The structure of an innovation ecosystem: foundations for future research

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Abstract
Purpose – The concept of an innovation ecosystem, based on the idea of business ecosystem, has increasingly grown in the literature on strategy, innovation, and entrepreneurship. However, not all innovation ecosystems have the same architectural models or internal collaboration, and existing research rarely deconstructs an ecosystem of innovation and examines its structure. The objective of this article is to systematize the discussion about the structure of an innovation ecosystem and offer a foundation for future research.
Design/methodology/approach – Using the Web of Science database as the source for the articles, this paper presents a systematic review of the literature on the structure of the innovation ecosystems. The period of analysis spanned from January 1993 to August 2019. Two methods, bibliometric analysis and content analysis, were used to structure the systematic review.
Findings – The results of the content analysis showed that the main classifications related to the structure of an innovation ecosystem are the ecosystem life cycle (birth, expansion, leadership, and self-renewal), the classification according to the ecosystem level (macroscopic, medium, and microscopic), and the layered structure (core–periphery structure, triple-layer structure, triple-layer core–periphery structure, and framework 6C). The results also showed that studies in the field are concentrated around a small group of authors, and few studies have discussed the structure of an ecosystem.
Research limitations/implications – This study includes only peer-reviewed articles from the Web of Science database.
Originality/value – This article contributes to innovation ecosystem theory by exploring the characteristics that influence ecosystem structure. In addition to the theoretical contribution, the triple-layer core–periphery framework and the 6C framework set a benchmark for future research on innovation ecosystems.

Keywords Business ecosystem, Value creation, Bibliometric analysis, Content analysis
Paper type Literature review

1. Introduction
The ecosystem concept has emerged as a promising approach in the literature on strategy, innovation, and entrepreneurship (Gomes *et al.*, 2018). The importance of building an ecosystem has gained prominence in both the strategy and practice of organizations (Adner, 2006). In a world of increasingly specialized organizations, a single organization usually does not have internal resources for the development and implementation of innovation (Adner and Kapoor, 2010; Talmar *et al.*, 2018). Thus, organizations need to rely on the contributions of different stakeholders, internal and external to the institution, to build a value proposition throughout the ecosystem (Talmar *et al.*, 2018).

The term *ecosystem* has been used in a wide variety of contexts outside its original application in biological systems (Autio and Thomas, 2014; Gomes *et al.*, 2018; Moore, 1993). In management, an ecosystem refers to a network of interconnected organizations that are linked to or operate around an organization or a technology platform and that produce valuable goods and services (Autio and Thomas, 2014; Senyo *et al.*, 2019). Moore (1993) first

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used the term to describe a set of producers and users that contribute to the performance of an organization. Subsequently, this basic concept has been applied to the field of innovation management (Adner, 2006), and some authors consider the business ecosystem as a synonym for an innovation ecosystem (Gawer and Cusumano, 2014; Nambisan and Baron, 2013; Overholm, 2015). Gomes *et al.* (2018) presented the main characteristics of and similarities and differences between business ecosystems and innovation ecosystems.

In this sense, the ecosystem of innovation is an emerging and popular concept in academic and industrial circles (Su *et al.*, 2018), which makes it possible to collectively work to enable knowledge flow, support technological development, and generate innovation (Wessner and Affairs, 2007). The innovation ecosystem is composed of different stakeholders, including industry players, the government, associations, customers, and others who inhabit the same scenario and coevolve with each other, appropriating new values through innovation (Autio and Thomas, 2014; Ma *et al.*, 2018; Moore, 1993; Su *et al.*, 2018).

According to Su *et al.* (2018), not all innovation ecosystems have the same architectural models and internal collaboration, and existing research rarely deconstructs an ecosystem of innovation and examines its structure. There needs to be a better understanding of the structure of an ecosystem and its interconnected layers (Guo and Bouwman, 2016; Pombo-Juárez *et al.*, 2017; Rong *et al.*, 2015a; Scaringella and Radziwon, 2018). Examining the internal structure of an ecosystem of innovation can open up a new perspective from which to study its subdimensions (Su *et al.*, 2018).

Given the said data and seeking to offer subsidies for the construction of an innovation ecosystem, this study aims to systematize the discussion on the structure of an innovation ecosystem and its evolution, trends, and gaps. It seeks to answer the following questions: How are innovation ecosystems structured? What are the trends and gaps in research on the structure of innovation ecosystems?

To answer these questions, this article is organized into four sections, following the structure developed by Gomes *et al.* (2018). The second section refers to research methods and explains in detail the methodological procedures of the systematic literature review. In the third section, the main findings are presented, and the structure of an innovation ecosystem is discussed as well as trends and new research opportunities. In the final section, the main conclusions of this paper are presented.

2. Research methods

2.1 Characterization of the research

The systematic literature review performed in this study includes both bibliometric and content analyses. Bibliometric analysis is used to measure and analyze the scientific literature with respect to a specific topic (Okubo, 1997), while content analysis provides a systematic, objective means of producing analyses from verbal, visual, or written data in order to describe and quantify specific phenomena (Downe-Wamboldt, 1992). The combination of bibliometric and content analyses allows us to identify the trends, topics, most discussed fields, and gaps in the literature (Gomes *et al.*, 2018).

2.2 Search procedures

2.2.1 Description of the sample. The articles for analysis were extracted from the Web of Science database, which is maintained by Clarivate Analytics. The Web of Science was chosen for its breadth of research on this subject and also because it offers resources for collecting metadata, including abstracts, authors' information, institutions, number of citations, cited references, and the journal impact factor (Gomes *et al.*, 2018). These are essential for the performance of a bibliometric analysis. To select the articles, the following search criteria were considered: ("innovation ecosystem*" OR "business ecosystem*") AND ("internal structure" OR "framework"). It should be noted that the concept of the innovation ecosystem was built on the constructs of the business ecosystem (Gomes *et al.*, 2018). Therefore, the inclusion of the search term "business ecosystem" was necessary. Figure 1 presents the phases of the systematic review.

The search resulted in 333 studies, categorized in Web of Science by area of research. From this initial sample, the "article" and "review" filters were applied to the "document types," because these documents underwent peer review and had a more complete set of metadata in the Web of Science database (Gomes *et al.*, 2018). Once the results had been refined, the sample resulted in 205 articles. All abstracts of the 205 articles were read, and some were deleted after this analysis. The exclusion criteria considered the fact that certain articles, while containing the topics used in the search, did not address the structure of the ecosystem as a central theme or as part of their theoretical contribution. After reading the abstracts, 144 articles were excluded, leaving a final sample of 61 articles published in 49 journals from January 1993 – with the publication of the first article on the business ecosystem (Moore, 1993) – to August 2019, which was the end date of the research.

2.2.2 Procedures of the bibliometric analysis. As shown throughout the study, some of the results of the analysis of the quantitative data from the 61 sample articles were obtained with the aid of bibliometric analysis tools for descriptive statistics available from the Web of Science. The VOS viewer software (Van Eck and Waltman, 2010) was used to analyze the network of keywords and cocitations. The cocitation network was analyzed to observe citations in the articles and to identify similarities. An analysis of these networks revealed the common themes and interests of research groups.

2.2.3 Content analysis procedures. The content analysis followed the method proposed by Bardin (2016), which includes three key phases: preanalysis; material exploration; and the treatment of results, inferences, and interpretations. In the preanalysis stage, reading occurred as a "floating" first contact with the documents, along with the development of indicators to guide the interpretation and formal preparation of the material. The indicators were defined as follows: area or ecosystem type, innovation or business ecosystem structure, trends, and research gaps in innovation or business ecosystems.

The next phase, material exploration, was conducted through reading all the articles, identifying defined indicators, and creating a scrapbook file. Finally, the results, inferences, and interpretations were conducted as described in Section 3.3.

3. Results and discussions

3.1 Descriptive statistics

One of the results of the bibliometric analysis revealed that seven journals had two or more articles published on the theme; these were responsible for the publication of 31.15 percent of the articles in the sample. Table I shows the number of articles published from January 1993 to August 2019 per journal and per year, as well as the journal impact factor (Journal Citation Reports – JCR) in the year 2018.

Table II presents the articles, the number of citations, and the percentage of citations in relation to the 61 articles identified, sorted by article impact index (A_{IF}). The article impact index (A_{IF}), proposed by Carvalho *et al.* (2013), is calculated based on the number of citations of an article and the JCR impact factor. The article impact index was calculated according to the equation $A_{IF} = \text{citation} \times (\text{JCR} + 1)$.

3.2 Bibliometric analysis

3.2.1 Network of keywords. The network of keywords (Figure 2) was used to identify concepts related to the structure of the innovation ecosystem. Keywords that were mentioned in the same article were linked, and the strength of the links between the keywords corresponded to

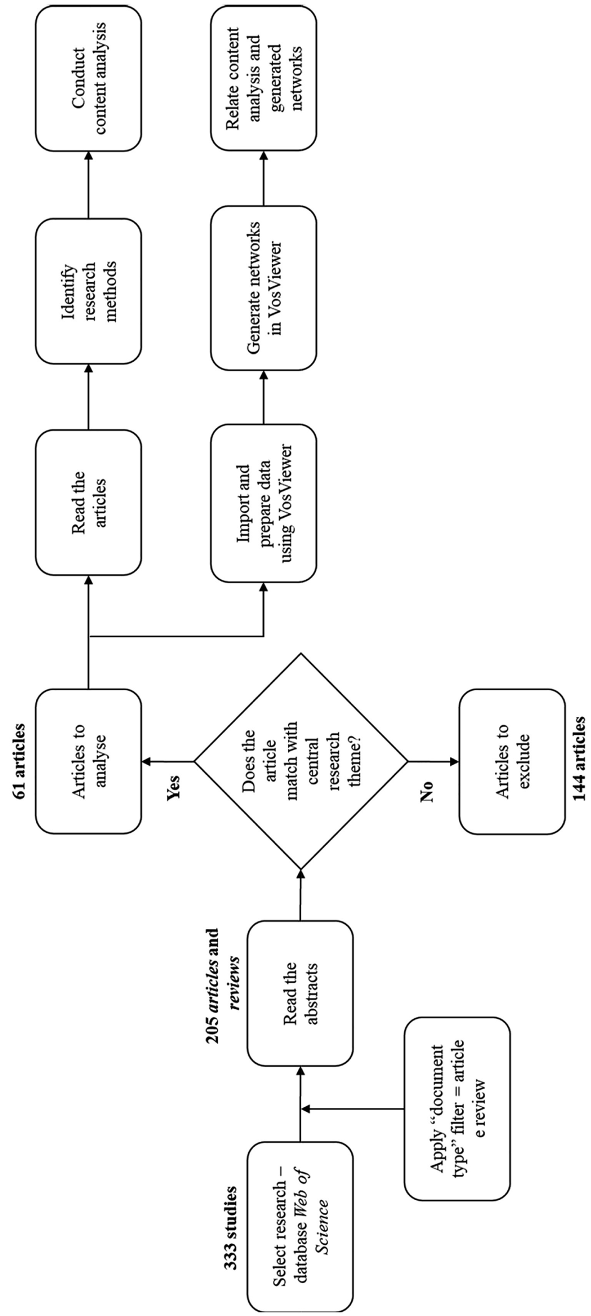

Figure 1.
Stages of the systematic review

Table I. Number of articles per journal per year (January 1993 to August 2019)

Journal	JCR (2018)	1993	2006	2008	2009	2011	2013	2014	2015	2016	2017	2018	2019	Total
Technological forecasting and social change	3.815									1	2	4		7
Industrial management and data systems	3.727								1			1		2
International journal of technology management	1.160							1		1				2
Journal of international management	2.830								1			1		2
Journal of the knowledge economy											2			2
Strategic management journal	5.572		1		1									2
Technology innovation management review										2				2
Asian academy of management journal											1			1
California management review	5.000							1						1
China communications	1.882							1						1
Collaboration and competition in business ecosystems							1							1
Concurrency and computation practice and experience	1.167						1							1
Construction management and economics										1				1
Development southern Africa	0.452											1		1
Enterprise information systems	2.122								1					1
Entrepreneurship theory and practice	6.193		1											1
European planning studies	2.101									1				1
Expert systems with applications	4.292							1						1
Foresight and STI governance											1			1
Harvard business review	5.691	1												1
Human systems management													1	1
IBM systems journal				1										1
IEEE access	4.098												1	1
IEEE transactions on visualization and computer graphics	3.780						1							1
IMP journal												1		1
Industrial marketing management	4.779										1			1
Industry and higher education											1			1
Industry and innovation	3.157												1	1
Information												1		1

(*continued*)

Table I.

Journal	JCR (2018)	1993	2006	2008	2009	2011	2013	2014	2015	2016	2017	2018	2019	Total
Innovation – the European journal of social science research	1.055											1		1
International journal of entrepreneurship and innovation											1			1
International journal of medical informatics	2.731										1			1
International journal of production economics	4.998								1					1
Journal of cleaner production	6.395									1				1
Journal of entrepreneurship in emerging economies											1			1
Journal of heritage tourism												1		1
Journal of international business studies	7.724												1	1
Journal of service theory and practice	2.363										1			1
Management decision	1.963											1		1
Organization science	3.257										1			1
Production planning and control	3.340					1								1
Project management journal	2.043												1	1
R&D management	2.354									1				1
Research policy	5.425							1						1
Science technology and society	0.647												1	1
Sensors	3.031										1			1
Technovation	5.250								1					1
Telecommunications policy	2.000									1				1
Total quality management and business excellence	2.181							1						1
Total		*1*	*2*	*1*	*1*	*1*	*3*	*6*	*5*	*9*	*14*	*12*	*6*	*61*

Title article	Citations	% Citation	JCR (2018)	A_{IF}
Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance	2872	58.28%	5.572	18874.8
Predators and prey – a new ecology of competition	648	13.15%	5.691	4335.8
Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations	522	10.59%	5.572	3430.6
Bridging differing perspectives on technological platforms: toward an integrative framework	177	3.59%	5.425	1137.2
Collaborative networked organizations and customer communities: value cocreation and coinnovation in the networking era	126	2.56%	3.340	546.8
Commentary: a framework for managing the familiness and agency advantages in family firms	57	1.16%	6.193	410.0
Understanding business ecosystem using a 6C framework in Internet of things–based sectors	47	0.95%	4.998	281.9
Collectively created opportunities in emerging ecosystems: the case of solar service ventures	38	0.77%	5.250	237.5
Design of a terminal solution for integration of in-home healthcare devices and services toward the internet-of-things	67	1.36%	2.122	209.2
Chez Panisse: building an open innovation ecosystem	32	0.65%	5.000	192.0
Business ecosystem and stakeholders' role transformation: evidence from Chinese emerging electric vehicle industry	23	0.47%	4.292	121.7
Understanding interfirm relationships in business ecosystems with interactive visualization	22	0.45%	3.780	105.2
An ecosystem service-dominant logic? – integrating the ecosystem service approach and the service-dominant logic	12	0.24%	6.395	88.7
Knowledge transfer in university quadruple helix ecosystems: an absorptive capacity perspective	25	0.51%	2.354	83.9
Nurturing business ecosystems for growth in a foreign market: incubating, identifying, and integrating stakeholders	20	0.41%	2.830	76.6
Network management in the era of ecosystems: systematic review and management framework	13	0.26%	4.779	75.1
Sustaining superior performance in business ecosystems: evidence from application software developers in the iOS and android smartphone ecosystems	14	0.28%	3.257	59.6
Creating the innovation ecosystem for renewable energy via social entrepreneurship: insights from India	11	0.22%	3.815	53.0
Analyzing technological convergence trends in a business ecosystem	11	0.22%	3.727	52.0
Exploring innovation ecosystems across science, technology, and business: a case of 3D printing in China	10	0.20%	3.815	48.2
The sharing economy globalization phenomenon: a research agenda	12	0.24%	2.830	46.0
Insights for orchestrating innovation ecosystems: the case of EIT ICT labs and data-driven network visualizations	18	0.37%	1.160	38.9
Open IoT ecosystem for enhanced interoperability in smart cities – example of metropole De Lyon	7	0.14%	3.031	28.2
Innovation, entrepreneurial, knowledge, and business ecosystems: old wine in new bottles?	5	0.10%	3.815	24.1
Wiring up multiple layers of innovation ecosystems: contemplations from personal health systems foresight	5	0.10%	3.815	24.1
Fuzzy front end of systemic innovations: a conceptual framework based on a systematic literature review	5	0.10%	3.815	24.1

(continued)

Table II. List of 61 articles with number of citations, JCR impact factor, and article impact index (A_{IF})

Title article	Citations	% Citation	JCR (2018)	A_{IF}
An analytical framework for an m-payment ecosystem: a merchants' perspective	8	0.16%	2.000	24.0
BSNet: a network-based framework for service-oriented business ecosystem management	11	0.22%	1.167	23.8
The platform business model and business ecosystem: quality management and revenue structures	7	0.14%	2.101	21.7
Beam: a framework for business ecosystem analysis and modeling	20	0.41%		20.0
The organization of innovation in ecosystems: problem framing, problem solving, and patterns of coupling	18	0.37%		18.0
Adapting and sustaining operations in weak institutional environments: a business ecosystem assessment of a Chinese MNE in central Africa	2	0.04%	7.724	17.4
Service quality management and ecosystem theory	5	0.10%	2.181	15.9
Business analysis for a sustainable, multistakeholder ecosystem for leveraging the electronic health records for clinical research (EHR4CR) platform in Europe	4	0.08%	2.731	14.9
Searching through the jungle of innovation conceptualizations system, network, and ecosystem perspectives	3	0.06%	2.363	10.1
Applicability and benefits of the ecosystem concept in the construction industry	10	0.20%		10.0
A multiplatform collaboration innovation ecosystem: the case of China	3	0.06%	1.963	8.9
The business ecosystem concept in innovation policy context: building a conceptual framework	4	0.08%	1.055	8.2
Managing innovation ecosystems to create and capture value in ICT industries	7	0.14%		7.0
Small town entrepreneurial ecosystems implications for developed and emerging economies	5	0.10%		5.0
The balanced development of the spatial innovation and entrepreneurial ecosystem based on principles of the systems compromise: a conceptual framework	5	0.10%		5.0
Architecture and evolvability of innovation ecosystems	1	0.02%	3.815	4.8
Establishing a CoPs-based innovation ecosystem to enhance competence – the case of CGN in China	2	0.04%	1.160	4.3
Entrepreneurial activity in postsocialist countries: methodology and research limitations	4	0.08%		4.0
Profiling regional innovation ecosystems as functional collaborative systems: the case of Cambridge	3	0.06%		3.0
A dynamic approach to the start-up business ecosystem: a cross-comparison of Korea, China, and Japan	2	0.04%		2.0
A transaction-based approach to social innovation	2	0.04%		2.0
Learning from global pacesetters to build the country innovation ecosystem	2	0.04%		2.0
The impact of local government policy on innovation ecosystem in knowledge resource scarce region: case study of Changzhou, China	1	0.02%	0.647	1.6
Changes of mobile Internet ecosystem structure and suggestions for regulatory policy	0	0.00%	1.882	0.0
Developing a local innovation ecosystem through a university coordinated innovation platform: the University of Fort Hare	0	0.00%	0.452	0.0
Toward a service-innovation ecosystem of enterprises in China	0	0.00%		0.0

Table II. (*continued*)

Title article	Citations	% Citation	JCR (2018)	A_{IF}
Analysis of the dynamism in university-driven innovation ecosystems through the assessment of entrepreneurship role	0	0.00%	4.098	0.0
The role of actors in interactions between "innovation ecosystems": drivers and implications	0	0.00%		0.0
Platform-based service innovation and system design: a literature review	0	0.00%	3.727	0.0
University–industry cooperation and the transition to innovation ecosystems in Japan	0	0.00%		0.0
The diffusion of a policy innovation in the energy sector: evidence from the collective switching case in Europe	0	0.00%	3.157	0.0
Modeling and visualizing smart city mobility business ecosystems: insights from a case study	0	0.00%		0.0
Toward a smart tourism business ecosystem based on industrial heritage: research perspectives from the mining region of Rio Tinto, Spain	0	0.00%		0.0
Projects in the business ecosystem: the case of short sea shipping and logistics	0	0.00%	2.043	0.0
Business models dynamics and business ecosystems in the emerging 3D printing industry	0	0.00%	3.815	0.0

Table II.

the intensity of their relationship. The keywords with the highest occurrence included "innovation" (with 20 occurrences and 229 connections), "business ecosystem" (with 17 occurrences and 205 connections), and "technology" (with 16 occurrences and 216 connections). The main connections with innovation included "value creation," "performance," "framework," and "ecosystem." Connections related to business ecosystems included "strategy," "innovation ecosystem," "ecology," and "management." The main keyword links related to ecosystem structure included "framework," "platform," and "model."

Figure 2a shows all 449 identified keywords and their links. To generate this network, cooccurrence analysis was conducted using the VOSviewer software, which determines the relationship between items based on the number of documents in which they occur together. For better visualization, Figure 2b shows only keywords that had at least three occurrences (47 keywords total).

3.2.2 Cocitation network. The cocitation network (Figure 3) was analyzed to identify similarities between the articles, noting whether the articles cited the same references, which might reveal common interests among the research groups. The cocitation analysis was performed with the VOSviewer software, which determines the relatedness of items based on the number of times they are cited together.

Figure 3a shows the complete cocitation network generated from the 61 articles studied. In all, 2766 authors were identified. To better visualize the relationship between the main authors, a new network (Figure 3b) was created with authors who had more than nine citations, which accounted for 47 authors. A cocitation network provides knowledge of the most relevant references for research on a particular subject. Through analyzing the number of citations, it was observed that many ecosystem scholars (Adner, 2006; Chesbrough *et al.*, 2014; Iansiti and Levien, 2004; Rong *et al.*, 2015a; Teece, 2007) built their studies based on Moore (1993).

3.3 Content analysis

3.3.1 Ecosystem structure. This section discusses the evolution, main features, and structure of ecosystems, business ecosystems, and ecosystems of innovation. The 61 articles are analyzed further.

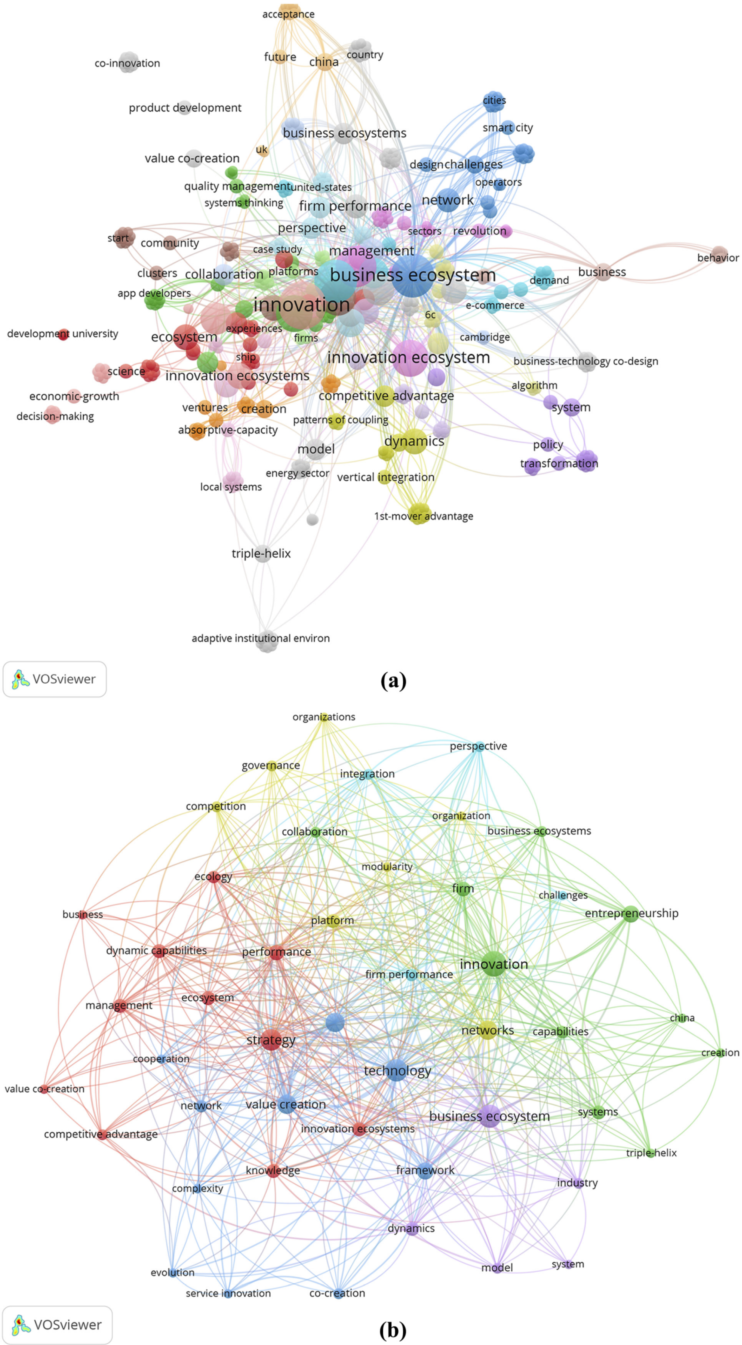

Figure 2.
Keyword network: (a) total of 449 keywords; (b) 47 keywords with three or more occurrences

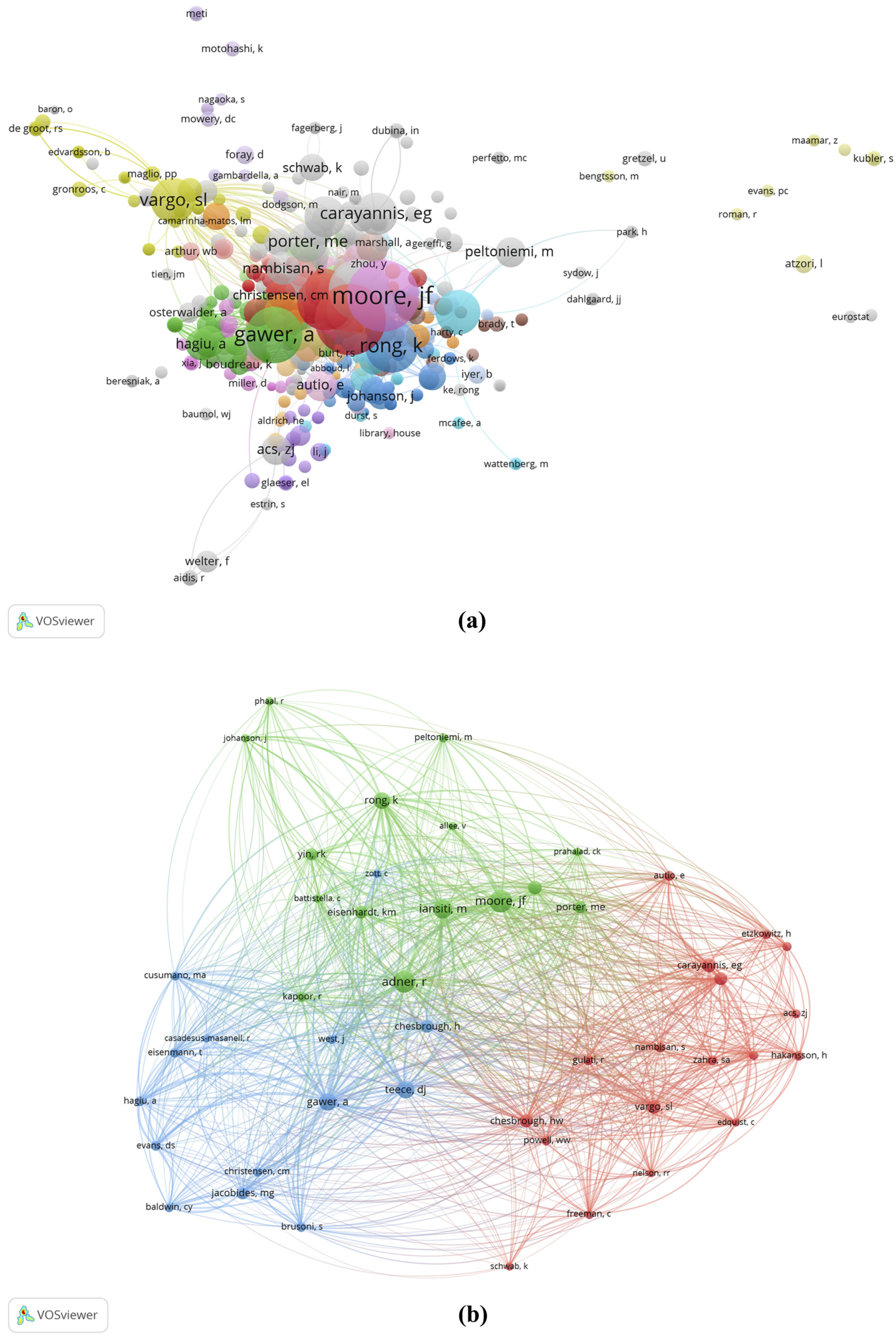

Figure 3.
Authors' cocitation network: (a) complete network; (b) authors with more than nine citations

Describing the structure of an ecosystem is not an easy task, and few studies have discussed the different functions and their internal collaborations (Su *et al.*, 2018). Existing research rarely deconstructs an innovation ecosystem and examines its subdimensions (Su *et al.*, 2018). If one were to look inside an innovation ecosystem, one might observe that not all such ecosystems have the same architecture and internal collaboration models (Su *et al.*, 2018).

Several papers dealt with ecosystem development but did not detail the ecosystem's internal structures. For example, these papers touched on Finland's development of a national ecosystem of successful innovation (Khorsheed, 2017); business ecosystems for high-tech start-ups in Korea, China, and Japan, using a dynamic approach (Lee *et al.*, 2017); the concept of a social innovation ecosystem (Slimane and Lamine, 2017); and developments in university–industry collaboration in the political formation of the innovation ecosystem in Japan (Ranga *et al.*, 2017). Other works focused on the discussion of collaboration between ecosystems and on the mechanisms of interaction (Dubina *et al.*, 2017; Pellikka and Ali-Vehmas, 2016).

Building a sufficiently open and modular architecture is essential to facilitate innovation across the ecosystem (Pellikka and Ali-Vehmas, 2016). Relationships within an innovation ecosystem transcend a traditional value chain due to the interactions between suppliers, partners, and consumers; further, ecosystems can be both tangible (monetary) and intangible (cultural and social) (Su *et al.*, 2018). In this context, considering the content analysis, the main elements and proposals identified in the studied articles, which influence the structure of an ecosystem, included the life cycle of the ecosystem, the classification according to the ecosystem level, and layered structures.

3.3.2 Life cycle of the ecosystem. The business ecosystem evolves in four distinct stages: birth, expansion, leadership, and self-renewal; this is called the business ecosystem life-cycle model (Chen *et al.*, 2014; Moore, 1993). In the early stages, companies and stakeholders are still organizing and discovering the best ways to create and capture value as new regulations are being implemented (Parente *et al.*, 2018). In the later stages, industry and the regulations around it have been established, and components have created barriers to entry due to technological leadership and wide market adoption (Parente *et al.*, 2018).

The business ecosystem literature addresses ecosystem structure and strategies throughout the business life cycle (Adner and Kapoor, 2010; Chen *et al.*, 2014; Moore, 1993). However, these authors did not address the process of interaction and transformation during the life cycle (Lu *et al.*, 2014; Rong *et al.*, 2015b). Lu *et al.* (2014) developed a conceptual model to analyze the relationship and interaction between different types of ecosystem agents and to optimize the behavior of the whole system.

The model of the business ecosystem life cycle is designed for established industries rather than for those that are emerging (Rong *et al.*, 2015b). Emerging innovation ecosystems are often composed of fragmented development communities, major market barriers, and duplication of effort (Pombo-Juárez *et al.*, 2017). Seeking to meet the emerging industries, a sequential model of triple nurturing was developed, composed of the following business ecosystem nutrition structures: incubating complementary partners (the main company works to incubate a favorable environment for the marketing of its products), identifying leading partners (the main company identifies the leading partners among the main industry or small companies, with strong business potential), and integrating ecosystem partners (encouraging a complementary partner ecosystem to work together) (Rong *et al.*, 2015b).

Letaifa (2014) analyzed the ecosystem life cycle in terms of value creation and capture in four phases: (1) birth requires a high level of cooperation and low-value capture; (2) the ecosystem expands and develops, with high-value cocreation and high-value capture; (3) the ecosystem is mature, with low-value creation and high-value capture; (4) this phase heralds the death of an ecosystem with low-value creation and capture. Cocreation of value drives the development of the business ecosystem (Tsou *et al.*, 2019).

3.3.3 Ecosystem level. Innovation ecosystems can be classified as macroscopic (collaborating at a national level), medium (focusing on the ecosystem of industrial or regional innovation), and microscopic (analyzing activities at the organizational level) (Su *et al.*, 2018). Pombo-Juárez *et al.* (2017) classified innovation ecosystems at local, regional, national, and international levels.

At the macro or national level, the creation of ecosystems requires the establishment of new government institutions, new policies and regulations to generate demand, and institutional support of bonds that promote new interactions and dissemination capabilities (Surie, 2017). Similarly, at the micro level, the main mechanisms of the ecosystem include the entry of social entrepreneurship organizations, technology platforms that disseminate entrepreneurship skills and multiply the level of interactions in the community, and external organizations that provide access to additional resources (Surie, 2017).

In this context, Roundy (2017) introduced the concept of entrepreneurial ecosystems in small towns, with seven elements that constituted the ecosystems: capital, markets, networks, support, culture, finance, and politics. The dimensions, also referred to as the pillars of entrepreneurial ecosystems, can be used as a framework to examine and compare the different components of ecosystem entrepreneurs (Roundy, 2017).

Ecosystems can also evolve from one level to another. For example, the Chez Panisse restaurant, which was initially built as a local ecosystem, now has global reach using an open innovation strategy with stakeholders such as suppliers, chefs, and officials, among others (Chesbrough *et al.*, 2014). The ability to expand or update the ecosystem is described by Pombo-Juárez *et al.* (2017) as having three subdimensions for scalability: input scalability (which makes it possible to involve varying amounts of contribution from a variable number of stakeholders), geographic scalability (which allows stakeholder engagement, regardless of the geographical distance between them), and scalability administration (which allows transitions between different levels).

3.3.4 Structure in layers. Innovation ecosystems arise or are created around a central node, such as a technology platform or sometimes a set of social or economic conditions that attract key players (Gawer, 2014; Su *et al.*, 2018; Teece, 2007). This structure is known as the core–periphery structure, which is comprised of a focal company and peripheral actors who constitute an innovation ecosystem (Su *et al.*, 2018).

In order to better understand the functioning mechanism of the innovation ecosystem, some authors, based on the work of Moore (1993), have used or referenced a triple-layered structure (Chen *et al.*, 2016; Guo and Bouwman, 2016; Habbershon, 2006; Letaifa, 2014; Perfetto and Vargas-Sánchez, 2018; Rong *et al.*, 2015a; Tian *et al.*, 2008). Perfetto and Vargas-Sánchez (2018) presented an industrial tourism business ecosystem made up of three layers: the central layer of business, consisting of the parts that form the heart of the business; the business layer, which broadens the vision of the business supply chain to include customers and suppliers as well as regulatory bodies in the specific field or related industry; and the last layer, which adds trade associations, unions, universities and other research bodies, investors, and other stakeholders to the business ecosystem.

Tian *et al.* (2008) also developed the service ecosystem architecture in three layers: the main layer, the modeler, which provides a way to describe the service ecosystem entities and the relationships between them (i.e. the network structure); a layer that simulates the dynamics of the ecosystem of services; and a service analysis layer. Guo and Bouwman (2016) constructed a three-layer m-payment ecosystem: the core business layer, including merchants as major contributors; the extended network layer, including suppliers; and the business ecosystem layer, including competitors, trade associations, labor unions, government agencies, and other regulatory bodies.

As discussed earlier, both the core–periphery structure and the three-tier structure are very instructive. However, these two structures have their limitations (Su *et al.*, 2018). In order to minimize these limitations, Su *et al.* (2018) combined the two structures and proposed a new triple-layer core–periphery structure for the business innovation ecosystem. In the triple-layer core–periphery structure, a central enterprise (core/core layer) can build some innovation platforms (platform layer) with diverse functions that connect different peripheral actors (development and application layer/periphery). The growth of innovation is driven by intensive interactions and collaborations between platforms (Su *et al.*, 2018). This allows for a systematic analysis of the innovation ecosystem and illustrates cross-platform collaboration.

Rong *et al.* (2015a) proposed a framework for understanding how an Internet of Things–based business ecosystem works. This structure was named 6C: context establishes the main characteristics for ecosystem development; construct defines the supporting infrastructure of a business ecosystem; configuration describes configuration patterns and external relationships between partners in the business ecosystem; cooperation reflects the collaboration mechanisms and governance system of the business ecosystem; capacity investigates key ecosystem success resources; and change occurs when the ecosystem is renewed into a new configuration pattern. Blasi and Sedita (2019) adopted the 6C framework to identify differences in the structure and behavior of energy business ecosystems.

3.3.5 Trends and gaps related to ecosystem structure: research agenda. The analyses carried out in this article were used to identify the main areas of research, articles on the topic, and the most cited authors. To do so, results of the bibliometric and content analyses were used, and some gaps and tendencies in the literature related to the structure of the ecosystem were identified.

The ecosystem scenarios raise a new set of issues for researchers to consider. Given the trend of using keywords in recent years, choices about business models and organizational designs need to be revisited in light of joint value creation (Adner and Kapoor, 2010). The hidden power of a business ecosystem lies in its dynamic mechanism, which makes it possible to transform a passive social network into an active chain of value creation (Rong *et al.*, 2015b).

With respect to more global aspects, future work should develop research and data collection methods to understand ecosystem-based business and innovation activities and their management (Aarikka-Stenroos and Ritala, 2017). Research is also still scarce on the internationalization of firms using a business ecosystem perspective (Rong *et al.*, 2015b), and future research could provide insights relevant to this important research flow (Parente *et al.*, 2018).

Future work should also allow the integration of data into the ecosystem to design and support more advanced and intelligent services (Robert *et al.*, 2017) as well as discuss actor behavior, value sharing, and the ecosystem coevolution process (Jing, 2014). Scaringella and Radziwon (2018) suggested studying ecosystem renewal and how they reinvent themselves to be sustainable in the long run.

Finally, in addition to the business context, the application of the innovation ecosystem within universities is still scarce (Grobbelaar, 2018). Future research should also assess the efficiency and cost reduction impacts of administrative innovations in procurement, human resources, and technology in the public sector (Sant'Ana *et al.*, 2019). Exploration of how social ecosystems work in comparison with commercial ecosystems is needed to promote social entrepreneurship and improve technology diffusion and empowerment (Slimane and Lamine, 2017; Surie, 2017).

4. Conclusion

The purpose of this article was to systematize the discussion on the structure of innovation ecosystems and their challenges and trends. A systematic review of the literature was applied using a hybrid methodology comprising bibliometric analysis and content analysis and covering the period from January 1993 to August 2019.

Descriptive statistics from the bibliometric analysis on ecosystem structure indicated that the 61 selected articles were published in 49 journals, with seven publications in the journal *Technological Forecasting and Social Change*. The articles had approximately 80 citations on average, and the most cited were Teece (2007) with 2872 citations, Moore (1993) with 648 citations, and Adner and Kapoor (2010) with 522 citations.

In the network analysis, the keyword network identified 449 keywords in total, with innovation (20 occurrences), business ecosystem (17 occurrences), and technology (16 occurrences) as the three most used keywords. The analysis of the cocitation network demonstrated that the literature remains concentrated around a small number of authors, notably Moore (1993) with 62 citations, Adner (2006) with 60 citations, Iansiti and Levien (2004) with 44 citations, and Teece (2007) and Gawer (2014) with 38 citations each.

The results of this work showed that few studies have discussed the structure of an innovation ecosystem. The existing research rarely deconstructed an ecosystem of innovation and analyzed its subdimensions. Some works focus on the development of the ecosystem and others on the collaboration discussion and ecosystem interaction mechanisms. The construction of open and modular architecture is fundamental for the development of an ecosystem of innovation.

Content analysis revealed that the main classifications related to the structure of an ecosystem of innovation include the life cycle, the level, and the layered structure. In the life cycle, business ecosystems are structured in four stages (i.e. birth, expansion, leadership, and self-renewal). Ecosystem development is driven by innovation ecosystem life-cycle analysis in terms of value creation and capturing. At birth, creation has high value and capture has low value; in expansion, creation and capture have high value; in leadership, the ecosystem is mature, with low-value creation and high-value capture; and self-renewal may generate the death (low-value creation and capture) or renewal (high-value creation and low-value capture) of the ecosystem.

Regarding the level, innovation ecosystems can be macroscopic (national or international), medium (regional), or microscopic (organizational). Ecosystems can evolve from one level to another through three methods: inbound scalability, geographic scalability, and scalability management (which allows transitions between different levels).

As for the layered structure, the following classifications were identified: the core–periphery structure, comprising a focal company and peripheral actors that constitute an innovation ecosystem; the triple-layer structure, consisting of the central layer, platform layer, and development and application layer; and the triple-layer core–periphery structure, where the central node (core/core layer) can build some innovation platforms (platform layer) with various functions that connect different peripheral actors (development and application/periphery layer). The proposal of the triple-layer core–periphery structure for the innovation ecosystem allows for a systematic analysis of the ecosystem and illustrates the collaboration between platforms from their elements and working mechanisms. Finally, the 6C framework sets out the characteristics needed for ecosystem development: context, construct, configuration, cooperation, capacity, and change.

Future work should develop the following questions: Who are the actors in the innovation ecosystem, and how do they communicate, cooperate, and interact? Can the structure of an innovation ecosystem affect its ability to evolve, its performance, or its competitive advantage? What is the structure of an innovation ecosystem for the public sector?

There are some limitations to this study, which are mainly related to the selection criteria of including only peer-reviewed articles from the Web of Science database. Thus, research should investigate other databases.

Finally, this research contributes to innovation ecosystem theory by exploring the characteristics that influence ecosystem structure. In addition to the theoretical contribution, the triple-layer core–periphery framework and the 6C framework set a benchmark for future research on innovation ecosystems, which are becoming increasingly useful for network structuring.

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