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Innovation ecosystems: A conceptual review and a new definition

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ABSTRACT

The concept of innovation ecosystems has become popular during the last 15 years, leading to a debate regarding its relevance and conceptual rigor, not the least in this journal. The purpose of this article is to review received definitions of innovation ecosystems and related concepts and to propose a synthesized definition of an innovation ecosystem. The conceptual analysis identifies an unbalanced focus on complementarities, collaboration, and actors in received definitions, and among other things proposes the additional inclusion of competition, substitutes, and artifacts in conceptualizations of innovation ecosystems, leading to the following definition: *An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*. This definition is compatible with related conceptualizations of innovation systems and natural ecosystems, and the validity of it is illustrated with three empirical examples of innovation ecosystems.

1. Introduction

A systems approach in studies of complex phenomena has a long tradition in a broad range of disciplines. The basic concepts and methodology of the approach have repeatedly been adopted, modified and further developed by new scholarly communities. From time to time this popularity of the approach has resulted in a flurry of derivative concepts, paralleled by popular and less stringent use of them, constituting a phenomenon in itself.[1] In innovation studies, the concept of innovation systems has been widely used, often with different qualifiers such as *national* innovation systems (Freeman, 1987; Lundvall, 1992) or *sectoral* innovation systems (Breschi and Malerba, 1997).

During the last 15 years, the concept of innovation *eco*systems has become popular with a rapidly growing literature (cf. Gomes et al., 2018), typically with a business and strategy origin and focus. This focus is in contrast to the dominant policy and institutional focus in the innovation system literature and the two literature streams have so far been largely disconnected, despite the syntactic closeness of the two concepts. The innovation ecosystem concept has moreover become subject to much debate, not the least in this journal. Oh et al. (2016) criticize the concept with regards to its usefulness and distinctiveness in relation to extant conceptualizations of innovation systems and with regards to the biologically inspired "eco" qualifier and its arguably flawed analogy to natural ecosystems. Ritala and Almpanopoulou (2017) agree with the critique that the concept is used ambiguously, but suggest that the concept may nevertheless provide a useful addition to the conceptualizations of innovation and innovation management, and call for more conceptual and empirical rigor. Finally, Baiyere (2018) observes a limited consensus among researchers about what innovation ecosystems actually are, despite the concept's widespread use. The innovation ecosystem concept has thus become not just a metaphor but also a persuasive definition and an essentially contested concept, calling for a conceptual review and analysis.[2]

This article is an answer to the call for more conceptual rigor and an attempt to increase consensus by providing an explicit definition. The purpose is to analyze the various received definitions of innovation ecosystems and related concepts and to propose a synthesized definition of an innovation ecosystem.

Our approach is inspired by conceptual history studies and literature on methodology for conceptual analysis.[3] In general terms conceptualizations of social behavior should balance generality, simplicity, and accuracy (Weick, 1979). More specifically our proposed definition should fulfill certain requirements such as:

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[1] It is symptomatic of the viability of the approach that it has even been applied to its self-generated phenomenon as elegantly forwarded by Ackoff (1971).

[2] A persuasive definition is "one which gives a new conceptual meaning to a familiar word without substantially changing its emotive meaning, and which is used with the conscious or unconscious purpose of changing, by this means, the direction of people's interests" (Stevenson and Leslie, 1938, p. 331). (The familiar word in our case is 'ecosystem'.) The notion of an essentially contested concept was first introduced by Gallie (1955) and has then stimulated a considerable social science literature on concept formation, analysis and polysemantic usage (e.g., Collier et al., 2006).

[3] For social science areas, see e.g. Weick (1979), Collier et al. (2006), and Podsakoff et al. (2016).

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1. Filling an empirical and/or theoretical need in light of existing concepts
2. Being sufficiently precise, parsimonious, and logically consistent (without circularity)
3. Being possible to operationalize, qualify, typologize and use for taxonomies
4. Being syntactically and semantically compatible with common conceptualizations of related concepts, in our case the concepts system, innovation system and ecosystem

The conceptual analysis will start with the concept of a system and an innovation system and types thereof as dealt with in selected literature, and then proceed to the notion of an ecosystem before focusing on a structured review of received definitions of the innovation ecosystem concept.

2. Conceptualizations of system, innovation, innovation system, and ecosystem

Before moving into the analysis of the extant definitions of innovation ecosystems, we present an overview of the different syntactic components of the innovation ecosystem concept as such, i.e., the concepts of system, innovation, innovation system, and ecosystem.

The system concept: A general concept of a system is that it is composed of a set C of components and a set R of relations among these components. Systems analysis is essentially the exercise to characterize C and R. A common characterization of a dynamic open system is in terms of transformation of inputs into outputs through activities performed by agents or actors interacting with an environment.[4]

The innovation concept: Innovation has a long conceptual history with many fluid connotations and denotations (Godin, 2015). Most contemporary definitions of 'innovation', seen as an outcome of a process, rest on two defining characteristics, a degree of newness of a change and a degree of usefulness or success in application of something new. The concept of 'new' could mean new to world, new to a nation, new to a firm, etc.

The innovation system concept: An explicit systems approach to the studies of innovations was first adopted and developed in the economics and policy literature in the 1990s with some antecedents in the late 1980s.[5] A number of conceptualizations of innovation related systems were introduced, such as national, sectoral, regional and corporate innovation systems, see Table 1 for selected ones. The syntactic structure of the received definitions of innovation systems is by and large: A set of components and the causal relations influencing the generation and utilization of innovations and the innovative performance.

The ecosystem concept: The ecosystem as a concept has its origins in the science of ecology, and it conceptualizes the flow of material and energy. As described by Shaw and Allen (2018, p. 90), it can be defined by "recycling flows of nutrients along pathways made up of living subsystems which are organised into process-orientated roles; connects living and non-living subsystems; energy gradients power recycling of scarce nutrients, e.g. a rainforest".

3. Review of received definitions of innovation ecosystem

The conceptual history of the innovation ecosystem concept differs substantially from the conceptual history of innovation system. The use of the concept took off after the publication of a Harvard Business Review article by Adner (2006), a publication which also provides the probably most widely used definition of innovation ecosystems. He defines an innovation ecosystem as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006, p. 2). The concept has its main roots in the related concept of business ecosystems, as used by Moore (1993) and others.

Several additional attempts to define or describe innovation ecosystems have been made during recent years. With the caveat that there is a somewhat blurred boundary between explicit definitions and descriptions (we have in general been generous in our interpretation of what should be considered a definition), a salient feature of the literature is that much research uses the concept of innovation ecosystems without explicitly defining it. However, in our systematic review of 120 publications on innovation ecosystems and their key references (see Appendix for method), we identified 21 more or less unique definitions, see Table 2.[6]

In the analysis of these definitions, we identified seven different themes of definition components (from here on denoted simply as components), which to different degrees are used for defining innovation ecosystems. The only component that occurs across all 21 definitions is *actors*. This can be contrasted with the *artifact* component (including for example products and technologies), which occurs only in about half of the definitions. The second most common component is *collaboration/complements*, occurring in 16 definitions. Again, this can be contrasted with the *competition/substitute* component, which occurs in only six definitions. The third most common component is *activities*, occurring in 15 definitions. Finally, *institutions* and *co-evolution/co-specialization* are occurring in seven definitions each.

In summary, innovation ecosystem definitions often place emphasis on collaboration/complements and actors, while less commonly so on competition/substitutes and artifacts. Actually, not a single definition includes substitution between artifacts. The concept has become conceptually asymmetrical, which could be argued for if it would have correctly reflected the empirical phenomenon. However, empirical descriptions of innovation ecosystems often identify the importance of not only collaborating but also competing actors (e.g., Rohrbeck et al., 2009; Gawer, 2014; Mantovani and Ruiz-Aliseda, 2016; Hannah and Eisenhardt, 2018) as well as the importance of artifacts (e.g., Carayannis and Campbell, 2009; Nambisan and Baron, 2013) and competing technologies and standards (Arthur, 1989).

Gomes et al. (2018) argue that the innovation ecosystem concept has partly come as a reaction to the value capture and competitive focus that was prevalent in the pre-existing *business* ecosystem literature, and that the innovation ecosystem concept put (more) emphasis on value creation and collaboration. However, in one of the most commonly used references on business ecosystems Moore (1993) actually put equal focus on collaboration and competition: "In a business ecosystem, companies co-evolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations" (p. 76). It seems like the shift from the concept of business ecosystems to innovation ecosystems might have overly shifted focus from

[4] See, e.g., Ackoff (1971) and Von Bertalanffy (1968) for early general references and, e.g., Carlsson et al. (2002) and Ritala and Almpanopoulou (2017) for later ones more closely related to innovation.

[5] If one can speak of some kind of a breakthrough for the systems approach in innovation studies occurring in the 1990s, it might be due to the surge of studies of innovations in general, the quest for meso-level concepts (like industrial clusters, development blocks, regional complexes), the general appeal of the systems approach as used in engineering and the adoption of the systems approach by key opinion leaders in economics and policy analysis. See Granstrand (2000) and Carlsson et al. (2002) for reviews of these concepts and research streams. See also Eklund (2007) for a review and a study of how the innovation system concept became endorsed by OECD and rhetorically adopted and used for political purposes in the case of Sweden.

[6] Notice that by focusing on *innovation* ecosystems we take a more focused approach than, e.g., Gomes et al. (2018) who mix definitions of innovation ecosystems with business ecosystems (e.g., Teece, 2007; Santos and Eisenhardt, 2005; Moore, 1993).

Table 1
Some selected definitions of innovation systems.[a]

Concept:	Definition:	Reference:	Comments:
Innovation system	All important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion and use of innovations.	Edquist (1997, p. 14)	The concept of innovation is not confined to technological innovations.
National innovation system	All parts and aspects of the economic structure and the institutional setup affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place.	Lundvall (1992, p. 12)	Focus on economic causal factors is implied. No explicit confinement to technological innovations, although the examples of subsystems given (incidentally leaving out the R&D system or subsuming it under the production system) indicates that the author has such technological innovations as prime examples. No reference to a nationality concept.
Regional innovation system	The institutional infrastructure supporting innovation within the production structure of a region.	Asheim and Gertler (2005, p. 299)	Geographically oriented innovation system (just as a national one is), motivated by the importance of spatial factors like location and physical proximity in R&D, innovation and diffusion, giving rise to regional clusters and networks with agglomeration economies. Emphasis on a region as a meso-level unit of analysis, however with no explicit definition of what constitutes a region.
Sectoral innovation system	That system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies; such a system of firms is related in two different ways: through processes of interaction and cooperation in artifact-technology development and through processes of competition and selection in innovative and market activities.	Breschi and Malerba (1997, p. 131)	The actor system at the core of the systems concept is confined to firms. Technological innovations are primarily in focus. No explicit mentioning of institutions. Systems boundary is defined in sectoral terms. The definition resembles the one by Carlsson and Stankiewicz (1991) of technological system in a specific industrial area, interpreted as sector. Note the specific mentioning of both competition and collaboration.
Corporate innovation system	The set of actors, activities, resources and institutions and the causal interrelations that are in some sense important for the innovative performance of a corporation or groups of collaborating companies and other actors (e.g. universities, institutes, agencies).	Granstrand (2000, p. 13)	Different groups of components are specified (actors, activities, resources and institutions) to indicate important subsystems like the actor system within and around the corporation involved in innovation.

[a] For additional definitions of a national innovation system, see Freeman (1987, p. 1), Metcalfe (1995), and Nelson and Rosenberg (1993, p. 4). For the related concept technology/technological systems, see Freeman et al. (1982, p. 64), Carlsson and Stankiewicz (1991, p. 111), and Hughes (1994, p. 432).

competition to collaboration. Moreover, substitution among artifacts and resources, including innovative technologies, is more or less left out from received definitions, despite its relevance in natural ecosystems as well as in artificial ones (cf. the Schumpeterian notion of creative destruction).

As mentioned above, conceptualizations of social behavior need to balance generality, simplicity, and accuracy (Weick, 1979). Received definitions and conceptual works have been important for pinpointing new systems aspects of innovation, such as strategies to actively design interfaces to achieve complementary benefits across actors. However, by mainly focusing on collaboration between actors, while often leaving competition and artifacts aside, these definitions have sacrificed too much accuracy to gain simplicity. Consequently they tend to be underspecified and overly general, or in other cases not parsimonious enough, see Table 2.

4. A new definition of innovation ecosystem

There are three recurring entities in the reviewed definitions, namely actors, artifacts, and institutions. In addition, our conceptual review identifies activities and relations, especially including collaborative/complementary and competitive/substitute relations, as well as the co-evolving nature of innovation ecosystems. All of these are important components of the innovation ecosystem concept, as highlighted by different definitions. However, no single definition includes them all in a precise, parsimonious, and logically consistent way. Most importantly, we argue that the components of competitors/substitutes and artifacts (including products, technologies, etc.) are missing in many definitions of innovation ecosystems. Including these components would go well in line with the concept of natural/biological ecosystems, which is the inspiration behind the concept of innovation ecosystems. In natural ecosystems different species often compete for the same resources (be it food, water, or light), and when one resource decreases, species might turn to another, substitute, resource, which could then lead to yet another species being outcompeted. Examples of this are countless in natural ecosystems. Similarly, they are very common in innovation ecosystems (see empirical examples below), albeit still not sufficiently accounted for in extant definitions. Therefore we propose the following definition of an innovation ecosystem:

An *innovation ecosystem* is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.

In this definition artifacts include products and services, tangible and intangible resources, technological and non-technological resources, and other types of system inputs and outputs, including innovations. An innovation ecosystem could in other words include an actor system with collaborative (complementary) and competitive (substitute) relations with or without a focal firm, and an artifact system with complementary and substitute relations.[7] Innovative performance is used rather than innovations or innovativeness in order to include related imitations in the system and to facilitate operationalizations in economic terms, and by so doing also avoid circularity.[8] The more precise meaning of 'importance' and ' innovative performance' is left to operationalizations when called for, which renders some flexibility to the concept, not necessarily at the cost of imprecision. The definition is finally syntactically and semantically compatible with various definitions of innovation systems and ecosystems. In summary, the definition is formally in line with the notion of a

[7] This idea of interconnected actor/artifact/activity subsystems of innovation ecosystems goes well in line with the concept of natural ecosystems, which are typically decomposable into subsystems (Shaw and Allen, 2018).

[8] Note that the term 'innovative performance' is also used by Nelson and Rosenberg (1993).

Table 2
List of definitions of the innovation ecosystem concept (in order of publication year).

Reference and times cited according to Web of Science[a]	Definition/	Actors	Activities	Artifacts	Coevolution/ co-specialization	Collaboration/ complements	Competition/ substitutes	Institutions
Adner (2006, p. 2) Times cited: 292	The collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution.	✓				✓		
Carayannis and Campbell (2009, p. 206) Times cited: 224	A 21st Century Innovation Ecosystem is a multi-level, multi-modal, multi-nodal and multi-agent system of systems. The constituent systems consist of innovation meta-networks (networks of innovation networks and knowledge clusters) and knowledge meta-clusters (clusters of innovation networks and knowledge clusters) as building blocks and organised in a self-referential or chaotic fractal (Gleick, 1987) knowledge and innovation architecture (Carayannis, 2001), which in turn constitute agglomerations of human, social, intellectual and financial capital stocks and flows as well as cultural and technological artifacts and modalities, continually co-evolving, co-specialising, and co-opeting. These innovation networks and knowledge clusters also form, re-form and dissolve within diverse institutional, political, technological and socio-economic domains including Government, University, Industry, Non-governmental Organizations and involving Information and Communication Technologies, Biotechnologies, Advanced Materials, Nanotechnologies and Next Generation Energy Technologies.	✓		✓	✓	✓	✓	✓
Rubens (2014) Times cited: na	We use the term "innovation ecosystems" to refer to the inter-organizational, political, economic, environmental, and technological systems of innovation through which a milieu conducive to business growth is catalysed, sustained and supported. A vital innovation ecosystem is characterized by a continual realignment of synergistic relationships that promote harmonious growth of the system in agile responsiveness to changing internal and external forces.	✓		✓	✓	✓		✓
Jackson (2011, pp. 2, 11) Times cited: na	An innovation ecosystem models the economic rather than the energy dynamics of the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation. In this context, the actors would include the material resources (funds, equipment, facilities, etc.) and the human capital (students, faculty, staff, industry researchers, industry representatives, etc.) that make up the institutional entities participating in the ecosystem (e.g. the universities, colleges of engineering, business schools, business firms, venture capitalists (VC), industry- university research institutes, federal or industrial supported Centers of Excellence, and state and/or local economic development and business assistance organizations, funding agencies, policy makers, etc.). The innovation ecosystem comprises two distinct, but largely separated economies, the knowledge economy, which is driven by fundamental research, and the commercial economy, which is driven by the marketplace. […] The innovation ecosystem consists of the actors, entities, and intangibles.	✓	✓	✓				✓
Nambisan and Baron (2013, pp. 1071–1072) Times cited: 76	An innovation ecosystem refers to a loosely interconnected network of companies and other entities that coevolve capabilities around a shared set of technologies, knowledge, or skills, and work cooperatively and competitively to develop new products and services (Moore, 1993). The three defining characteristics of an innovation ecosystem then are the dependencies established among the members (members' performance and survival are closely linked to those of the ecosystem itself), a common set of goals and objectives (shaped by the ecosystem-level focus on a unique customer value proposition), and a shared set of knowledge and skills (complementary set of technologies and capabilities) (Adner and Kapoor, 2010; Iansiti and Roy, 2004; Teece, 2009).	✓	✓	✓	✓	✓	✓	
Brusoni and Prencipe (2013, p. 168) Times cited: 14	Scholars have proposed the construct of innovation ecosystem to capture the cross-industry and cross-country complexity of the innovation process (see, e.g., Adner, 2006; Iansiti and Levien, 2004; Moore, 1993). Similar to biological ecosystems, innovation ecosystems are inhabited by a variety of different species of actors who share their fate (Moore, 1993). Species operate cooperatively and competitively to create value – that is, they develop and deliver new products, and to capture value – that is, they satisfy customer needs (Adner and Kapoor, 2010). Innovation characterizes the ecosystem in constituting the locus around which species coevolve, and acts as a catalyst for the ecosystem's evolution (Moore, 1993).	✓	✓	✓	✓	✓	✓	

(*continued on next page*)

Table 2 (*continued*)

Reference and times cited according to Web of Science[a]	Definition/	Actors	Activities	Artifacts	Coevolution/ co-specialization	Collaboration/ complements	Competition/ substitutes	Institutions
Still et al. (2014, pp. 3–4) Times cited: 17	Innovation ecosystems, generally seen as entities consisting of organizations and connections between them, have been defined as human networks that generate extraordinary creativity and output on a sustainable basis (Hwang and Horowitt, 2012) and also as consisting of interdependent firms that form symbiotic relationships to create and deliver products and services (Basole and Rouse, 2008). A broader definition sees innovation ecosystems as a network of relationships through which information, talent and financial resources flow through systems, creating sustained value co-creation (Russell et al., 2011), including human networks and firm-level networks as well as the "inter-organizational, political, economic, environmental and technological systems of innovation through which a milieu conducive to business growth is catalysed, sustained and supported" (Russell et al., 2011: p. 3).	✓	✓		✓	✓		
Autio and Thomas (2014) Times cited: na	Hence we define an innovation ecosystem as: a network of interconnected organizations, organised around a focal firm or a platform, and incorporating both production and use side participants, and focusing on the development of new value through innovation.	✓	✓	✓				
Gobble (2014, p. 55) Times cited: 3	Innovation ecosystems are dynamic, purposive communities with complex, interlocking relationships built on collaboration, trust, and co-creation of value and specialising in exploitation of a shared set of complementary technologies or competencies. (p. 55)	✓	✓	✓		✓		
Kukk et al. (2015, p. 48) Times cited: 6	It [innovation ecosystem] is mostly used on an organizational level, to study "the collaborative arrangements through which firms combine their individual offerings (i.e. technologies) into a coherent, customer facing solution" (p. 98) Adner (2006). According to Rubens et al. (2011, p. 1734) a successful innovation ecosystem enables a "goal-focused creation of new goods and services tailored to rapidly evolving market needs (i.e. technologies) with multiple institutions and dispersed individuals for parallel innovations".	✓	✓			✓		✓
Gastaldi et al. (2015, p. 4) Times cited: 8	We define a CI ecosystem as a community of actors interacting as a unique system to produce inter-organisational streams of CI. Drawing on Kapoor and Lee (2013), we recognise that firms are increasingly embedded in networks of interdependent activities carried out by external agents. On the one hand, these interdependencies underlie the ability of firms to appropriate returns from investments in CI (Adner and Kapoor, 2010). On the other hand, firms can exploit these interdependencies to sustain efforts of inter-organisational CI (Stadler et al., 2013). Thus, CI ecosystems require processes characterised by simultaneous cooperation and competition (Afuah, 2009), and an orchestration of the actors involved in the inter-organisational efforts of CI (Dhanaraj and Parkhe, 2006).	✓	✓			✓	✓	
Guerrero et al. (2016, p. 555) Times cited: 20	In this sense, an entrepreneurial and innovation ecosystem could be understood as a set of interconnected actors (potential and existing), entrepreneurial organizations (e.g., firms, venture capitalists, business angels, banks, public sector agencies), innovative organizations (e.g., universities, research centers), and entrepreneurial and innovative processes (e.g., business birth, high growth firms, serial entrepreneurs, degree of entrepreneurial and innovative mentality within firms, and levels of ambition) which formally and informally coalesce to connect, mediate by the government initiatives oriented to the performance of the local entrepreneurial environment (Mason and Brown, 2014, p. 5).	✓	✓			✓		✓
Scozzi et al. (2017, p. 867) Times cited: 3	According to West and Wood (2008) and Chesbrough et al. (2014), an open innovation ecosystem comprises communities of different stakeholders who, linked by competitive as well as cooperative relationships, co-create value by adopting an open approach.	✓	✓			✓	✓	
Bomtempo et al. (2017, p. 221) Times cited: 3	The term innovation ecosystem (Adner and Kapoor, 2010) refers to the set of innovative actors – upstream suppliers, buyers and downstream complementors – normally organised into a network. This set of actors provides products and services in order to create value and enable market diffusion of an innovation produced by a central organization called the leader or focal firm.	✓	✓	✓		✓		
Tamayo-Orbegozo et al. (2017, p. 1365) Times cited: 8	The regional eco-innovation ecosystem is a dynamic system in which organizations influence and are influenced by the interaction of different forces.	✓						

(*continued on next page*)

Table 2 (*continued*)

Reference and times cited according to Web of Science[a]	Definition/	Actors	Activities	Artifacts	Coevolution/ co-specialization	Collaboration/ complements	Competition/ substitutes	Institutions
Dattée, Alexy, and Autio (2018) Times cited: 5	Firms increasingly form 'innovation ecosystems' to implement complex value propositions (e.g. Adner, 2012; Kapoor and Lee, 2013; Nambisan and Baron, 2013; van der Borgh et al., 2012; Williamson and De Meyer, 2012). Defined as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006:98), at the core of an innovation ecosystem, one often finds a technology platform: a set of shared assets, standards, and interfaces that underpins an activity system surrounding it (Gawer, 2014; Thomas et al., 2014).	✓	✓	✓		✓		
Walrave et al. (2018) Times cited: 3	We therefore define an innovation ecosystem as a network of interdependent actors who combine specialized yet complementary resources and/or capabilities in seeking to (a) co-create and deliver an overarching value proposition to end users, and (b) appropriate the gains received in the process.	✓	✓		✓	✓		
Witte et al. (2018, p. 3) Times cited: 2	Innovation ecosystems can be defined as "the large and diverse array of participants and resources that contribute to and are necessary for ongoing innovation in a modern economy" (Massachusetts Technology Collaborative, 2016). Ecosystems include entrepreneurs, investors, re- searchers, venture capitalists, as well as business developers, policy- makers and students.	✓		✓				
Tsujimoto et al. (2018, p. 55) Times cited: 4	Integrating this basic concept, we define the objective of the ecosystem in the field of management of technology and innovation as follows: "To provide a product/service system, a historically self-organized or managerially designed multilayer social network consists of actors that have different attributes, decision principles, and beliefs."	✓		✓				✓
Gomes et al. (2018) Times cited: 6	We proposed a conceptual framework, in which we characterized the innovation ecosystem construct with respect to the following features: an innovation ecosystem is set for the co-creation, or the jointly creation of value. It is composed of interconnected and interdependent networked actors, which includes the focal firm, customers, suppliers, complementary innovators and other agents as regulators. This definition implies that members face cooperation and competition in the innovation ecosystem; and an innovation ecosystem has a lifecycle, which follows a co-evolution process.	✓	✓		✓	✓	✓	✓
Ding and Wu (2018, p. 2) Times cited: 3	This study defined innovation ecosystem as "a network system consisting of the communities of governments, product enterprises, complementary products enterprises, and customers, which interact, communicate, or promote innovation in order to create valuable new products". CNG vehicle innovation ecosystem is defined as a network system consisting of the communities of governments, CNG vehicle product enterprises, CNG complementary products enterprises, and customers, which interact, communicate, or promote innovation in order to create valuable new CNG vehicle products.	✓	✓	✓		✓		
	Count of definitions with included components (out of 21 definitions):	**21**	**15**	**12**	**7**	**16**	**6**	**7**

[a] Publications that are not included in Web of Science are just noted na.

system. It is general, yet reasonably precise and parsimonious (simple), and in line with the general notion of a dynamic system.

Fig. 1 depicts the main components of our proposed definition. Some comments can be made in relation to the figure. Relations (arrows) are of multiple different characters. Within entity types, for example between two actors or between two artifacts, they may include complementary and substitute relations, and between entity types they may include ownership and usage rights, transformative relations, and externalities. Institutions refer to "the rules of the game" (North, 1990). The institutional relations are understated in the figure, as are the evolving nature of the innovation ecosystem as well as the relations between multiple innovation ecosystems.

5. Empirical examples

The empirical validity of our proposed definition of innovation ecosystems can be illustrated by means of three empirical cases. They have been selected on the basis of being well-documented in previous literature without being doctored in advance to fit our definition.

5.1. The innovation ecosystems in video cassette recorders (VCRs)

The multi-level "systems competition" between Sony's Betamax ecosystem and JVC's VHS ecosystem in the 1970s and 1980s is by now a classical case, well documented in the literature (e.g., Granstrand, 1984; Rosenbloom and Cusumano, 1987; Cusumano et al., 1992; Grindley, 1995). The two competing artifact systems, Betamax and VHS, were by and large functional substitutes with incompatible competing standards for video cassette recorders (VCRs) (Granstrand, 1984).[9] Sony was a first mover in the mid-1970s on the compact consumer VCR market. Sony, with the proprietary Betamax standard, was initially adverse to collaborate with others on Betamax development partly due a tradition of being the innovative leader and partly due to bad experiences from compromising in previous standardization attempts (Cusumano et al., 1992). The second mover JVC responded to Sony's first move by actively building up a group of collaborators and licensees (including Hitachi and Sharp) of JVC's VHS technology. This licensing was on favorable terms for licensees and premised upon intra-group cross-licensing of production experience and process improvements across group members (Granstrand, 1984). The JVC business strategy was innovative at the time, in fact invented by JVC's marketing director, Mr. Takano, assisted by JVCs R&D director Mr. Shiraish, and could be labeled a true business model innovation. The enabling of substitutes among both VCRs and cassettes through generous licensing opened up for a mix of competition and collaboration (i.e., coopetition) among the actors in the VHS innovation ecosystem, which over time led to lower prices and increasing value of the VHS offering, including an increasing amount and variation of artifacts, both in terms of hardware products and movie content adapted to the VHS format[10], and Betamax eventually became outcompeted. Sony finally gave in and bought a VHS license from JVC, as did others who migrated from the Betamax ecosystem to the VHS ecosystem (Ibid.), whereby the actor systems of the Betamax and VHS ecosystems essentially merged, while the Betamax artifact system was replaced by VHS through substitution. Thus, JVC succeeded in outcompeting the first mover by building and managing an innovation ecosystem that allowed for both complements and substitutes among artifacts and both collaboration and competition among actors, in technology development processes as well as in in product sales.

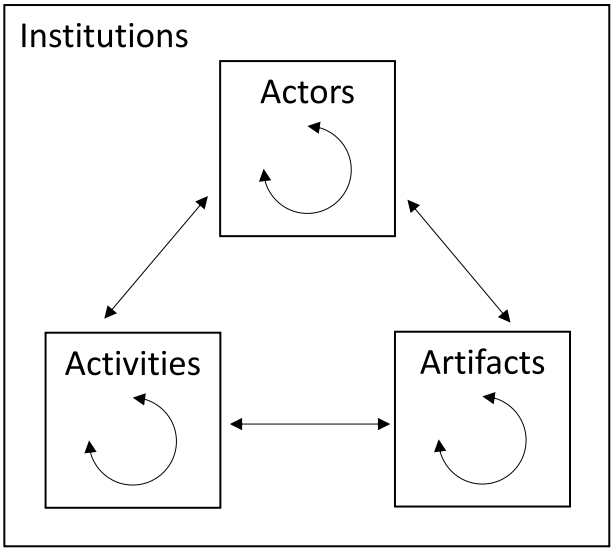

Fig. 1. Illustration of the innovation ecosystem definition.

5.2. The innovation ecosystems in mobile telecommunications

The case of the development of mobile telecommunication systems illustrates evolving innovation ecosystems over several decades, involving shifts between different technological generations. In this sequence of generation shifts the artifact system was radically transformed through creative destruction with entries and exits, as was the actor system. In each generation there was one or more technical compatibility standard(s), which enabled complementarities across a set of components in the system. An institutionalized standardization process provided a selection mechanism to filter out each standard from a set of competing technical solutions, around which a group of actors was formed, usually governed in part by (cross-)licensing agreements (Bekkers et al., 2002). Each selected standard in turn competed with other standards. Most standards also competed, at least partially, with a preceding generation of the standard, thereby causing cannibalization of sales within and across actors. Thus there was competition at several levels among substitutes with regards to capturing value from complementarities. The complexity of mobile telecommunications systems required interorganizational coordination beyond what competitive markets by themselves likely could accomplish through prices. Thus, already in the first generation standard a collaborative group of at the time monopolistic national telecom operators in the Nordic countries was formed in order to govern the development and launch of the so called NMT system. This activity involved organizing groups of competing suppliers of various key components in the artifact system (terminals, exchanges, and radio base stations) as well as groups of competing distributors and retailers for the various telecom market segments (Granstrand, 1993). Timing regarding technological and industrial capabilities was essential since a pre-mature roll out of a communication network without available complements such as terminals, sufficiently powerful integrated circuits, and high capacity exchanges would incur high costs as well as competitive disadvantages in relation to competing systems. A similar strategy was used in the second generation when the so called GSM group was formed, mainly on a European basis initially. By then institutional changes in form of deregulation and liberalization of telecom markets were taking place (Lindmark, 2002). Competing standards and systems started to emerge together with new entrants, and even more so in later generations.

[9] What is less known is that Betamax and VHS had overlapping technology bases with a certain amount of patent cross-licensing taking place between the competitors Sony and JVC, who in that respect were cooperative technologically (i.e., Sony and JVC were coopetitors), intertwining the two innovation ecosystems.

[10] E.g., pornographic movies were sold on VHS. This type of movies were arguably what we today would call a "killer application" in certain customer segments.

Institutional changes in form of an evolving pro-patent era also strongly influenced the innovation ecosystem from being largely unaffected to becoming increasingly patent licensing and litigation intensive, thus impacting the nature of collaboration and competition (Holgersson et al., 2018; Granstrand, 2018).

5.3. Apple's innovation ecosystem

One of the main actors in the mobile telecommunications ecosystem was Nokia, an active contributor to telecommunication standards and the world's largest mobile phone manufacturer during the first decade of the 2000s. However, after the introduction of Apple's iPhone, Nokia quickly lost its lead, which led its CEO Steve Elop to famously acknowledge: "Our competitors aren't taking our market share with devices; they are taking our market share with their entire ecosystem."[11]

The most important one among these competitors was Apple. In its work with the music player iPod, Apple had successfully positioned itself as a systems integrator and managed to build up an ecosystem of complementary technologies and actors, including content providers (record companies/music publishers) (Schoemaker et al., 2018). Applying the same strategy in mobile telecommunications and smartphones proved to be extremely successful. By strictly controlling the smartphone hardware and operating system with a proprietary IP strategy while opening up for a plethora of complementary innovators in apps and contents, Apple managed to balance collaboration and competition (Hannah and Eisenhardt, 2018), both regarding competition between itself and complementary actors (e.g., in terms of how to split revenues from content sales), and competition between the different complementary actors (e.g., between different gaming apps). Apple's innovation ecosystem allowed for successful complementors to reap sufficient, and sometimes huge, returns from their innovations (e.g., King with its Candy Crash Saga), while at the same time allowing for competition among app providers, all in all leading to a dynamic innovation ecosystem in which complementary innovators were continuously providing new value to customers, part of which Apple could tap into and appropriate (e.g., Grant, 2016).

5.4. Empirical summary

These three cases, briefly described here but well documented in the literature, illustrate the presence of all the defining characteristics of an innovation ecosystem as proposed in this article, including the presence of complementary as well as substitute relations in the sub-systems of actors, activities and artifacts, together with relations between them involving rights allocation through market transactions, including licensing rights, and non-market relations in form of externalities, especially positive network externalities, all governed by institutions. Competitive relations existed on multiple levels both in the artifact and actor systems, and mixed with cooperative relations into coopetition in all cases (cf. Hannah and Eisenhardt, 2018). Technical compatibility standards, often with some shared technologies, played a key role in creating value as well as capturing value within and between actor groups in all cases.

In contrast to the Apple case the VCR case and the mobile telecommunications case both illustrated multi-centric ecosystems and in contrast to the VCR case and the Apple case the mobile telecommunications case illustrated how an innovation ecosystem evolved over a sequence of generation shifts with creative destruction taking place in the artifact system as well as in the actor system, with a manageable rather than a rigid coupling between these two processes. In line with the spirit of a systems approach, innovation ecosystems could be decomposed into several innovation ecosystems, in which case they may compete or complement each other (cf. Adner and Kapoor, 2010). This is not the least illustrated by the connections between the general multi-centric mobile telecommunications innovation ecosystems, and Apple's own firm-centric innovation ecosystem.

The three cases all represent major radical innovations in systems technologies in electronic industries. This calls into question whether our innovation ecosystem concept has similar descriptive and explanatory power in other industries and for minor or less radical innovations. The genericness of complementary and substitute relations and the prevalence of actors, activities, artifacts, and institutions across industries suggest that the concept is generally applicable, albeit perhaps some components of it are less warranted for minor or less radical innovations. However, as digital technologies are entering into more and more industries, the relevance of all components of the innovation ecosystem concept will likely increase due to the connected and generic nature of such technologies.

6. Concluding discussion

Innovations create value by definition, being new to all and useful to some actors, but also tend to destroy value, being harmful to some actors (Schumpeter, 1942). The complementary and substitute effects from innovations, especially economically major and technologically radical ones, typically interact and propagate outside buyer and seller populations on a narrowly defined market. This justifies a systems approach in innovation analysis, an approach that was developed by economists in the 1980s and 90s, generating a rich stream of literature on various types of innovation systems with a main focus on actors and institutions, while a related literature in economic history of technology focused more on artifacts in technological systems (cf. Carlsson et al., 2002). Another concept introduced in the 1990s was that of a business ecosystem, often with an innovation-related business focus (Moore, 1993).

In light of all these preceding concepts, a valid question is if there is a need for the concept of innovation ecosystems (cf. Oh et al., 2016; Ritala and Almpanopoulou, 2017; Baiyere, 2018). We argue that there is, and especially so if the concept is sufficiently well-defined. Our conceptual review shows that received definitions typically focus on collaborating actors, while much less commonly include components of competition/substitution and artifacts (products, services, resources, technologies, etc.). A synthesis of the review shows that actors, artifacts, and activities are all elements in an innovation ecosystem, linked together through relations, including complement and substitute relations. The synthesis also points at the importance of institutions and the evolving nature of innovation ecosystems, and all of these components are included in our proposed definition (see section 4).

The main contribution with our definition, and with this article more generally, is its focus on complementary/cooperative *and* substitute/competitive relations (CS-relations for short here) and its focus on the actor system *and* the artifact system. The focus on the prevalent and often mixed and intertwined CS-relations provides additional precision and a more comprehensive and balanced view of what is going on in an innovation ecosystem compared to the received definitions. The CS-relations moreover enable operationalizations by the use of established concepts such as economies/diseconomies of scope, positive and negative synergies, complementarities, super/sub-additivity, or modularity in economics, and degrees of strategic complements and substitutes in the industrial organization literature.

The CS-relations also enable theorizing along the lines of cooperative and competitive game theory as well as along the lines of industrial organization, economics and strategy in general. Needless to say, CS-relations are of central interest in management and strategy, as well as in policy-making, for example regarding disruptive innovations (Christensen, 1997) or complementary assets (Teece, 2018), platforms, and modularizations for appropriation of complementarities (Baldwin

[11] See "Nokia CEO Stephen Elop Rallies Troops," Engadget, February 8, 2011, https://www.engadget.com/2011/02/08/nokia-ceo-stephen-elop-rallies-troops-in-brutally-honest-burnin/.

and Henkel, 2015; Jacobides et al., 2018). Dynamic balancing of value creation through "growing the pie" across complements, complementors, collaborating competitors, and consumers, and value sharing ("slicing the pie") among them, while curtailing effects from substitute ecosystems and competitors threatened by value destruction, is key to building up and running a well-performing innovation ecosystem, as illustrated also by our empirical examples. In connection to this, allowing for substitute artifacts and competing actors within (parts of) an innovation ecosystem is sometimes instrumental for the ecosystem's competitiveness in relation to other ecosystems.

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Appendix: Method for literature review

Our review is based on a structured search for received definitions of the innovation ecosystem concept. We started the process of identifying definitions by doing a basic search for "innovation ecosystem*" in Web of Science on 25 December 2018. We limited the results to the document types *article*, *review*, and *editorial*, and thereby identified 303 publications. Most of these had hardly any citations, so we limited our sample to the 100 most cited ones, which included articles with four or more citations. In addition, we included the 20 most cited ones from each of the year 2016, 2017, and 2018 to avoid a bias towards old and thereby more cited literature. Due to substantial overlaps with the top 100 articles, this step resulted in 20 additional articles, leading to a total sample of 120 articles which were downloaded.

For each one of these 120 articles, a text search for "innovation" and "ecosystem" was performed to help find explicit definitions of the innovation ecosystem concept. Definitions were identified in 22 of these articles.[12] Some of these definitions built on previous publications, so the next step was to find definitions in these key references. Many of the key references were already included in our sample, but 18 new publications were identified, out of which four provided explicit definitions of the innovation ecosystem concept. To sum up, the first structured search resulted in 22 definitions, and the analysis of key references from these definitions resulted in four additional definitions, all in all resulting in 26 definitions. However, a few of these were complete overlaps, either in the form of the same author(s) publishing the same definition twice or in the form of author(s) defining the concept by exactly citing an earlier definition. By excluding overlaps, we ended up with a final sample of 21 explicit and unique definitions of the innovation ecosystem concept. This selection process is illustrated in Fig. 2, and the list of identified definitions is presented in Table 2.

When the definitions had been identified, they were analyzed and the content of each definition was coded using open coding (Berg, 1989). This process led to a list of 24 component codes. These component codes were analyzed in order to find joint themes of codes, leading to seven component themes. For example, codes covering knowledge, resources, products, and platforms all relate to artifacts in the innovation ecosystem, and are therefore thematically grouped within the coding theme artifacts. A few component codes are included in two different component themes. For example, the component code 'co-creation' is part of both 'collaboration' and 'activity', as it is an innovation activity that is performed jointly by several actors. The scheme of component themes was then validated by coding all definitions again, but now based on the higher-level themes instead of open coding, and then comparing the coding. The resulting coding scheme is illustrated in Fig. 3.

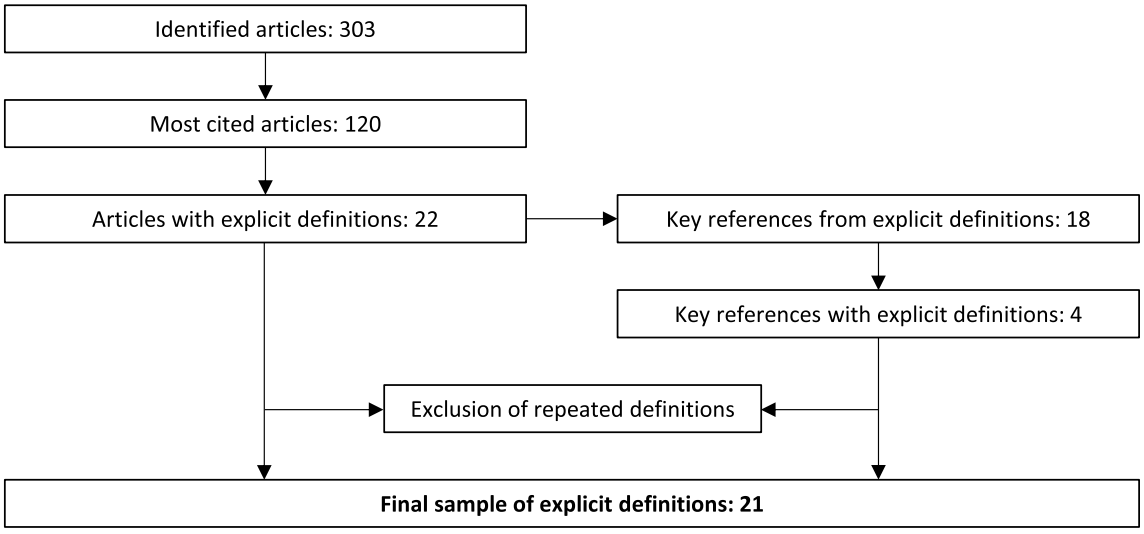

Fig. 2. Article selection process.

[12] In this process, we also identified definitions of related concepts such as business ecosystem (Moore, 1993) and entrepreneurial ecosystem (Mason and Brown, 2014).

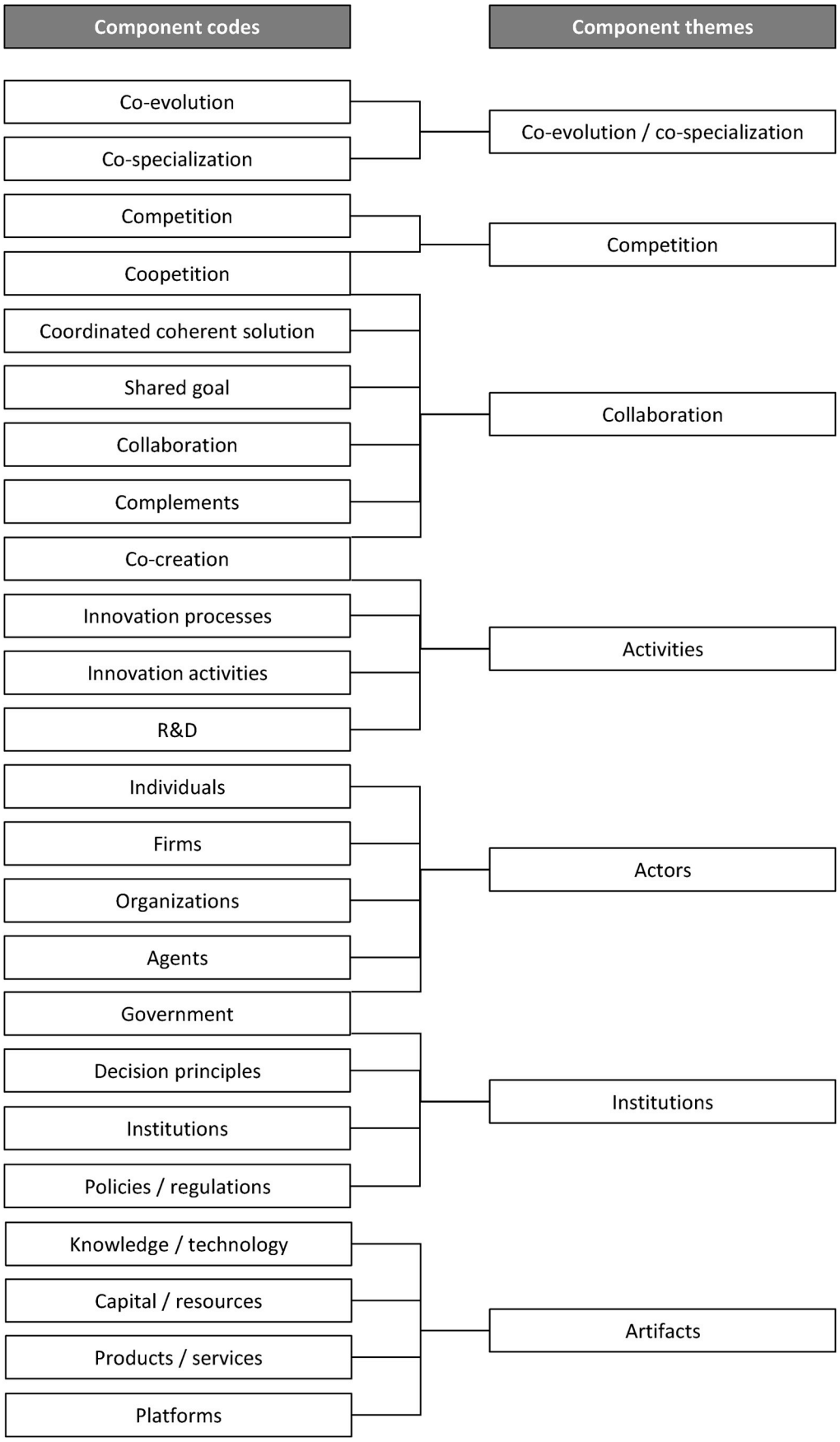

Fig. 3. Coding scheme including component codes and component themes.

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