.1016/j.technovation.2024.103083

Álvarez Scanniello, J., & Menéndez, M. de las M. (2024). Technological Change and Productivity Growth in Livestock Systems: Denmark, New Zealand and Uruguay (1870–1970). *Scandinavian Economic History Review*, *72*(3), 266–286. https://doi.org/10.1080/03585522.2024.2342788

Andersen, M. M., Ogallo, E., & Diniz Faria, L. G. (2022). Green economic change in Africa – green and circular innovation trends, conditions and dynamics in Kenyan companies. *Innovation and Development*, *12*(2), 231–257. https://doi.org/10.1080/2157930X.2021.1876586

Andrews-Speed, P., Xu, X., Jie, D., Chen, S., & Zia, M. U. (2022). Deficiencies in China's innovation systems for coal-bed methane development: Comparison with the USA. *Journal of Science and Technology Policy Management*, *14*(3), 511–528. https://doi.org/10.1108/JSTPM-04-2020-0071

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*(3), 407–429. https://doi.org/10.1016/j.respol.2007.12.003

Berkers, E., & Geels, F. W. (2011). System innovation through stepwise reconfiguration: The case of technological transitions in Dutch greenhouse horticulture (1930–1980). *Technology Analysis & Strategic Management*, *23*(3), 227–247. https://doi.org/10.1080/09537325.2011.550392

Berthe, A., Grouiez, P., & Fautras, M. (2022). Heterogeneity of Agricultural Biogas Plants in France: A Sectoral System of Innovation Perspective. *Journal of Innovation Economics & Management*, *38*(2), 11–34.

Binz, C., Gosens, J., Hansen, T., & Hansen, U. E. (2017). Toward Technology-Sensitive Catching-Up Policies: Insights from Renewable Energy in China. *World Development*, *96*, 418–437. https://doi.org/10.1016/j.worlddev.2017.03.027

Binz, C., & Truffer, B. (2017). Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. *Research Policy*, *46*(7), 1284–1298. https://doi.org/10.1016/j.respol.2017.05.012

Bowman, A., & Chisoro, S. (2024). Inclusive agro-industrial development and sectoral systems of innovation: Insights from South Africa. *Innovation and Development*, *0*(0), 1–30. https://doi.org/10.1080/2157930X.2024.2312311

Capone, G., Li, D., & Malerba, F. (2021). Catch-up and the entry strategies of latecomers: Chinese firms in the mobile phone sector. *Industrial and Corporate Change*, *30*(1), 189–213. https://doi.org/10.1093/icc/dtaa061

Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*, *1*(2), 93–118. https://doi.org/10.1007/BF01224915

Chung, S. (2002). Building a national innovation system through regional innovation systems. *Technovation*, *22*(8), 485–491. https://doi.org/10.1016/S0166-4972(01)00035-9

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology*, *62*(7), 1382–1402. https://doi.org/10.1002/asi.21525

Cooke, P., Gomez Uranga, M., & Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions. *Research Policy*, *26*(4), 475–491. https://doi.org/10.1016/S0048-7333(97)00025-5

Cruz, S. C. S., & Teixeira, A. A. C. (2010). The Evolution of the Cluster Literature: Shedding Light on the Regional Studies–Regional Science Debate. *Regional Studies*, *44*(9), 1263–1288. https://doi.org/10.1080/00343400903234670

Cusmano, L., Morrison, A., & Rabellotti, R. (2010). Catching up Trajectories in the Wine Sector: A Comparative Study of Chile, Italy, and South Africa. *World Development*, *38*(11), 1588–1602. https://doi.org/10.1016/j.worlddev.2010.05.002

Dahmén, E. (1988). 'Development blocks' in industrial economics. *Scandinavian Economic History Review*, *36*(1), 3–14. https://doi.org/10.1080/03585522.1988.10408102

Damioli, G., Ghisetti, C., Vertesy, D., & Vezzulli, A. (2021). Open for growth? Evidence on EU countries and sectors. *Economics of Innovation and New Technology*, *30*(2), 197–219. https://doi.org/10.1080/10438599.2019.1688459

Debref, R. (2012). The Paradoxes of Environmental Innovations: The Case of Green Chemistry. *Journal of Innovation Economics & Management*, *9*(1), 83–102. https://doi.org/10.3917/jie.009.0083

Diercks, G., Larsen, H., & Steward, F. (2019). Transformative innovation policy: Addressing variety in an emerging policy paradigm. *Research Policy*, *48*(4), 880–894. https://doi.org/10.1016/j.respol.2018.10.028

Doloreux, D., & Gomez, I. P. (2017). A review of (almost) 20 years of regional innovation systems research. *European Planning Studies*, *25*(3), 371–387. https://doi.org/10.1080/09654313.2016.1244516

Edquist, C. (2005). Systems of Innovation: Perspectives and Challenges. In J. Fagerberg, D. C. Mowery, & R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 181–208). Oxford University Press.

Engen, O. A., Simensen, E. O., & Taran, T. (2018). *The evolving sectoral innovation system for upstream oil and gas in Norway* (pp. 23–39). Routledge.

Figueiredo, P. N., Larsen, H., & Hansen, U. E. (2020). The role of interactive learning in innovation capability building in multinational subsidiaries: A micro-level study of biotechnology in Brazil. *Research Policy*, *49*(6), 103995. https://doi.org/10.1016/j.respol.2020.103995

Fontana, R., Malerba, F., & Marinoni, A. (2015). Knowledge intensive entrepreneurship in different sectoral systems: A taxonomy. *Dynamics of Knowledge Intensive Entrepreneurship: Business Strategy and Public Policy*, 191–213.

Fukugawa, N. (2018). Is the impact of incubator's ability on incubation performance contingent on technologies and life cycle stages of startups?: Evidence from Japan. *International Entrepreneurship and Management Journal*, *14*(2), 457–478. https://doi.org/10.1007/s11365-017-0468-1

Gallouj, F., Weber, K. M., Stare, M., & Rubalcaba, L. (2015). The futures of the service economy in Europe: A foresight analysis. *Technological Forecasting and Social Change*, *94*, 80–96. https://doi.org/10.1016/j.techfore.2014.06.009

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology Analysis & Strategic Management*, *17*(4), 445–476. https://doi.org/10.1080/09537320500357319

Geels, F. W. (2006). Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet (1930–1970). *Technovation*, *26*(9), 999–1016. https://doi.org/10.1016/j.technovation.2005.08.010

Grimm, A., & Walz, R. (2024). Current and future roles of the automotive and ICT sectoral systems in autonomous driving—Using the innovation system approach to assess value chain transformation. *Technological Forecasting and Social Change*, *198*, 122990. https://doi.org/10.1016/j.techfore.2023.122990

Hegerty, S. W., & Weresa, M. (2023). The determinants of innovative capacity in the medical sector in Central Europe and across the European Union. *Technological and Economic Development of Economy*, *29*(1), Article 1. https://doi.org/10.3846/tede.2022.17737

Intarakumnerd, P., & Chaoroenporn, P. (2013). The roles of intermediaries in sectoral innovation system in developing countries: Public organizations versus private organizations. *Asian Journal of Technology Innovation*, *21*(1), 108–119. https://doi.org/10.1080/19761597.2013.810949

Intarakumnerd, P., & Gerdsri, N. (2014). Implications of Technology Management and Policy on the Development of a Sectoral Innovation System: Lessons Learned Through the Evolution of Thai Automotive Sector. *International Journal of Innovation and Technology Management*, *11*(03), 1440009. https://doi.org/10.1142/S0219877014400094

Iyer, C. G. (2016). Impact of entrepreneur on the sectoral system of innovation: Case study of the Indian crude oil refining industry. *Technological Forecasting and Social Change*, *102*, 102–111. https://doi.org/10.1016/j.techfore.2015.02.019

Jarský, V. (2015). Analysis of the sectoral innovation system for forestry of the Czech Republic. Does it even exist? *Forest Policy and Economics*, *59*, 56–65. https://doi.org/10.1016/j.forpol.2015.05.012

Kang, D.-I., & Choung, J.-Y. (2023). Repercussions of innovation actors' pursuit of institutional transition: Evidence from emerging innovations in Korea. *Technology Analysis & Strategic Management*, *35*(2), 194–207. https://doi.org/10.1080/09537325.2021.1971189

Kern, F., & Markard, J. (2016). Analysing Energy Transitions: Combining Insights from Transition Studies and International Political Economy. In T. Van de Graaf, B. K. Sovacool, A. Ghosh, F. Kern, & M. T. Klare (Eds.), *The Palgrave Handbook of the International Political Economy of Energy* (pp. 291–318). Palgrave Macmillan UK. https://doi.org/10.1057/978-1-137-55631-8_12

Kim, J.-S., & Flanagan, K. (2024). The use of foresight to anticipate and prioritise innovation system failures: The case of machine learning in broadcasting in South Korea. *Futures*, *163*, 103454. https://doi.org/10.1016/j.futures.2024.103454

Kim, Y.-Z., & Lee, K. (2008). Sectoral Innovation System and a Technological Catch-up: The Case of the Capital Goods Industry in Korea. *Global Economic Review*, *37*(2), 135–155. https://doi.org/10.1080/12265080802021151
Klepper, S. (1996). Entry, Exit, Growth, and Innovation over the Product Life Cycle. *American Economic Review*, *86*(3), 562–583. Scopus.
Kristinsson, K., & Rao, R. (2008). Interactive Learning or Technology Transfer as a Way to Catch-Up? Analysing the Wind Energy Industry in Denmark and India. *Industry and Innovation*, *15*(3), 297–320. https://doi.org/10.1080/13662710802040903
Kubeczko, K., Rametsteiner, E., & Weiss, G. (2006). The role of sectoral and regional innovation systems in supporting innovations in forestry. *Forest Policy and Economics*, *8*(7), 704–715. https://doi.org/10.1016/j.forpol.2005.06.011
Landini, F., Lema, R., & Malerba, F. (2020). Demand-led catch-up: A history-friendly model of latecomer development in the global green economy. *Industrial and Corporate Change*, *29*(5), 1297–1318. https://doi.org/10.1093/icc/dtaa038
Lee, K. (2019). *The Art of Economic Catch-Up: Barriers, Detours and Leapfrogging in Innovation Systems*. Cambridge University Press. https://doi.org/10.1017/9781108588232
Lee, K., & Malerba, F. (2017). Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems. *Research Policy*, *46*(2), 338–351. https://doi.org/10.1016/j.respol.2016.09.006
Leeuwen, T. N. V., Visser, M. S., Moed, H. F., Nederhof, T. J., & Raan, A. F. J. V. (2003). The Holy Grail of science policy: Exploring and combining bibliometric tools in search of scientific excellence. *Scientometrics*, *57*(2), 257–280. https://doi.org/10.1023/A:1024141819302
Li, D., Capone, G., & Malerba, F. (2019). The long march to catch-up: A history-friendly model of China's mobile communications industry. *Research Policy*, *48*(3), 649–664. https://doi.org/10.1016/j.respol.2018.10.019
Lundvall, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter.
Magnusson, T., & Berggren, C. (2018). Competing innovation systems and the need for redeployment in sustainability transitions. *Technological Forecasting and Social Change*, *126*, 217–230. https://doi.org/10.1016/j.techfore.2017.08.014
Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, *31*(2), 247–264. https://doi.org/10.1016/S0048-7333(01)00139-1
Malerba, F. (2004). *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*. Cambridge University Press.
Malerba, F. (2005). Sectoral systems of innovation: A framework for linking innovation to the knowledge base, structure and dynamics of sectors. *Economics of Innovation and New Technology*, *14*(1–2), 63–82. https://doi.org/10.1080/1043859042000228688
Malerba, F. (2018). Moving Forward in Sectoral Systems Research: Taxonomies, Evolution and Modelling. In J. Niosi (Ed.), *Innovation Systems, Policy and Management* (pp. 27–52). Cambridge University Press. https://doi.org/10.1017/9781108529525.003
Malerba, F., & McKelvey, M. (2019). Knowledge-Intensive Innovative Entrepreneurship. *Foundations and Trends® in Entrepreneurship*, *14*(6), 555–681. https://doi.org/10.1561/0300000075

Malerba, F., & Nelson, R. (2011). Learning and catching up in different sectoral systems: Evidence from six industries. *Industrial and Corporate Change*, *20*(6), 1645–1675. https://doi.org/10.1093/icc/dtr062

Malerba, F., & Orsenigo, L. (1993). Technological Regimes and Firm Bebavior. *Industrial and Corporate Change*, *2*(1), 45–71. https://doi.org/10.1093/icc/2.1.45

Malerba, F., & Orsenigo, L. (1997). Technological Regimes and Sectoral Patterns of Innovative Activities. *Industrial & Corporate Change*, *6*(1), 83–117. https://doi.org/10.1093/icc/6.1.83

Malhotra, A., Schmidt, T. S., & Huenteler, J. (2019). The role of inter-sectoral learning in knowledge development and diffusion: Case studies on three clean energy technologies. *Technological Forecasting and Social Change*, *146*, 464–487. https://doi.org/10.1016/j.techfore.2019.04.018

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, *37*(4), 596–615. https://doi.org/10.1016/j.respol.2008.01.004

McKelvey, M., Alm, H., & Riccaboni, M. (2003). Does co-location matter for formal knowledge collaboration in the Swedish biotechnology–pharmaceutical sector? *Research Policy*, *32*(3), 483–501. https://doi.org/10.1016/S0048-7333(02)00020-3

Merigó, J. M., Cancino, C. A., Coronado, F., & Urbano, D. (2016). Academic research in innovation: A country analysis. *Scientometrics*, *108*(2), 559–593. https://doi.org/10.1007/s11192-016-1984-4

Meuer, J., Rupietta, C., & Backes-Gellner, U. (2015). Layers of co-existing innovation systems. *Research Policy*, *44*(4), 888–910. https://doi.org/10.1016/j.respol.2015.01.013

Nelson, R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press.

Nikas, A., Doukas, H., Lieu, J., Tinoco, R. A., Charisopoulos, V., & Gaast, W. van der. (2017). Managing stakeholder knowledge for the evaluation of innovation systems in the face of climate change. *Journal of Knowledge Management*, *21*(5), 1013–1034. https://doi.org/10.1108/JKM-01-2017-0006

Niosi, J. (2011). Complexity and path dependence in biotechnology innovation systems. *Industrial and Corporate Change*, *20*(6), 1795–1826. https://doi.org/10.1093/icc/dtr065

Patana, A.-S., Pihlajamaa, M., Polvinen, K., Carleton, T., & Kanto, L. (2012). Qualitative evaluation of the finnish life science innovation system with comparison to the San Francisco Bay Area. *2012 Proceedings of PICMET '12: Technology Management for Emerging Technologies*, 3083–3094. https://ieeexplore.ieee.org/abstract/document/6304326

Persson, O., Danell, R., & Schneider, J. W. (2009). How to use Bibexcel for various types of bibliometric analysis. *Celebrating Scholarly Communication Studies: A Festschrift for Olle Persson at His 60th Birthday*, 9–24.

Proksch, D., Busch-Casler, J., Haberstroh, M. M., & Pinkwart, A. (2019). National health innovation systems: Clustering the OECD countries by innovative output in healthcare using a multi indicator approach. *Research Policy*, *48*(1), 169–179. https://doi.org/10.1016/j.respol.2018.08.004

Rakas, M., & Hain, D. S. (2019). The state of innovation system research: What happens beneath the surface? *Research Policy*, *48*(9), 103787. https://doi.org/10.1016/j.respol.2019.04.011

Rametsteiner, E., & Weiss, G. (2006). Innovation and innovation policy in forestry: Linking innovation process with systems models. *Forest Policy and Economics*, *8*(7), 691–703. https://doi.org/10.1016/j.forpol.2005.06.009

Rikap, C. (2022). Becoming an intellectual monopoly by relying on the national innovation system: The State Grid Corporation of China's experience. *Research Policy*, *51*(4), 104472. https://doi.org/10.1016/j.respol.2021.104472

Rogge, K. S., & Hoffmann, V. H. (2010). The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany. *Energy Policy*, *38*(12), 7639–7652. https://doi.org/10.1016/j.enpol.2010.07.047

Saritas, O., & Nugroho, Y. (2012). Mapping issues and envisaging futures: An evolutionary scenario approach. *Technological Forecasting and Social Change*, *79*(3), 509–529. https://doi.org/10.1016/j.techfore.2011.09.005

Savory, C., & Fortune, J. (2014). An emergent sectoral innovation system for healthcare services. *International Journal of Public Sector Management*, *27*(6), 512–529. https://doi.org/10.1108/IJPSM-03-2014-0036

Schlaile, M. P., Urmetzer, S., Blok, V., Andersen, A. D., Timmermans, J., Mueller, M., Fagerberg, J., & Pyka, A. (2017). Innovation Systems for Transformations towards Sustainability? Taking the Normative Dimension Seriously. *Sustainability*, *9*(12), Article 12. https://doi.org/10.3390/su9122253

Small, H., Boyack, K. W., & Klavans, R. (2014). Identifying emerging topics in science and technology. *Research Policy*, *43*(8), 1450–1467. https://doi.org/10.1016/j.respol.2014.02.005

Smith, H., & Romeo, S. (2016). Regional Environments and Sector Developments: The Biotech Sector in Oxfordshire. *Journal of the Knowledge Economy*, *7*(4), 905–919. https://doi.org/10.1007/s13132-015-0303-2

Stephan, A., Schmidt, T. S., Bening, C. R., & Hoffmann, V. H. (2017). The sectoral configuration of technological innovation systems: Patterns of knowledge development and diffusion in the lithium-ion battery technology in Japan. *Research Policy*, *46*(4), 709–723. https://doi.org/10.1016/j.respol.2017.01.009

Sun, Y., & Grimes, S. (2015). The emerging dynamic structure of national innovation studies: A bibliometric analysis. *Scientometrics*, *106*(1), 17–40. https://doi.org/10.1007/s11192-015-1778-0

Teh, K., & Roos, G. (2015). A patent perspective of South Australian innovation: An indicator within the regional innovation system story. In *Integrating Innovation: South Australian Entrepreneurship Systems and Strategies* (pp. 63–89). University of Adelaide Press.

Teixeira, A. A. C. (2014). Evolution, roots and influence of the literature on National Systems of Innovation: A bibliometric account. *Cambridge Journal of Economics*, *38*(1), 181–214. https://doi.org/10.1093/cje/bet022

Thitinunsomboon, S., Chairatana, P., & Keeratipibul, S. (2008). Sectoral innovation systems in agriculture: The case of rice in Thailand. *Asian Journal of Technology Innovation*, *16*(1), 83–100. https://doi.org/10.1080/19761597.2008.9668648

Truffer, B., & Coenen, L. (2012). Environmental Innovation and Sustainability Transitions in Regional Studies. *Regional Studies*, *46*(1), 1–21. https://doi.org/10.1080/00343404.2012.646164

Tuncel, C. O., & Polat, A. (2016). Sectoral System of Innovation and Sources of Technological Change in Machinery Industry: An Investigation on Turkish Machinery Industry1. *Procedia - Social and Behavioral Sciences*, *229*, 214–225. https://doi.org/10.1016/j.sbspro.2016.07.131

Turovets, J., Proskuryakova, L., Starodubtseva, A., & Bianco, V. (2021). Green Digitalization in the Electric Power Industry. *Foresight and STI Governance*, *15*(3), Article 3. https://doi.org/10.17323/2500-2597.2021.3.35.51

Utterback, J. M. (1994). *Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change*. Harvard Business School Press.

van Eck, N. J., & Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

van Leeuwen, T. (2006). The application of bibliometric analyses in the evaluation of social science research. Who benefits from it, and why it is still feasible. *Scientometrics*, *66*(1), 133–154. https://doi.org/10.1007/s11192-006-0010-7

van Raan, A. F. J. (2003). The use of bibliometric analysis in research performance assessment and monitoring of interdisciplinary scientific developments. *Technikfolgenabschätzung-Theorie Und Praxis/Technology Assessment-Theory and Practice*, *1*(12), 20–29.

Van Rooij, A., Berkers, E., Davids, M., & Veraart, F. (2008). National innovation systems and international knowledge flows: An exploratory investigation with the case of the Netherlands. *Technology Analysis & Strategic Management*, *20*(2), 149–168. https://doi.org/10.1080/09537320801931291

Wangwe, S., Simonetti, R., Tibandebage, P., Mackintosh, M., Israel, C., & Mujinja, P. G. M. (2022). Upgrading under globalization in health-related industries in Tanzania: The case for dynamic industrial deepening. *Innovation and Development*, *12*(3), 479–496. https://doi.org/10.1080/2157930X.2021.1886415

Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy*, *41*(6), 1037–1047. https://doi.org/10.1016/j.respol.2011.10.015

Xiong, J., Zhao, S., Meng, Y., Xu, L., & Kim, S.-Y. (2022). How latecomers catch up to build an energy-saving industry: The case of the Chinese electric vehicle industry 1995–2018. *Energy Policy*, *161*, 112725. https://doi.org/10.1016/j.enpol.2021.112725

Zhou, Y., Miao, Z., & Urban, F. (2020). China's leadership in the hydropower sector: Identifying green windows of opportunity for technological catch-up. *Industrial and Corporate Change*, *29*(5), 1319–1343. https://doi.org/10.1093/icc/dtaa039