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Review

Innovation Ecosystem Research: Emerging Trends and Future Research

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Abstract: The innovation ecosystem term has increasingly been attracting the interest of scholars and practitioners for fifteen years. Contrary to the flourishing landscape, knowledge in this field is criticized as being fragmented. While past reviews revealed the conceptual and theoretical connections between innovation ecosystem and other related concepts, there is still a lack of comprehensive appreciation of the intellectual structure of state-of-the-art innovation ecosystem studies, hindering future research in this domain. To fill this void, this study utilized a systematic literature review approach combining bibliographic coupling and content analysis methods. Drawing on 136 studies reflecting the core and latest knowledge of innovation ecosystem literature, this study identifies five streams of the current innovation ecosystem research (i.e., technology innovation, platform innovation ecosystem, regional development, innovation ecosystem conceptualization and theorization, and entrepreneurship and innovation). Suggestions for future research are distilled via systematic analysis and discussion of these streams. Contributions of this study lie in decoding the intellectual structure of current innovation ecosystem research and offering targeted recommendations for future research.

Keywords: innovation ecosystem; sustainable innovation; systematic literature review; platformization and digitalization; regional development; entrepreneurial innovation

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1. Introduction

In the past fifteen years, literature on innovation ecosystem (IE) experienced exponential growth, especially the boom in the recent three years when more than half of the IE studies were published. IE has been increasingly gaining significant and widespread academic attention in multiple fields, including innovation [1,2], business [3,4], economic [5,6], and sustainability [7–9]. Taking the research on sustainability as an example, IE has been utilized to explore diverse sustainable issues, including green product production [10–12], sustainable enterprise development [13,14], circular industrial economies [15–17], and sustainable regional transformations [7,18,19]. This indicates that IE as an effective approach has played a significant role in advancing sustainability in recent years. Contrary to its popularity in academia, IE was found to be loosely mentioned and discussed under various backgrounds [20–22], leading to heterogeneous and inconsistent IE connotations in the literature [23–25]. Extant IE literature is regarded as fragmented, lacking comprehensive appreciation [20,25,26].

This scenario has promoted several literature reviews on IE in recent years, mainly decoding the IE concept and research themes [22,23,27,28], or primarily differentiating IE from other interrelated concepts and clustering studies in these cross-connected domains [6,20,26]. As one of the key types of ecosystems, IE has also been reviewed by prior reviews classifying ecosystem concepts and studies [3,24,25,29–32]. These reviews mainly contributed to the conceptualization of IE, distinguishing IE from other related concepts, and classifying and comparing the sub-fields of ecosystem research. While they confirm

that IE research has been established as one domain distinct from others such as innovation system and business ecosystem, they fall short in decoding the research fronts of the IE literature and distilling targeted implications for future IE studies. To fill the gap, the current review unfolds to focus closely on IE studies, unpack the intellectual structure of state-of-the-art IE studies, and propose targeted pathways for future IE studies.

To this end, this study utilized a systematic literature review approach that combines a bibliographic coupling technique and content analysis method. Specifically, it may contribute to the IE literature mainly in three ways. First, it centers on IE and includes the latest updated IE studies to achieve more targeted and comprehensive findings and implications for IE research. This is mainly due to the considerations that prior IE literature has proposed an explicit and universal IE definition [23] and validated the differences between IE and other relevant concepts [27,30,31], that excluding other interrelated concepts helps to reduce noise knowledge from those fields, and that the newly published IE studies in recent years are far more than those that have been reviewed. Second, this study complements existing reviews by revealing the complex intellectual structure of the core part of IE studies that is most reflective of the common knowledge and emerging research trends of extant IE studies. Finally, the identified research suggestions distilled from the respective research streams may contribute to IE literature by inspiring future research. In sum, this review differs from previous reviews due to its distinct investigated IE literature, the different research aims, and the complementary findings focusing on IE.

Following this section, Section 2 presents past literature reviews on IE. Section 3 displays the research method, followed by Section 4 presenting the main results. Section 5 discusses the results to produce suggestions for future IE research. At the end are the conclusions.

2. Literature Review

2.1. IE Definitions

Explicitly defining IE is one of the prerequisites to comprehensively appreciate this emerging field. Twenty-two explicit IE definitions were generated by past IE studies (Table A1, Appendix A). From a longitudinal view, these IE definitions have been increasingly comprehensive and compatible. Specifically, from 2006 to 2009, IE was seen as "arrangements" in industry chains [33] or "processes" in innovation clusters [34]. Then, a network view was utilized to define the IE concept in the period from 2013 to 2017. For instance, IE was regarded as "a loosely interconnected network" [35]. From 2018 to date, both the system view and network view have been adopted to define the IE concept. As defined recently, IE refers to a "system" [36], "network" [37], or "network system" [10]. Besides, methods to generate IE definitions tend to be more complex and systematic, shifting from citing related studies [35] in the early phase to systematic literature reviews [23] in recent years, which contributes to the robustness of IE definitions.

From a horizontal view, following Granstrand and Holgersson [23], five classes of keywords consisting of actors, activities, relations, artifacts, and evolution were found from the 22 influential and widely used definitions of IE (Table A1, Appendix A). To be specific, actors (e.g., organizations, suppliers, customers, and governments) and activities (e.g., develop products and services, promote innovation, and create and capture value) were included in all these IE definitions. However, relations (e.g., collaborative, cooperative, competitive, and symbiotic) and artifacts (e.g., offerings, resources, technologies, and information) were missed in 2 of these 22 IE definitions. evolution (e.g., dynamic, evolutionary, coevolve, and lifecycle) was ignored in 6 of these 22 IE definitions. In sum, these keywords present a complete set of components that were agreed upon by most scholars in defining IE. These five classes of keywords were employed as a conceptual framework of IE in the discussion and future research section of this study.

2.2. IE-Related Reviews

Some reviews contributed to conceptualizing IE. For instance, Oh et al. [22] argued that the loosely defined IE concept in past literature might bring more risks than benefits.

Gomes et al. [27] reviewed the research on IE and business ecosystem between 1993 and 2016 and concluded that IE relates more to value creation while business ecosystem relates more to value capture. Tomas et al. [28] illustrated three ways to categorize IE structure (i.e., ecosystem life cycle, ecosystem levels, and ecosystem layers). Granstrand and Holgersson [23] synthesized diverse IE definitions into a more compatible one by integrating structural ecosystem elements, including actors, activities, artifacts, and institutions.

Meanwhile, IE is rooted in other maturing research fields such as innovation network and innovation system [6,26]. Hence, past reviews also examined the connections between IE and those established concepts. For example, Russo-Spena et al. [26] identified five shared topics among three streams of innovation research (i.e., system, network, and ecosystem) and revealed the research commonalities and differences among them. Bassis and Armellini [6] argued that IE and innovation systems complement each other and found that they share three elements (i.e., innovation perception, agents' role, and interaction and network). Suominen et al. [20] compared the research streams and theoretical foundations of innovation systems and ecosystem studies, respectively.

In addition, other literature reviews compared the research on IE and other concepts under the umbrella concept ecosystem. For instance, Jacobides et al. [30] and Shipilov and Gawer [31] divided ecosystem research in the management field into three streams (i.e., IE, business ecosystem, and platform ecosystem), and compared the differences among them. Gupta et al. [24] found that the IE area shares few studies with business ecosystem and digital ecosystem domains. Hakala et al. [29] argued that IE, business ecosystem, and entrepreneurial ecosystem respectively focus on the dynamic of interaction, the quantity of interaction, and regional development. Aarikka-Stenroos and Ritala [3] highlighted that notwithstanding the fact that IE and other sub-concepts of ecosystem involve different themes and assumptions, ecosystem as a broader perspective may serve as a promising layer or perspective to advance B2B (business to business) network research. Thomas and Autio [25] found that the confusing ecosystem concepts and applications in management literature mainly result from different types of unit of analysis and ecosystem output, according to which ecosystems can be divided into IE (business ecosystem, modular ecosystem, and platform ecosystem), entrepreneurial ecosystem, and knowledge ecosystem.

These IE-related reviews not only enhanced the conceptual understanding of IE by revealing its commonalities and differences with other similar concepts, but also demonstrated the research situations where IE and these concepts appear in different periods (see Table 1). However, the literature shows a lack of revealing the intellectual structure of IE research front to offer recommendations for future research. This is more urgent considering the fragmented landscape of this field combined with the proliferation of published IE papers in the recent three years beyond the timespan of prior reviews. Besides, recent studies have provided a reasonable conceptual and theoretical basis to screen IE from other analogous concepts to generate more targeted findings to promote IE research [23,25,29,30,38]. Therefore, drawing on existing methodological and theme-relevant studies, this study aims to smooth the gap by a systematic literature review approach detailed in the next section.

Table 1. Representative IE-related reviews.

Authors, Year	Themes (Number of Documents)	Period	Methods	Summary
Oh et al., 2016 [22]	IE (undefined)	Undefined	Conceptual and theoretical	• A critical review of the IE term. • The ambiguous usage of the IE term is not more beneficial than national and regional IS.

Table 1. *Cont.*

Authors, Year	Themes (Number of Documents)	Period	Methods	Summary
Dedehayir et al., 2018 [21]	IE (60)	1996–2015	Content analysis	• Discern four sets of roles that characterize actors' behaviors and activities across three stages of IE birth.
Gomes et al., 2018 [27]	IE, BE (125)	1993–2016	Bibliometric and content analysis	• Identify a transition from BE mainly focusing on value capture to IE mainly focusing on value creation in the literature. • Summarize six streams of IE research and propose corresponding research opportunities.
Granstrand and Holgersson, 2020 [23]	IE (21)	2006–2018	Content analysis	• Define IE based on synthesizing the elements of 21 IE definitions in previous IE literature. • Validate this IE definition by three cases.
Tomas et al., 2020 [28]	IE, BE (61)	1993–2019	Bibliometric and content analysis	• Identify and analyze three approaches to define IE structure, namely ecosystem life cycle, ecosystem level, and layered structure.
Russo-Spena et al., 2017 [26]	IS (1833), IN (444), IE (227)	1985–2015	Content analysis	• Identify and compare five shared thematic elements in IS, IN, and IE domains. • Elaborate how the SE approach can advance service innovation research.
Zhang and Guan, 2017 [39]	IE, EE, BE, PE, etc. (314)	1996–2016	Co-citation and network meta-analysis	• Define IEE that emphasizes network openness, organization symbiosis, and actor interdependence. • Analyze IEE research metaknowledge in terms of trends and features using a novel method.
Amitrano et al., 2018 [40]	IS (334), IE (92)	2006–2017	Content analysis	• Identify seven mutual topics reflecting the roles of technology in IS and IE literature.
Bassis and Armellini, 2018 [6]	IE, BE, IS (undefined)	Undefined	Content analysis	• Compare the concepts, literature, and framework of IS and IE theories. • The two theories complement each other in terms of actors' interactions, evolutionary theories, and building elements.
Suominen et al., 2019 [20]	IS, BS, BE, IE (3652); BE, IE (329)	1990–2015	Bibliographical coupling and co-citation analysis	• Explore six research streams and five clusters of theoretical foundations of IS and ecosystem literature. • Identify seven research streams and five groups of theoretical bases of ecosystem literature.
Aarikka-Stenroos and Ritala, 2017 [3]	Ecosystem (71)	1999–2016	Content analysis	• Categorize four ecosystem approaches in B2B literature. • Ecosystem-as-layer and ecosystem-as-perspective may revise extant B2B network research framework.
Jacobides et al., 2018 [30]	Ecosystem (undefined)	Undefined	Conceptual and theoretical	• Propose an ecosystem definition by leveraging complementarity and modularity. • Divide ecosystem literature in management domain into three clusters, namely BE, IE, and PE.
Tsujimoto et al., 2018 [32]	Ecosystem (90)	1995–2014	Content analysis	• Analyze ecosystem concept in technology and innovation management literature. • Identify four research streams of ecosystem research contributing to an integrated model. • Define ecosystem and propose a coherency concept helpful to explain ecosystem evolution.
Gupta et al., 2019 [24]	BE (545), IE (150), DE (406)	Undefined	Keywords network analysis	• Map the sharing and distinct terminologies in BE, IE, and DE fields. • Illustrate three keywords covering BE-IE-DE, BE-DE, and IE literature, respectively.
Hakala et al., 2020 [29]	BE, EE, IE (55)	1993–2018	Content analysis	• Propose a novel method for reviewing the dominant narratives in a given field. • Employ this method to compare the themes and theoretical puzzles, construction of ecosystem stories, and relevance of ecosystem studies in BE, EE, and IE fields.

Table 1. *Cont.*

Authors, Year	Themes (Number of Documents)	Period	Methods	Summary
Shipilov and Gawer, 2020 [31]	Ecosystem, network (undefined)	Undefined	Conceptual and theoretical	• Partially integrate two streams of literature (i.e., networks and ecosystems) to advance each other. • Divide ecosystem studies in management field into three streams (i.e., BE, IE, and PE).
Thomas and Autio, 2020 [25]	Ecosystem (undefined)	Undefined	Conceptual and theoretical	• Conceptual heterogeneity of the ecosystem constructs mainly results from the differences in terms of the unit of analysis and ecosystem outputs. • Categorize ecosystem concepts in management literature into IE (involving BE, ME, PE), EE, and KE.
Wang, 2021 [41]	Ecosystem (undefined)	Undefined	Conceptual and theoretical	• Identify and classify six types of ecosystem concepts from information system and organization studies fields into four levels of analysis. • Propose a digital IE definition and "Information Ecology Theory" to address part-whole relations by integrating digital innovations with ecosystems literature.

Note: IE (innovation ecosystem), IS (innovation system), IN (innovation network), SE (service ecosystem), EE (entrepreneurial ecosystem), BE (business ecosystem), PE (platform ecosystem), DE (digital ecosystem), BS (business system), IEE (innovation and entrepreneurial ecosystem), KE (knowledge ecosystem), and ME (modular ecosystem).

3. Method

This study utilized a systematic literature review method following prior review studies [42,43]. Specifically, Science Citation Index Expanded (SCIE) and Social Sciences Citation Index (SSCI) databases were selected to identify IE studies because they provide wide studies with high academic influence as well as complete bibliometric metadata for each document [24,26,28]. Drawing on previous reviews [23,24], documents were retrieved in January 2021 by an exact search query of "innovation ecosystem *" in the Topic field that covers the content of Title, Abstract, Author Keywords, and KeyWords Plus® of each paper. Limiting document type to English Article or Review, consistent with past IE review [27], resulted in 428 documents published in the past fifteen years. Further, the title, keywords, abstract, and main body of each article were analyzed, excluding 23 studies not relevant to IE. Finally, 405 articles produced by 174 journals between 2006 and 2020 served as the literature pool to identify core IE studies.

To unpack the structure of IE research front, a hybrid methodology combining the bibliographic coupling technique with the content analysis method was employed in line with prior works [20,43]. On the one hand, the bibliographic coupling technique is among the most suitable methods for evaluating state-of-the-art research in a given domain [43,44]. On the other hand, the content analysis method allows improving the analysis according to the main content of each document rather than the objective citation relationships considering the ambiguities of IE concept and literature [20,23]. The specific steps and tools are as follows: VOSviewer 1.6.10 software [45] was utilized to generate bibliographic coupling network files based on the bibliometric metadata of the 405 IE publications. Then, these files were imported into Pajek64 5.13 software [46] to extract the bibliographic coupling matrix. The matrix was reduced using Excel by only including the documents that rank in the top 30% in reflecting the common knowledge of IE research according to two indicators, namely the tie strength (indicating the total frequencies of shared references of a given document with other documents) and node degree (representing the number of documents sharing references with a given document) of each document in the bibliometric coupling matrix. Since there was a large overlap of the results for the two indicators, 136 studies (tie strength ranging from 384 to 1529, node degree ranging from 181 to 275) from 58 journals between 2009 and 2020 were selected as the core IE studies reflecting the research fronts. We analyzed the contents of the research questions, aims, and objects of these articles to identify their research focuses. Based on this, the 136 IE studies were

grouped into five research streams, each of which mainly reflecting a research focus shared by the IE studies in this research stream.

4. Results

4.1. Descriptive Analysis

Figure 1 shows the distribution of the extracted IE articles and identified core IE articles. Most of the articles in both groups were published in the recent five years with rapid growth. Table 2 presents the 36 main source journals that published about 50% of the IE articles and 80% of the core IE articles. *Sustainability* ranks as the first and second journal in the two lists, contributing 42 IE articles and 14 core IE articles, respectively.

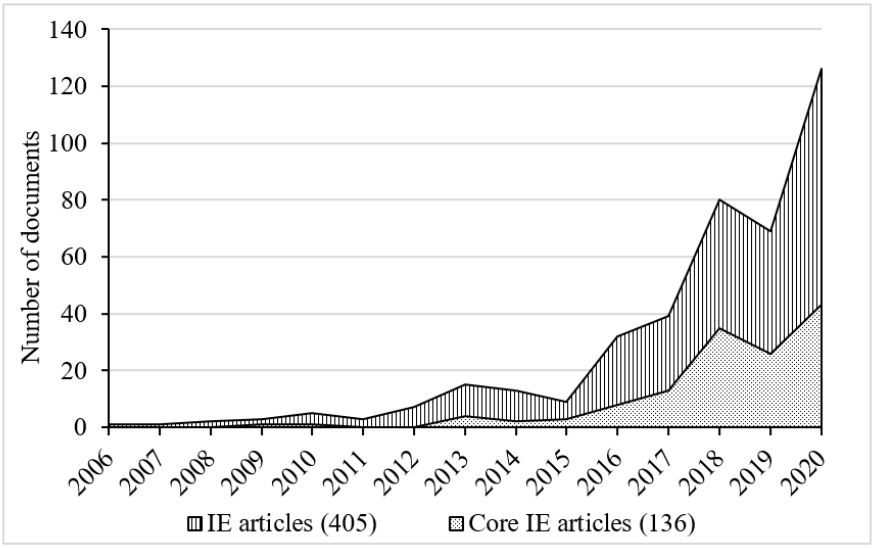

Figure 1. Published articles in IE field from 2006 to 2020.

Table 2. Source journals of IE research.

Representative Journals	Number of IE Articles	Number of Core IE Articles
Academy of Management Annals	2	2
Academy of Management Journal	1	1
Academy of Management Review	2	1
Administrative Science Quarterly	1	1
Business & Society	2	1
California Management Review	4	2
Computers in Human Behavior	1	1
Energy Policy	1	1
Entrepreneurship Theory and Practice	1	1
European Journal of Innovation Management	12	5
European Management Review	1	1
Industrial Marketing Management	1	1
Industry and Innovation	3	2
International Journal of Information Management	2	1
International Journal of Management Reviews	1	1
International Journal of Production Economics	4	3
International Journal of Technology Management	11	8
Journal of Business Research	3	2
Journal of Cleaner Production	8	5
Journal of International Business Studies	2	2

Table 2. *Cont.*

Representative Journals	Number of IE Articles	Number of Core IE Articles
Journal of Management	1	1
Journal of Management Studies	1	1
Journal of Strategic Information Systems	2	1
Long Range Planning	3	3
Management Decision	4	2
Management Science	2	1
Organization Science	2	2
R & D Management	3	1
Research Policy	7	4
Scientometrics	4	2
Small Business Economics	6	3
Strategic Entrepreneurship Journal	1	1
Strategic Management Journal	9	8
Sustainability	42	14
Technological Forecasting and Social Change	40	24
Technovation	6	3
Others (journals)	209 (138)	23 (22)
Total (journals)	405 (174)	136 (58)

Table 3 summarizes the methods utilized by the 136 core IE articles. Similar to prior findings, case studies and conceptual and theoretical studies are still two of the dominant methods, while different findings are that literature review has become a new main method and fuzzy set qualitative comparative analysis has emerged as a new method [27]. This highlights that quantitative studies are still needed to consolidate existing qualitative, conceptual, and context-specific findings on IE.

Table 3. Research methods of the core IE studies.

Research Method	Number	%
Case study	78	57.35
Literature review	20	14.71
Conceptual-theoretical	18	13.24
Survey	11	8.09
Modeling-simulation	6	4.41
Fuzzy set qualitative comparative analysis	2	1.47
Experimental	1	0.74

4.2. Analysis of Identified Research Streams

4.2.1. Stream 1: Technology Innovation

Articles in this stream mainly focus on issues related to how to implement technology innovation by leveraging IE. Some studies investigated the key channels to establish IE for technological innovation. Results show that cooperating with external actors for external complementary innovation resources contributes to cultivating a nascent IE [1,47], which requires the focal firm to coordinate its internal sub-organizations and external IE actors [48]. The focal firm also needs to position itself in IE according to the policy environments of different regions [49]. In this process full of uncertainties and complexities, system building strategies coping with complementarity, complexity, and timing issues [50], dynamic control via coupled feedback loops [51], experiments generating complete prototypes of technological solutions [52], and joint knowledge search integrating knowledge producers and users [53] have been found helpful in the establishment of technological IE.

More broadly, some articles explore the life cycle of technological IE. Playing distinct roles at different phases, value creation and capture mechanisms advance the evolution of IE [54,55]. Research also revealed that IE architecture or structure is featured in the interactions among IE actors at the system level [56,57] and managerial cognitive capability and dynamic capacities of focal firms at the actor level [13,58]; both are main drivers of IE evolution. Besides, sustainability is one of the key issues for the evolution of technological IE. To improve the sustainability of technological innovation, scholars highlighted the roles of complementary technological resources and dynamic demands and policies [59,60].

To orchestrate dynamic technological IE, studies highlighted the roles of selective knowledge revealed in governing collaborations between focal firms and their IE partners [61], and patent licensing from the focal firm to SMEs (small- and medium-sized enterprises) in improving IE stability [62]. Scholars argued that effective control of knowledge transfer in IE depends on comprehensive consideration of the features of knowledge, relationship, and organization [63].

Regarding the specific impacts of inter-organizational collaborations on innovation in IE, evidence shows that collaborating with IE partners helps to increase innovation inputs and outputs [64], but contradictions arising from interactions between actors may hinder innovation [65]. Some characteristics of interdependent relationships between focal firms and their IE partners have been found to be closely related to the outcomes of innovation, including locations and strengths [66,67] and distribution [68]. Research also revealed that product innovation always depends on the appropriate combinations of different kinds of inter-organizational cooperation rather than a single collaborating mode [4].

Technology as one of the key artifacts of IE always evolves. Studies illustrated that the transitions from incumbent to new technologies depend on the challenges confronting the emergence of new technologies and the opportunities supporting the extension of old technologies [69], and the cooperative and competitive relationships between IE actors, assets, and technologies, respectively [36]. Besides, technologies may act as IE environments to influence organizational technology innovation. For instance, Gao et al. [70] decoded how the focal firm responds to external technological changes by leveraging complementary partners and their technologies. Eggers and Park [71] highlighted that IE environment is one of the important antecedents of incumbent firms to adapt to technological changes.

4.2.2. Stream 2: Platform IE

Studies in Stream 2 emphasize how to organize platform IE, and how to develop platform technologies and products in IE. For the former, scholars mainly center on the structural configurations of platforms from an IE perspective. Gawer [72] conceptually defined platforms (firm, supply chain, and industry platforms) as "evolving organizations or meta-organizations" with modular and core-periphery structure characteristics. Leader organizations at the core of IE need to collaborate with periphery complementors and create complementary sub-systems to organize platform IE [73,74]. The interactions among platform actors advance the activities to create and merge multiple kinds of values [75]. Firms may gain more benefits in collective activities aiming to set standards for technological platforms when they have more nondisclosed components which complement their disclosed patents [76]. However, collaborating with complementors does not necessarily bring more gains for the firms, but may trap them in a prisoner's dilemma once the market is saturated [77]. More comprehensively, integrated approaches have been developed and utilized to analyze the configuration of platform IE, such as the 6C (context, cooperation, construct, configuration, capability, and change) framework [5], ecosystem-as-structure perspective [78], and synthesized actor-activity view [79]. Scholars also conceptualized ecosystem-specific advantages (resources, structure, and governance) and developed a framework to manage the collaborations among actors and leverage these advantages for the internationalization of digital platforms [80].

For the latter, studies primarily investigated how to develop platform technologies and products in the IE context. One of the prominent challenges in this process is to

appropriately balance cooperation and competition. Focal organizations usually need to dynamically govern multilateral cooperative relations with other actors and mitigate potential conflicts by supra dyadic mechanisms [81]. Evidence shows that competitive positions and cooperative motivations of the firms could together shape both the level of individual support and the level of group consensus in collective activities for the creation of technological standards of platforms [82]. Ecosystem strategies, both considering cooperation and competition with different emphases, may be viable to address this tension, such as bottleneck strategy to simultaneously cooperate and compete, component strategy mainly to cooperate, and system strategy chiefly to compete [83]. Additionally, to develop greener products in platform IE, symbiosis strategies (mutualism and predation symbiosis) have been found effective in the emerging market [84].

Moreover, the diffusion of platform technologies and products in ecosystems as a critical issue has also been studied. For instance, software platforms may be diffused among developers through hackathons, and the level of platform diffusion is shaped by the characteristics of hackathons and the experience of the attendees [85]. Over time, complementary developers in the videogame industry may defect from the incumbent firms that introduce a new generation of technology platforms with greater developing challenges and migrate to the rival platforms that are easier to support, which forces these firms to share more knowledge with developers and emphasize internal development more [86]. In addition, the sales of the video games launched at late stages of the life cycle of platforms may be lower than those launched earlier [87]. Finally, scholars also highlighted the significance of institutional complementarities to the creation and diffusion of product platforms [88].

4.2.3. Stream 3: Regional Development

Documents in Stream 3 primarily explored innovation in different regions and industries. For innovation at the cluster level, articles revealed the contribution of actors' joint development to cultivate digital industry clusters [89], the uniform effects of regional policies to create biotech clusters in Spain [90], and the IE environmental factors (economic, technological, and market) for the manufacturing cluster in Brazil to develop complementary capabilities [91]. For national industrial innovation, authors found that the government and public organizations have a domain position in governing the evolution of IE [92]. The IE approach was found to be critical to promote the environmental sustainability of regional industries in emerging markets [11,92]. Identifying the collaborative actors and potential stakeholders is also important to industrial innovation [93]. IE at the industry level such as the 3D printing industry in China may be divided into three sub-ecosystems (i.e., science, technology, and business ecosystems) [94], while IE at the country level such as the creation of Society 5.0 may be composed of science, technology, and innovation ecosystems [95]. Additionally, for the transitions towards innovative regions, the economic delta IE has been studied from the industrial system and social network perspectives [96].

Scholars also paid close attention to factors and approaches driving the creation of smart and sustainable cities. For instance, the establishment of smart cities collectively depends on the technological, environmental, and institutional factors in Europe [97]. It is of importance that the actors are aligned to gain shared objectives in value creation and capture activities in the Netherlands [98]. As one of the key actors, universities may play a dominant role as the orchestrator for the creation of innovative cities [99]. To build sustainable cities, the viable approaches include collaborations among actors, experimentation for IE design, and platformization of technological innovation [100].

4.2.4. Stream 4: IE Conceptualization and Theorization

Stream 4 provides studies contributing to conceptualizing and theorizing IE. Some scholars focused on distinguishing IE from IE-related concepts, contributing to explicitly conceptualizing this emerging concept. As presented above, the connections between IE and IS [6,20,101], and between IE and BE [24,27,29], have been systematically investigated.

In addition, the main applications of the ecosystem concept in B2B [3] and management [32] fields have been summarized. Recently, based on these works, scholars have begun to generate contextual and general IE concepts. For instance, Yin et al. defined the "sustainable and smart product IE" concept to explore the development of products characterized by smart and sustainable properties [102], while Jütting introduced the "mission-oriented IE" term to investigate how to address sustainability issues [8]. More comprehensively, Granstrand and Holgersson [23] decoded the main IE definitions from existing literature and conceptualized the IE concept with higher compatibility.

The authors also advance the theorization of IE by structuring and modelling the architecture of ecosystems. From the structuralism perspective, the ecosystem has been constructed by four components: activities (specific actions to realize value propositions), actors (entities to perform activities), positions (locations connecting activities and actors), and links (transfers among actors) [38]. This framework was utilized to generate the Ecosystem Pie Model for the design of ecosystems [103]. In the same line, authors also constructed ecosystems from the perspective of modular complementarities in production and consumption dimensions [30]. From the system perspective, scholars highlighted the complexity and evolvability of ecosystems and treated them as complex adaptive systems [104,105]. From the multi-level view, Walrave et al. [37] proposed a framework for path-breaking innovation emphasizing both the internal alignment and external viability of ecosystems. From the network perspective, Shipilov and Gawer [31] argued that ecosystem research may be extended based on the achievements in the domain of inter-organizational networks. They focused on the modular and complementary components of ecosystems and utilized network approaches (e.g., matrix thinking and link strengths) to advance the development of a Graph Theory to theorize ecosystems. Finally, scholars also summarized the structures of IE [28].

4.2.5. Stream 5: Entrepreneurship and Innovation

Most of the studies in Stream 5 investigated entrepreneurship and innovation at the organizational level from an IE perspective. First, university entrepreneurial organizations are playing increasingly important roles and have gained significant academic attention. Evidence shows that dynamic university-industry [106] and industry-university [107] knowledge transfer advances the establishment and growth of university spin-offs. In addition, social capital (in structural, cognitive, and relational dimensions) can be leveraged by business incubators of entrepreneurial universities to cultivate entrepreneurial IE and advance its sustainable development [108]. Second, generally for entrepreneurial firms, public-private interactions driven by regional-specific policies contribute to the success of business models for commercializing new products [2]. Identifying, matching, and bridging novel resources and potential needs can also assist focal firms to work as resource integrators, collaborators, transaction enablers, or bridge providers in digital entrepreneurial activities [109]. Finally, enhancing the absorptive capacities of regional ecosystems may be effective to attract multinational enterprises and then catalyze more entrepreneurial ventures [110].

Articles also examined the challenges and countermeasures for individual entrepreneurs in entrepreneurial and innovative practices in IE environments. Challenged by collective uncertainties in ecosystem entrepreneurial activities, entrepreneurs may deal with this kind of uncertainty through a perceive-bridge-mitigate process [111]. The individual entrepreneur may also encounter discrepant goals and complex opportunities across ecosystem boundaries, which could be addressed by their self-regulatory processes [35]. Moreover, entrepreneurs could leverage the advantages of four kinds of platform-based IE categorized by capabilities in terms of product/service innovation and commercialization in their entrepreneurial processes [112]. Academic entrepreneurs can also utilize the social networks of entrepreneurial universities and the corresponding spin-offs as knowledge intermediaries to gain innovation resources [113].

Table 4 presents the five research streams in detail.

Table 4. Emerging streams, issues, and studies of IE research.

Streams (Number of Documents)	Issues Investigated (Representative Studies)
Technology innovation (34)	• Creation of technological IE [1,47–53,59]. • Evolution of technological IE [13,54–58]. • Orchestration of technological IE [15,61–63,114]. • Inter-organizational collaborations in technological IE [4,64–68]. • Technological substitutions in IE [36,60,69]. • Technological environments in IE [70,71].
Platform IE (32)	• Organization of platform IE [5,72–80]. • Cooperation and competition in developing platform technologies and products [81–83]. • Diffusion of platform technologies and products [85–88].
Regional development (29)	• Cluster IE [89–91,115]. • National and industrial IE [10,11,92–95]. • Economic delta IE [96]. • Smart and sustainable city IE [97–100,116].
IE conceptualization and theorization (27)	• IE conceptualization [3,6,20,23,24,27,29,32,101,102]. • IE theorization [28,30,31,37,38,103–105].
Entrepreneurship and innovation (14)	• University entrepreneurial organizations [106–108,117]. • Entrepreneurial firms [2,109,110]. • Individual entrepreneurs [35,111–113].

5. Discussion and Future Research

5.1. Technology Innovation

As summarized above, studies in Stream 1 mainly explored how to implement technology innovation in evolutionary and changing IE. Since technology innovation is increasingly challenging in dynamic IE, burgeoning technologies may dim the dominant position of the focal firm, but enhance the roles of other IE actors such as universities, users, and public research institutions in orchestrating the evolution of technological IE. This may be more possible for radical, inclusive, and sustainable technology innovation and product development. For instance, sustainable technology innovations are increasingly challenging and need the collective actions of all stakeholders and the leadership of other IE actors such as public organizations. Moreover, the impacts of interdependent relationships in technology innovation on focal firms' performance have been studied in this line of research, but how focal firms motivate other IE actors to participate in collaborative innovation activities has not received enough attention. Besides, the benefits of collaborations do not exist alone but co-exist with diverse conflicts and contradictions among IE actors. In addition, the changing technological IE is not a closed but an open system, which sometimes is even determined by factors from other systems such as policy, cultural, and academic systems that are overlooked in these articles.

Therefore, ways to extend existing studies in this stream may be the following. For instance, exploring the roles of other IE actors such as universities and small firms, rather than focal large firms in creating and orchestrating IE, could extend existing findings. Distinguishing different types of technological innovation may also complement extant research. Besides, examining the impacts of cognitive and emotional factors on actors' decision making can also enrich the limited knowledge on actors' innovation behaviors in IE. The tensions between collaborative benefits and the corresponding drawbacks deserve more extensive investigations. Last but not least, research attention to the roles of non-technological factors in influencing the dynamics of technological IE is worthy.

5.2. Platform IE

Regarding the research in Stream 2, scholarly attention has been paid to the organization of platforms and the development of platform technologies and products. On one

hand, these studies advance the structural and configurational understanding of platform organizations. They have highlighted the aspects of the complexity of platform IE (e.g., components, evolution, and links) that were mainly conceptually and theoretically discussed but that lacked empirical investigations. Thus, to better understand how to organize and govern platform IE, dynamics- and complexity-related perspectives or approaches may be promising tools for both theoretical and empirical examinations of the organization of platform IE. On the other hand, in this stream, relationship management and platform diffusion are core issues to research new platform technologies and products development. These achievements chiefly extend the understanding of the cooperation, competition, and coopetition of focal organizations with complementary platform components or participants, as well as the diffusion of platforms among component developers and platform users. These studies mainly investigated one kind of digital or software platform that the focal firms or platform leaders leverage to develop platform technologies and products. Challenges raised from these empirical studies may concern whether these findings apply to other kinds of platforms, i.e., the universality of these findings across different platforms, and what are the differences between platform leaders and complementors in managing innovation resources and adapting innovation environments in dynamic IE to develop platform technologies and products. For example, knowledge on how to diffuse sustainable platform products and technologies by different IE actors may be scarce.

Hence, to address these gaps in existing research on platform IE, adopting the evolutionary and complex adaptation system perspectives may be beneficial to unpack how a platform IE evolves and how it can be orchestrated. Among this kind of research, coordinating complementary IE artifacts (e.g., resources and components) and actors across industrial, geographical, and IE boundaries may serve as a fruitful direction to provide insightful findings for theories and practices. Besides, comparative studies on different kinds of platforms may also extend existing findings in this stream. This is the same for research on how different actors (e.g., leaders, followers, and complementors) match their internal and external innovation resources and environments.

5.3. Regional Development

Research in Stream 3 advances the literature on different levels of regional and industrial innovation. They mainly revealed the innovation mechanisms in a given level (e.g., cluster, city, or country), leaving the cross-level studies less explored. What is also lacking is exploring the orchestrating tools and mechanisms of regional IE by other actors (e.g., public agents, research institutions, and industrial associations) excepting focal firms. More specifically, these studies extend the research on the creation of smart and sustainable cities by utilizing the IE approach. The findings highlight the importance of collaborative activities and sharing objectives to establish smarter and greener cities. However, knowledge on how to integrate actors and activities in different sub-systems is limited. In addition, how to generate universal indicators and principles from these city-specific findings is also a challenging task for future research.

Thus, this body of research on regional development may be advanced by cross-boundary and comparative investigations. For instance, revealing interaction mechanisms across different levels of regional IE could complement existing findings primarily based on single-level research. Studies on different orchestrators in terms of their governing tools and mechanisms may also contribute. Since IE elements from different sub-systems impact each other, studies on how to collectively orchestrate cross-system factors will contribute to systematic findings. More fundamentally, compatible indicators or principles for smart and sustainable regional (city, region, and country) transitions will enable quantitative evaluation and comparison between regions.

5.4. IE Conceptualization and Theorization

Studies in Stream 4 provide fruitful achievements for conceptualizing and theorizing IE by review and theoretical works. These articles fundamentally not only distinguish IE

from other relevant concepts through unpacking their similarities and differences but also advance the theorization of IE by communicating the connection between IE and other closely related theories. These findings extend the understanding of what IE looks like via explicit definitions and how IE could be managed by structural frameworks. This group of studies is among the ones that can most inspire and advance future explorations in the IE field, especially for empirical studies. These studies will also significantly advance future research on sustainability.

Promising research opportunities may be catalyzed by these fundamental and profound theoretical achievements. For instance, these studies (e.g., [23,30,38]) may stimulate more theoretical discussion and empirical examinations of the key elements of IE (actors, activities, relations, artifacts, and evolution). This is also applied to exploiting the findings results from bridging IE and other maturing theories (e.g., [31,104,105]). Additionally, exploring the structural features of IE, especially in terms of the dynamic interaction mechanisms between IE elements, is also one promising direction.

5.5. Entrepreneurship and Innovation

Scholars in Stream 5 contribute to the literature on entrepreneurship and innovation. They pay great attention to university entrepreneurial organizations (e.g., university spin-offs and university entrepreneurial incubators), multinational enterprises, and individual entrepreneurs. The investigated entrepreneurial IE is always led by focal firms, keeping other actors or stakeholders (e.g., governments, non-profit institutions, research institutions, and users) located at the periphery of IE and acting as complementors. However, since the activities and outcomes of innovative entrepreneurship are increasingly dependent on the collective actions of diverse partners, it is not necessarily a case of which actor is the most important. Therefore, what is lacking in this stream may be investigation of the collective arrangements of IE at the system level as well as the orchestration of entrepreneurial IE across regions by different actors. Meanwhile, these scholars also highlighted that entrepreneurial challenges arise from multiple aspects of the complexity of entrepreneurial IE such as different kinds of uncertainty, goal, and performance, any of which may determine the processes and outcomes of individual entrepreneurship. These challenges and the corresponding countermeasures for entrepreneurs have not received enough investigation in this stream.

To smooth these gaps, future research could pay more attention to how to motivate diverse IE actors at the system level to advance entrepreneurial innovation and how to orchestrate entrepreneurial IE by different actors. More specifically for individual entrepreneurs, how to cope with complex challenges in evolutionary IE by different tools including cognitive mechanisms is also a challenge for future research. Besides, leveraging sustainable innovation for entrepreneurship and promoting sustainability through entrepreneurship processes are also promising research directions in the IE field.

Based on the identified IE conceptual framework (Table A1) and the discussion of state-of-the-art IE research, Table 5 summarizes the main recommendations for future IE research.

Table 5. Suggestions for future IE research.

Streams	Suggestions
Technology innovation	• Study roles of neglected actors (e.g., governments, users, SMEs, and universities) in evolutionary IE especially for sustainable innovation. • Consider features of technological innovation (e.g., incremental, radical/disruptive, sustainable, social, and inclusive) in the orchestration of IE. • Explore the influence of cognitive and emotional factors (e.g., over-optimism, willingness, risk perception, expectation) on IE actors' collaborative behaviors. • Investigate collaborations and conflicts among actors across IE boundaries. • Research potential technological and non-technological factors influencing the substitutions of technologies and firms' adaptations of new technologies in IE.

Table 5. *Cont.*

Streams	Suggestions
Platform IE	• Introduce evolutionary and complex system perspectives to unpack the process of dynamic platform IE orchestration. • Explore coordinating mechanisms of complementary resources, components, and actors across industrial, geographical, and IE boundaries to organize platform IE and create different platform products and technologies such as green and smart products and technologies. • Study how to diffuse different kinds of platforms (e.g., digital vs. non-digital, tangible vs. intangible, and sustainable vs. general) across actors and markets by the IE approach. • Reveal how IE actors acting as leaders and complementors match internal and external resources, capabilities, goals, and environments.
Regional development	• Examine the dynamic development process of regional industry IE across levels (cluster, city, province, economic delta, country). • Study how different IE orchestrators govern regional and industrial innovation by specific tools and mechanisms. • Integrate collective activities among actors embedded in different sub-systems (knowledge, business, technology, political, academic, cultural, and stakeholder systems) of IE. • Develop compatible indicators, elements, principles, and frameworks for the creation and governance of smart and sustainable regional IE (city, region, and country) by comparable studies.
IE conceptualization and theorization	• Apply these IE-related concepts to guide empirical studies, including research on diverse issues to promote sustainability. • Bridge the IE and other relevant concepts, as well as bridge the emerging IE theory and other maturing theories. • Employ the key elements of the IE concept (e.g., actors, activities, relations, artifacts, evolution, and the specific affiliated elements) and their configurations (e.g., different structures, diversified relations, modularity, alliances, networks) to conduct empirical studies. • Explore the interacting mechanisms between IE elements across evolutionary stages (e.g., cooperation or complementarity, competition or substitution, coopetition, and symbiosis).
Entrepreneurship and Innovation	• Research how to collectively motivate diverse regional IE actors/stakeholders (e.g., public, private, market, academic, and governmental organizations) to advance innovative entrepreneurship. • Study how to govern entrepreneurship by different IE actors/orchestrators (e.g., university spin-offs, public organizations, and non-profit organizations) across regions. • Reveal individual's cognitive factors in managing complex IE uncertainties and risks, goals and performance, and technologies and products. • Unpack the mechanisms that individuals leverage to cope with complex, ever-changing, and collective IE challenges. • Leverage sustainable innovation for entrepreneurship and promote sustainable innovation in the process of entrepreneurship in the IE context.

6. Conclusions

This study departs from past reviews on the connections between IE and other related concepts by focusing on IE to unpack the intellectual structure of the research fronts of IE literature and distill corresponding recommendations to progress future IE research. Utilizing a systematic literature review approach, 136 articles representing the core and latest knowledge of the IE literature were identified from the 405 IE studies via a bibliographic coupling technique, and subsequently, emerging research streams of IE literature were detected according to the research focuses of these articles by a content analysis method. Results show that current IE research fronts include five research streams, namely technological innovation, platform IE, regional development, IE conceptualization and theorization, and entrepreneurship and innovation. Through analysis and discussion of these streams, recommendations for future IE research in each stream are offered. Therefore, this review extends past reviews and provides a comprehensive appreciation of the state-of-the-art IE research providing targeted theoretical and practical implications.

This study provides implications for leveraging the IE approach to advance sustainable development. Theoretically, to advance sustainability research in the above five research streams, future research can employ the IE approach (including the five key components

and corresponding diverse affiliated elements) as operational conceptual and theoretical tools. In practice, to identify and govern the diverse factors shaping the outcomes of sustainability practices in dynamic and interdependent socio-techno-economic environments, enterprise managers, policy makers, non-profit groups, and other stakeholders are more likely to succeed with the help of the IE approach and mindset. To sum up, sustainability research and practice might significantly benefit from utilizing the IE approach.

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Appendix A

Table A1. Main keywords defining innovation ecosystem.

Author, Year	Views Defining IE	TC	Keywords and Affiliated Elements				
			Actors	Activities	Relations	Artifacts	Evolution
Adner, 2006 [33], p. 2	Arrangements	568	Firms, customer	Combine offerings into solutions	Collaborative	Offerings	
Papaioannou et al., 2009 [34], p. 326	Interrelations and processes	28	Individual actors	Adaptation and survival	Interrelations		Evolutionary, functional processes
Nambisan and Baron, 2013 [35], p. 1071	Network	210	Companies and other entities	Develop new products and services	Loosely interconnected, cooperatively and competitively	Technologies, knowledge, skills, products, and services	Coevolve
Still et al., 2014 [118], p. 246	Network	32	Organizations, human networks, interdependent firms	Generate creativity and output, create and deliver products and services, creating sustained value, co-creation	Connections, symbiotic relationships, a network of relationships	Information, talent and financial resources, a milieu conducive to business growth, products and services, value	Sustainable
Jucevicius et al., 2016 [119], p. 430	Network	8	Actors from industry, government, and academia	Innovative activities and performance	A complex network		Interactions
Bomtempo et al., 2017 [120], p. 221	Network	21	Innovative actors (including focal firm, suppliers, buyers, and complementors)	Provide products and services, create value, diffuse innovations	Organized into a network	Products and services, value, innovations	
Ding and Wu, 2018 [10], p. 2	Network system	10	Governments, enterprises, and customers	Interact, communicate, or promote innovation, create products	Complementary, interact, communicate	Innovation, products	
Gomes et al., 2018 [111], p. 172	Context	35	Entrepreneur, complementary innovators (including suppliers, customers, and other partners)	Create and capture value	Complementary	Context, value	Different moments
Gomes et al., 2018 [27], p. 45	Network	120	Actors (including focal firm, customers, suppliers, complementary innovators, and regulators)	Co-creation value	Interconnected and interdependent network, complementary, cooperation, and competition	Value	A lifecycle, a co-evolution process

Table A1. *Cont.*

Author, Year	Views Defining IE	TC	Keywords and Affiliated Elements				
			Actors	Activities	Relations	Artifacts	Evolution
Holgersson et al., 2018 [36], p. 303	System	42	Actors, firm	Open innovation activity, activities	Interconnected, organizational and market relations, institutions	Resources	
Mazzucato and Robinson, 2018 [47], p. 168	Network	21	Actors (including public agencies, firms, intermediaries, and other actors)	Contribute to the production and use of a product or service	Interconnected, organized around a particular value chain/industry	A product or service	
Reynolds and Uygun, 2018 [121], p. 179	Economic relationships, systems	36	Actors (university faculty and students, entrepreneurs, industry leaders, government officials), entities (market and non-market organizations)	Enable innovation	Economic relationships, synergistic relationships	A milieu conducive to business growth, knowledge, resources, internal and external forces	Dynamic, a continual realignment, changing
Russell and Smorodinskaya, 2018 [105], p. 115	Systems	35	Actors, decision-makers, entities, and economies	Enable self-adaptability to rapid change	Network relationships, collaborative, non-hierarchic models, horizontal linkages	Context (social, economic, institutional, etc.), collaborative cohesive milieu, feedback	Changing, persistent structural trans-formations, continual networking
Schuelke-Leech, 2018 [122], p. 263	System	39	Agents	Innovation	Feedback, interacting with each other	Feedback and disturbances, context, technologies	Dynamic, adaptive, progression, change and evolve
Walrave et al., 2018 [37], p. 104	Network	59	Actors, end users	Co-create and deliver value proposition, appropriate the gains	Interdependent, complementary	Specialized yet complementary resources and/or capabilities	Process
Witte et al., 2018 [123], p. 226	Participants and resources	17	Participants	Contribute to innovation		Resources	Ongoing
Wu et al., 2018 [106], p. 224	System	11	Actors and organization, customer	Promote interaction and communication, enable technology development, inspire innovation, innovation activities	Interaction, cooperative	Technology, innovation	Long-term or temporary, development
Xu et al., 2018 [94], p. 211	System	51	Researchers, university, enterprises, outsourcing partners, technology providers, and complementary product makers	Generates/produces knowledge, advances technological development, develops products and services, realizes value propositions	Interconnected, complementary, and synergistic	Scientific and industrial knowledge, products, and services	Development
Ding et al., 2019 [84], p. 1565	System, network	5	Innovation organizations	Promote interaction, communication, and innovation		Ecological environment, innovation	Long-term or temporary
Gao et al., 2019 [70], p. 242	Network	3	Organizations, focal firm, related providers	Value creation and appropriation through innovation	Interconnected, complementary	Technologies and assets	
Boyer, 2020 [115], p. 1	System	9	Heterogeneous actors	Perform activities, play roles, contribute to the development of innovation processes or technologies	Complex relationships	Motivations and capabilities	Dynamic and adaptive, development, processes
Granstrand and Holgersson, 2020 [23], p. 3	System	71	Actors	Activities	Relations (complementary and substitute), institutions	Artifacts	Evolving

Note: TC (times cited), reported by Web of Science by September 2021.

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