Journal of Open Innovation:
Technology, Market, and Complexity

MDPI

Article

The System Thinking Perspective in the Open-Innovation Research: A Systematic Review

Mario Tani [1,*], Ornella Papaluca [1] and Pasquale Sasso [2,*]

[1] Department of Economics, Management, Institutions, University of Naples Federico II, 80126 Naples, Italy; ornella.papaluca@unina.it

[2] Department of Economics, Università degli Studi della Campania Luigi Vanvitelli, 81043 Capua, Italy

* Correspondence: mario.tani@unina.it (M.T.); pasquale.sasso@unicampania.it (P.S.)

Received: 20 June 2018; Accepted: 14 August 2018; Published: 18 August 2018

Abstract: The new logics of competitions are mostly based on exploiting relationships to implement new mechanisms in managing Knowledge. Today, a successful company should be, lean, modular, and with a smart approach to new products development. In this context, the source of competitive advantage cannot be found into a static heterogeneity of resources, but companies must be able to create and manage a dynamic competitive process to continuously reinvent their products/services and to re-combine their resources with their partners' ones. A paradigm for this behavior is the Open Innovation one, as created by Chesbrough. According to the rules of this paradigm, companies have to acknowledge that they operate in a network of relationships, they must be open to cooperate with their external partners, and they must not try to limit their actions in reaching only for some pre-defined result. So, Open Innovation Networks appear to be similar to those described by the scholars in the Complex Adaptive Systems field where the actions of the system, and of its parts, are the result of the various actors' interactions in an emergent way. In this paper, we use a Systematic Literature Review approach to explore how the main topics in the System Thinking Perspective, and in particular, those related to Complex Systems, are linked to the Open Innovation studies.

Keywords: Open Innovation; resource-based theory; interactions; innovation; system thinking; Complex Systems; systematic literature review

1. Introduction

According to several authors, the convergence between technologies is usually considered as one of the consequences of the permeating role of the ICTs and is changing the way companies can innovate [1–3]. In this new contest, companies find that their innovation potential is tightly tied to the new logics of the relational economies [4] where the relational management capabilities, and resources, can become an effective source of competitive advantage [5] when companies are able to focus on implementing new mechanisms to create and share the resulting new knowledge [6].

On a similar page, scholars had already urged companies to adopt a new, more informal, model of relationship management [7,8] as a way to speed up the change needed to go on in the various steps of the famous Nonaka and Takeuchi's SECI Model [9]. Relationships were found to be a potential source of competitive advantage since the early contributions to the Resource Based Theory [RBT] [10,11]. The authors in this stream highlighted that companies need to defend the core-competences in order to not give all of their partners easy access to the real sources of their competitive advantage [10,12,13].

Authors in both streams highlight that the greater innovation potential coming out of a good relationship management is the results of the opportunity to leverage a far greater amount of knowledge resources in their processes [5,10,14,15] with the consequence of leveraging a greater Cognitive Processes Generativity [16] and reaching for a higher potential creativity [17]. It follows that supporting the interactions with the various company partners can be a powerful way to innovate as managers get access to the whole set of knowledge resources that the other actors have, even those tacit knowledge [18], which is the founding stone of the more explicit one [19].

Managers can use relationships to leverage the full set of explicit and tacit knowledge shared among the various partners of the network, so they are not only able to go beyond the known-known—i.e the full spectrum of the knowledges each single player has—to enter the realm of the known-unknown—i.e., those new knowledges that each single actor does not have, but he can expect to get leveraging some other partners' knowledge resource—but they can, sometimes, enter the realm of the unknown-known—i.e., the unexpected combinations of the various explicit knowledge of the various partners that can lead to previously unforeseen innovations—and in the most favorable cases, they can even border the area of the unknown-unknown when the innovation is the result of the interaction of several kinds of tacit knowledge [20]. The effective use of these combinations helps each manager to get more potential value out of these relationships [17,21], and, moreover, the whole potential value can become greater than the sum of its parts [22].

On the other side, the management of each single partner is not able to have a full comprehension of the full potential he can get out of these interactions as it emerges out of the interaction between the various specific actors involved [23,24].

At the same time, these networks can reach their full potential only when several of their actors, if not all of them, are able to access freely, and with no pre-defined target, the full set of knowledge resources embedded in the network as a whole [25]. In spite of this, other authors hold that the effectiveness of each interaction can be maximized only when the various partners are able to be market-driven in their research for new combinations of resources, so, in reality, the research activities cannot be fully free of any scope and aims [26,27]. According to the authors in this stream, the effectiveness of innovative processes depends on management's ability to combine the market orientation with several effective organizational processes to facilitate the combination of the different forms of knowledge (market-based knowledge, scientific or technical, and organizational one) in the decision-making processes [28–30].

In this paper, after presenting the main points of relationship management of the three different streams, we have just presented [namely the RBT, the Open Innovation, and the Complex Systems Theory], we highlight the current state of the art of the interaction between Open Innovation and Complex System Theory. We have chosen to carry on an exploratory research focusing on these two latter theories, as, according to our initial literature review, these two seems to be able to complement each other. In particular, we have tried to highlight how the main topics in Complex Systems Theory have been used in the Open Innovation field of research in order to identify the potential areas to look-up for new knowledge gaps. In this exploratory paper, we have carried on an extensive systematic literature review in order to highlight the degree of diffusion of Complex System Theory in the Open Innovation literature. In this research, we have taken into consideration both the literature frameworks and the keywords that were used in the papers citing the most popular work of the Open Innovation field of research.

We have found out that there is a somewhat diffused utilization of the main topics, and the main features, of the Complex Systems in the literature on Open Innovation literature, but at the same time, the relationship between the two fields are still not so widespread to let the Complex Systems become a prominent part of the literature on Open Innovation.

2. The Theoretical Framework

In literature, we have found several streams and fields that have studied how relationships can help businesses to get, and sustain, a competitive advantage.

2.1. Relationships as a Source of Competitive Advantage

The idea of using external relationships as a way to be more efficient is an old one in the strategic management field (for example see reference [31]). Relationships were initially seen as a way to be more efficient in reducing the overall costs of the production processes and they were seen as a new solution when confronted with the "hierarchical one". The main focus of these studies was, on finding, the best way to manage the relationship between two opportunistic partners [31–33].

A different approach was used by the scholars in the Resource-based theory. They considered relationships as a way to get access to external resources [10,11] in order to get an economic rent leveraging a heterogeneous resource endowment [13].

At the same time, some scholars in this research stream highlighted that relationships could become a way to address the increasing turbulence of modern markets paving the way to a faster, and more flexible, answer to the changes the context was imposing on businesses [5,34]. Companies could leverage their partnerships and alliances to get access to a more various, and potentially more valuable, set of resources that they can combine with the internal ones as a way to enhance the potential value of innovation-based strategies [9,34,35].

As relationships let the company be faster in developing new processes, they can be used to increase the value of the company products/services starting a Dynamic Competitive Process [DCP] and driving the company to change their market offer before competitors can have the chance to adapt [35,36]. At the base of this DCP, there are the various knowledge resources that the company can leverage in its innovative processes, even in a discontinuous way while using their combinative capabilities [4,7,34,37].

According to Grant [38], managers can leverage the broader set of knowledge resources they can have access to in their relationship networks while using two different processes: knowledge integration and knowledge transfer. With the first process, companies can effectively combine the knowledge resources they have got access to according to their effectiveness—i.e., the possibility that the new knowledge will be able to help in creating new knowledge—broadness—i.e., the broadness of the specialized knowledge the company has—the more specialized it is the more difficult is to correctly see the potential in their combination and flexibility—i.e., the possibility to re-use the same piece of knowledge in different fields. The second one, knowledge transfer is the process that was used to continuously innovate the knowledge endowment and it requires the company to adopt the right organizational tools to be really effective [38].

In this research stream, a strong focus is put on the initial endowment of knowledge resources in order to leverage the knowledge generativity [16] and relationship are one good way to make this endowment bigger and broader [39].

Building on these considerations, Dyer and Singh [5: 662] state that relationships can be a source of sustainable competitive advantage as they create relational rents when they help companies in leveraging a heterogeneous set of resources. In particular, they state that these relational rents can be reached when the company is able to adopt the correct governance tools to leverage a fruitful combination of the knowledge resources diffused among partners with a heterogeneous and complimentary set of resources.

The need to manage the continuous interactions with a broad set of partners asks companies to develop the specific capabilities that are needed to get the most out of them, and, sometimes, this can drive them to create a dedicated organizational unit/function [40,41]. Moreover, as the capabilities that are needed to manage the continuous interaction are getting more and more honed, and more and more specific over time, they can even create some relation-specific capabilities, that scholars in this field consider as a source of barrier to imitation as they help in reducing the risks that are linked to unwanted knowledge spill-overs during the various interactions [42].

Another strategic opportunity that companies have to profit from the relationships is to not use a short-run perspective, only focusing on getting the most for themselves, but in trying to drive their various partners toward solutions able to create the most value for the network as a whole knowing that this increased value will make the network stronger and more attractive in the future.

In particular, in this stream of the RBT, a central role is given to the network itself as it can be seen as a governance tool to move from a path-dependent to a path-creation strategy [40,43]. Moreover, these authors state that the relationship network itself can help in creating several strategic advantages and it can help in limiting some of the dangers of cooperating with potential competitors.

When companies are able to create a stable and mutually beneficial relationship network, they can help to create knowledge-based trust to reduce the risks of opportunistic behavior by their partners [44,45]. When companies are embedded in a stable and trusted network they can use it to reduce the future costs of finding new partners as they can leverage the relationships the other actors have—i.e., they can start an indirect relationship partner research.

Finally, the existence of a network with a higher relationship density can help companies in two different ways. On one side, it can help in improving the knowledge flows as the denser and the more active the network is, the easier it is for companies to know which knowledges the other players are sharing [46]. On the other side, they can help in creating a deterrence-based trust as all of the actors know that if they betray another one, the other partners can start to distrust them, and consequently, to not interact with them anymore depriving them of the various advantages they get from participating in the network [47,48].

In this sharing process, companies should focus on getting a sustainable competitive advantage from managing their relational capabilities. In order to do so, they have to be able to reach new knowledge, to combine it with their own and to transfer it in their organizational structure as a way to create new competences to exploit in their products/services.

2.2. The Open Innovation Approach to Relationship Management

Building on the previous streams of research, linking external resources to the competitive advantage a specific firm can get, some scholars have proposed a different approach where companies increase their efforts in interacting with the other players in their network of relationships in order to change both the "how to innovate" and the "how innovation processes can be managed".

These scholars have proposed a model for managing innovative processes in the modern, turbulent environment, which is based on the need, and only on the opportunity, for companies to open up their innovation processes in order to combine internal inputs with external ones and to create business value leveraging, as for the resource-based theory, not the resource similarity in the partners knowledge resources, but their complementarity and their flexibility [4,10].

The term open innovation was introduced for the first time in the famous Chesbrough's book [6], in which the author outlines a new model for industrial innovation. Since then, the concept and the theoretical foundations of the "open innovation" has been the focus of several researches and it has been adopted as an innovation management practice by a large number of companies [49,50].

In particular, the open innovation concept assumes that "firms can and should use external idea as well as the external ones, and internal and external paths to market, as they look to advance their technology, translating that into architectures and systems" [51]. Some scholars, also, defined open innovation [52] as the cooperative creation of ideas and applications outside of the boundaries of any single firm.

Gassmann and Enkel [52] identify three "open innovation process archetypes":

- **outside-in**: enriching the company's own knowledge base through the integration of suppliers, customers, and external knowledge sourcing in internal innovation and knowledge creation processes;
- **inside-out**: providing new ideas coming from sources of knowledge and innovation internal to the firm to external users in the outside environment; and,
- **coupled**: coupling outside-in and inside-out approaches in alliances with partners.

In this way, the engagement refers not only to the consumers, but also the whole groups and individuals willing to deal with a project or a proposal through sharing common ideas and opinions, creating value for firms as well as for the society [53].

Organizations should be able to enhance their innovations performance adopting an open innovation model [51], leveraging inter-firm cooperation [54] to create two processes:

- the "inbound, open innovation", referring to the acquisition of and use of external knowledge internally; and,
- the "outbound innovation", referring to the external use of internal knowledge [55].

This part of the researches on the open innovation highlights the meaningful role that the ability to manage knowledge flows has in the area. Particularly, the open innovation focuses the attention on the role of interaction between the ideas coming from outside (the case of the in-bound open innovation) and ideas that are generated within the firm (this is the case of out-bound open innovation) for the value creation [6].

The specific premise of open innovation is opening up the innovation process has to be open to use incoming and outgoing knowledge flows in order to accelerate the internal innovation, and, at same time, to expand the market for the external uses of innovation [51].

The open innovation literature has been divided in several sub-streams [56]. In fact, the difference between inbound open innovation (the internal use of external knowledge) and outbound open innovation (the external exploitation of internal knowledge) is not the only way to classify the efforts in this perspective. Another classification of this literature is the one that is referring to three different knowledge processes that could be fulfilled inside or outside company's boundaries [57]: knowledge exploration, retention, and exploitation. In an open innovation context, even if firms contaminate each other with their knowledge base, they remain fully autonomous economic actors.

Another interesting topic about open innovation refers to its effectiveness. Some authors found that cooperation in the vertical direction (between suppliers and buyers) has a positive impact on innovative performance, because it depends on the strength of the link more than on its existence [58]. Others [59] found an interesting relationship between open innovation and firm's performance. In fact, they found that too much open innovation could have a negative impact on firm's performances. Others research on the open innovation effectiveness would know the reasons why firms open up their innovation processes. They have identified two different approaches: offensive approach in order to stimulate the growth and defensive approach, in order to decrease costs and risks.

Some empirical studies found that offensive reasons were stronger that defensive ones [60]; in these, the studies on open innovation seems to be tightly linked to those of the RBT, as they highlight the need to identify complementary assets to get the most out of this approach [34,44,46,61].

The open innovation context and its main characteristics is another interesting topic in this field's academic literature. These characteristics can be divided in internal and external ones. The internal characteristics refer to those company features that are linked to demographics and strategy. In particular, the demographics characteristics are those linked to the firm size, number of its employees, its location, and profits; strategy characteristics, instead, refer to the company strategic orientation and the goals of its innovation process. The second one (the external characteristics) are usually defined at the level of the specific industrial sector (such as electronics), but several authors [62,63] suggest that, in the open innovation processes, there are less differences across industries.

The Open Innovation context is a network that can be composed by different actors with different goals linked by different type of relationships. Accordingly, the network's complexity increases.

In addition, Gassman [64] suggests that open innovation is more relevant in contexts with a higher technology intensity, which is linked to the fusion of different technologies, and to the development of new business models. Open innovation is not a simple topic; in fact, this concept is often linked to different concepts, such as absorptive capacity [65].

The partners absorptive capacity is relevant as it rules the potential combinations of the partner's knowledge's endowment coming out of the interaction with the other actors in the open innovation network. The open innovation processes involve different groups or organizations and if can have different initiators. Moreover, collaboration among different types of subjects increases the flexibility of the participants in the network to use the knowledge of the network partners.

At the same time, some scholars have focused their efforts on the great difficulty of managing these networks effectively, as they appear to be very complex because they require to take into consideration the many, different, points of view of the various actors; for this reason, in open innovation processes, is not always possible to predict the result of the innovation process [66,67].

2.3. Complexity and System Thinking

As highlighted in the last paragraph, the results of the activities in the relationship network that is created by players adopting an open innovation approach can be quite difficult to forecast. These networks are composed of many agents; they can operate in different ways, driven by different motivations, while they are trying to reach for some specific innovation but without hindering the innovative potential of the system as a whole. It is the network as a whole that has the biggest potential to open new, and not previously defined, innovative paths in the future. These networks share several characteristics with the Complex Systems, a part of the more general approach that is defined under the broad umbrella of the System Thinking Perspective.

The label of System Thinking has been used to encompass many different theories from its beginning in the 1950 [68,69]. Its various parts have been, somehow, coordinated after the famous contribution by von Bertalanffy: "General System Theory" [22]. In his book, the Austrian biologist posed the foundations to develop a useful model to represents dynamic systems in various fields of knowledge.

The various system theories share, as a common factor, several characteristics allowing for the emergence of a universal language to direct and contextualize complex models of interaction between different system components without going out of the boundary of the complex adaptive systems [70,71]. The flexibility of this theory has proven to be useful in understanding the behavior of agents in several disciplines, such as sociology [72], economics [73,74], political science [75,76], clinical care [77], business [78–80], and organizations [25,81,82].

As highlighted by Dominici and Levanti [83], the logic behind the various systemic approaches was an attempt to go beyond the traditional reductionist-analytical methodology that was adopted to analyze complex phenomena. System thinking takes into consideration the various effects emerging off the interactions between heterogeneous and autonomous parts. In this way, the system theories acknowledge that the whole and its parts exist at the same time, but at different levels [83,84].

The systemic approach is a bottom-up one as it focuses on the system as a dynamic whole, while taking into account the dynamic interactions at the microlevel—i.e., among the various agents, in order understand how its properties can emerge naturally while giving a holistic perspective on the paths of the system evolution [85,86]. This approach acknowledges the existence of an outward influence as the action of the various systems' actors can change its evolution path as a whole.

Among the various system theories, we focus on the Complex System Theory and its various main streams [83]. We refer to the Complex Systems as they share several characteristics with the Open-Innovation networks, such as [87]:

- the connectivity and interdependence of the actors;
- the co-evolution of the system's actors and the presence of some sort of feedback system to regulate it;
- the presence of dissipative structures to interact with the environment external to the network itself;
- the need to make emerge new "states" in the "space of possibilities"; and,
- a link with history (path-dependence).

As these structures share several traits with those that are defined in the Open-Innovation literature, looking at them through the lens of Complex Systems perspective can be useful in order to better understand the relationship between the behavior of each agent and the one of the whole, and what is the effect of the related dynamics [83,88]. These results can be obtained while leveraging these systems main properties, such as:

- **Emergence**: The birth of new systemic behaviors, paths and properties of networked systems from spontaneous interactions among agents [89];
- **Self-Organization**: The unplanned creation of augmented order, emerging from the internal dynamics of the system as learning, process variation, tuning and improvement [90];
- **Path dependence**: The overall behavior of the complex system, and its structure as well, depends on the past stimuli and the past behaviors of its parts. Hence, the evolution of the system and its historical roots can affect the system overall structure and its agents' behavior [91];
- **Operational closure and thermodynamic openness**: The system is autonomous and can be identified as a whole in each space–time momentum regardless of its specific structure [92]; and,
- **Co-evolution, adaptation, and learning**: Agents have to adapt to each other and to external stimuli, in order to operate their semi-autonomous strategies [93–95].

Moreover, these systems, labeled as Complex Adaptive Systems [96] or Complex Evolving Systems [97], are basically multilevel—i.e., the interaction between the agents can take place and be studied at different levels so that they can be divided in meaningful sub-systems [98]. At the same time, as highlighted by Anderson [93], these systems have a "tangled composite" structures so it is possible to study them at several different levels, highlighting a number of semi-autonomous structures. In each level, the agents will operate and interact, even with those at a different level in order to co-evolve and adapt [93].

3. Materials and Methods

As the interaction between the System Thinking Perspective, with a particular focus on the Complex Systems and the Open Innovation literature, is still an unexplored one, we have chosen to adopt an Exploratory Research Design [99] to highlight its current state of the art.

We focus on the Complex Systems as the literature review has highlighted how their characteristics can create networks with a structure that is similar to those that are described in the Open Innovation field of research.

In particular, in this paper, we seek to understand if the main topics of the Complex Systems Theory have been used in the literature on Open Innovation, and eventually, we try to understand how they are related to the other main topics in the Open Innovation literature. To understand the interaction between the two fields, we have carried on an extensive systematic literature review.

Our research has been divided in four main steps:

(1) Preliminary Analysis

   a. Identify the main streams in the Open Innovation literature.
      i. Identify the interaction of these streams with the complex system theory;
   b. Build up a corpus of articles citing the more relevant articles in the Open Innovation managerial literature.

(2) General Analysis of the main topics used in the corpus

   a. Identify the most used Keywords (both author, and curators ones) used to describe the topics in each article.
   b. Look for the Complex System-related topics.

(3) Co-citation Analysis of the references in each corpus article

a. Extract the references used in each article.
b. Build the Co-citation network.
    i. Analyze the structure of the network.
c. Look for the main Complex Systems Theory Scholars.

(4) Keywords co-occurrence analysis

a. Identify the most used Curators Keywords used to describe each of the articles in the corpus.
b. Build the Keywords Co-occurrence network
    i. Analyze the structure of the network.
c. Look for the Complex System-related Keywords.

The starting point of this research has been the traditional literature review developed by Huizing in the 2011 [56]. This article has been cross-referenced with our own traditional literature review to identify 3 main topics to consider as sub-stream in the major stream of the literature on Open Innovation:

- Absorptive Capacity.
- Complementary Assets.
- Knowledge Flows.

Then, we have looked into Google Scholar to identify whether these sub-streams were still relevant, and to have a first look in their potential overlapping. The results of this first research are reported in the following Table 1.

The results of this first step in the research have shown that the stream of the Open Innovation has slowly grown momentum in the academic research, as, since the 2011, it has more than doubled the number of articles and conference proceedings dedicated to it in its first ten years.

Moreover, the research highlights that it is slowly taking over the research on absorptive capacity (see query 2 and 5), and a similar path is forecastable for the "knowledge management" research that is slowly focusing on the effects of the Open Innovation approach on the management of knowledge flows.

At the same time, this research has highlighted how not all of the topics can be considered really relevant when considered as a sub-stream of the Open Innovation academic literature. In particular, this holds true for the topic of the "Complementary Resources" is only partially focused on Open innovation.

Finally, the 14th query highlights that there is a good amount of literature (376 papers) that explicitly refers to all three topics with an Open Innovation perspective.

In order to understand how this body of research efforts is related with the general topic of complexity, one of the cornerstones of the Complex System Theory, we have refined the previous query with the term "complexity" and "complex systems". The results of this refinement are reported in the following Table 2 in number of articles, and in the following Table 3 as a percentage of the whole research efforts on each topic without filtering for Open Innovation.

These results shed some light on the specific topic of our research.

This preliminary analysis confirms that open innovation and complexity are somehow related, but, at the same time, it shows that most of the research on Open Innovation does not acknowledges the role of complex systems.

A similar result can be found in each of the sub-streams with the notable exception of the "complementary resources" that is only marginally overlapped with the Complex System perspective. This is not an unexpected result as the general idea of focusing on complementary resources is usually not related with a holistic perspective, but, instead, it focuses on the point of view of a single actor. As this stream of research lacks the needed multi-level perspective it is only rarely related with the Complex System Theory.

After the first two phases of the research process, we have decided to focus the next steps only on the three main streams.

In order to build up a corpus of articles we have used Google Scholar and Web of Science by Clarivariate Analytics (usually referred as "ISI Web of Science" (WoS)). We have used Google Scholar, as it has been often acknowledged as the biggest bibliographic index and we have used WoS as it indexes all of the seeds.

As Google Scholar has a broader reach, we have used it to identify the most "relevant contributes"—i.e., those appearing first in the Google Scholar ranking—in each stream of the literature. For each one of the topics we have saved the five more relevant articles to use as seeds in the following sub-steps.

We report the selected articles in each of the streams in the following Table 4.

For each of these seeds, we have then used WoS, as we consider it to be a more relevant source of academic research than Google Scholar, and in particular, we have used its "Cited Reference Search" (CRS) in order to identify the articles that cite it.

As CRS gives the opportunity to identify the literature citing a work in several ways (taking into account slight variation on spelling and/or incomplete records), we have refined the research of each item to correctly identify only the results really citing the seed we were considering. For each seed we have saved the articles resulting out of the first five most used different ways to cite the work.

In order to have only relevant articles we have further refined each search with the following parameters:

- **Web of Science Categories**: Management; Business
- **Document Types**: Article.

Then, we have saved each query in the cloud and then we have used the WoS option to safely remove all of the duplicates (WoS assigns each contribute a unique identifier, so that they can delete duplicate in a sure way without having to use some sort of heuristics).

The results of this phase are reported in the following Appendixs A and B (We needed to carry on two separate researches as the WoS research was carried on by two authors at the same time and WoS does not offer a tool to merge the researches done with different accounts).

The first research gave us an initial corpus of 4435 articles in the management, or business, literature listed in the WoS database that make an explicit reference to the 10 main seeds related to "open innovation" or to "absorptive capacity". The second corpus is made of the 1647 articles listed in the WoS database making an explicit reference to the five seeds of "knowledge management".

In order to eliminate all the duplicates from the corpus defined merging the two research results we adopted an R-Cran function (duplicateMatching) that identifies duplicates using the restricted Damerau-Levenshtein distance and saves those that have a relative similarity measure greater than 0.95 in a separate data-frame.

This research was able to identify 307 duplicates, giving us a final corpus dimension of 5776 articles. Then, we read the titles of these articles to confirm that they could be classified in one of the topics of our research. In the few cases, we were not sure if deleting or not an article after reading its title we read its abstract to confirm if it was to stay or to be deleted. In reality, we have not deleted a single record in this step as no one was found to be completely off-topic; in reality, this was the expected result as we refined the corpus in the WoS search engine.

Table 1. The interaction among the various sub-streams.

#	Research Query	Results of the Query		
		before 2001	2001–2010	after 2010
1	"Open Innovation"	376	12,800	27,800
2	"Absorptive Capacity"	17,500	29,900	23,300
3	"Complementary Resources"	2560	8550	12,800
4	"Knowledge Management"	19,000	541,000	155,000
5	"Open Innovation" and "Absorptive Capacity"	27	2260	11,100
6	"Open Innovation" and "Complementary Resources"	2	319	1710
7	"Open Innovation" and "Knowledge Management"	54	3120	14,400
8	"Absorptive Capacity" and "Complementary Resources"	127	1500	2710
9	"Absorptive Capacity" and "Knowledge Management"	463	10,300	16,700
10	"Complementary Resources" and "Knowledge Management"	76	1380	2240
11	"Open Innovation" and "Absorptive Capacity" and "Complementary Resources"	2	163	913
12	"Open Innovation" and "Absorptive Capacity" and "Knowledge Management"	14	891	4650
13	"Absorptive Capacity" and "Complementary Resources" and "Knowledge Management"	18	515	935
14	"Open Innovation" and "Absorptive Capacity" and "Complementary Resources" and "Knowledge Management"	2	72	376

Table 2. The interaction of the Open Innovation main topics and complexity [number of articles].

#	Research Query	Results of the Query		
		before 2001	2001–2010	after 2010
1	"Open Innovation" and "Complex systems"	11	687	3080
2	"Absorptive Capacity" and "Complex systems"	264	1330	2510
3	"Complementary Resources" and "Complex systems"	59	312	516
4	"Knowledge Management" and "Complex systems"	1170	12,300	16,400

Table 3. The interaction of the Open Innovation main topics and complexity.

#	Research Query	% of Topic's Research Stream		
		before 2001	2001–2010	after 2010
1	"Open Innovation" and "Complex systems"	2.93%	5.37%	11.08%
2	"Absorptive Capacity" and "Complex systems"	1.51%	4.45%	10.78%
3	"Complementary Resources" and "Complex systems"	2.31%	3.65%	4.03%
4	"Knowledge Management" and "Complex systems"	6.16%	2.27%	10.58%

Table 4. The 15 seeds identified in the sub-phase 3.1 of the research project.

Stream	Seed
Open Innovation	1. Chesbrough, H., Vanhaverbeke, W., & West, J. (Eds.). (2006). Open innovation: Researching a new paradigm. Oxford University Press on Demand. 2. Chesbrough, H. W. (2006). Open innovation: a new paradigm for understanding industrial innovation, in Chesbrough, H. W. (ed). Open innovation: The new imperative for creating and profiting from technology (0–19). Harvard Business Press. 3. Chesbrough, H. W. (2003). Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press. 4. Chesbrough, H., & Crowther, A. K. (2006). Beyond high tech: early adopters of open innovation in other industries. R&d Management, 36(3), 229–236. 5. Enkel, E., Gassmann, O., & Chesbrough, H. (2009). Open R&D and open innovation: exploring the phenomenon. R&d Management, 39(4), 311–316.
Absorptive Capacity	1. Cohen, W. M., & Levinthal, D. A. (2000). Absorptive capacity: A new perspective on learning and innovation. In Strategic Learning in a Knowledge economy (pp. 39-67). 2. Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. Academy of management review, 27(2), 185–203. 3. Tsai, W. (2001). Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. Academy of management journal, 44(5), 996–1004. 4. Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. Strategic management journal, 461–477. 5. Lane, P. J., Salk, J. E., & Lyles, M. A. (2001). Absorptive capacity, learning, and performance in international joint ventures. Strategic management journal, 22(12), 1139–1161.
Knowledge Management	1. Alavi, M., & Leidner, D. E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS quarterly, 107–136. 2. Leonard-Barton, D. (1995). Wellsprings of knowledge: Building and sustaining the sources of innovation. 3. Tiwana, A. (2000). The knowledge management toolkit: practical techniques for building a knowledge management system. Prentice Hall PTR. 4. Gold, A. H., Malhotra, A., & Segars, A. H. (2001). Knowledge management: An organizational capabilities perspective. Journal of management information systems, 18(1), 185–214. 5. Ruggles, R. (1998). The state of the notion: knowledge management in practice. California management review, 40(3), 80–89.

This final corpus was studied while using the Bibliometrix package in R-Cran to map the relationship between the various manuscripts that it is made of [100].

In particular, we have looked into the Keywords the authors have used to describe their articles, or those provided for by the WoS curators when they were missing, as a way to identify the main topics that are discussed in each article.

Using the Bibliometrix package, and some of its dependencies, such as as SNA, iGraph, and FactoMineR, we have carried on a Bibliometric Analysis to know the most relevant keywords, authors and articles.

Then we have looked into the co-citation network. This is a social network graph, and the related matrices, which are composed by all of the authors in the corpus. In this network, two authors are tied when they are both cited in the same work. This kind of network is usually studied to understand how the various contributions and the main authors are linked in the evolution of a given field of research. Obviously, this network can be biased, as the first writers in a given field will tend to be more connected, as they have been published for a longer period, so they will be cited in more papers, and they will appear to be more central.

In order to go beyond this limitation, we have studied the network of the Curator's keywords co-occurrences. This network should not be biased by the moment in time a specific author wrote its main contributions. Moreover, the Keywords co-occurrence network is able to highlight the main structure of the sub-streams in a given research field [100].

In each of these analyses, we have looked for the authors, keywords, and words that are related to Complex System Theory.

The R-Cran program for the analyses has been reported in the Appendix C.

4. Results

In order to make the exposition clearer we present the data in three main sections: General Analysis, Co-citation Analysis, and Co-occurrence Analysis.

4.1. General Analysis

In the corpus, we have 5776 documents, written by 9155 authors. The articles were published in 403 sources (Journals, Books, etc.) from the 1996 to the 2018. We do not consider the part of the corpus before the 2001 as capable to influence the set as it accounts only of 105 articles (1.82% of the whole set) at the same time they can be useful not to exclude some meaningful articles in the Absorptive Capacity and Knowledge Management that may show some still unbeaten path for Open Innovation Studies. The distribution of the article has been provided in Figure 1.

The figure makes explicit that the full scope of the field has been reached after the 2010 (so it is not included in the work by Huizing, which was published in the 2011 [56] as they account for 63.37% of the whole corpus.

The following Table 5 reports the ten most used author, and curator, keywords.

The table confronts the keywords that are assigned by the authors to their works, to those that are defined by Web of Science Curators. The latter are higher, as the authors tend to be more specific, while the curators tend to classify the article on a limited set of keywords. In fact, the authors have defined a set of 10349 keywords, while the curators have classified the whole corpus using 5093 different keywords (less than half of those used by the authors).

The most cited contributions are listed in the following Table 6.

The table highlights the tight link between the three topics that we have focused on. Moreover, as Chesbrough famous book is in the second position, it highlights the meaningful role that Open Innovation has got in the academic literature.

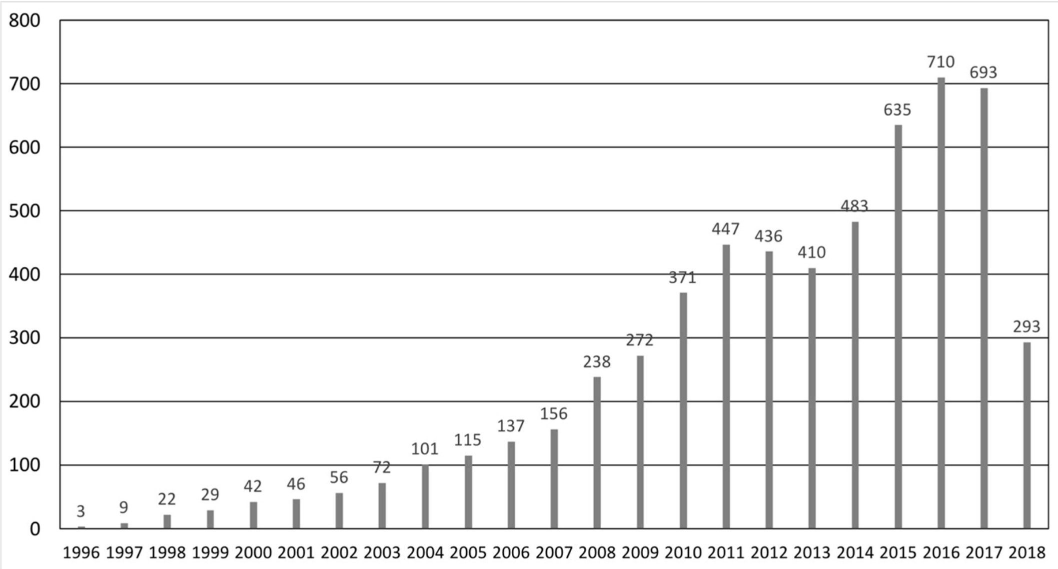

Figure 1. The article published in each year.

Table 5. Most Frequently used Keyword.

	Author Keywords	Articles	Keywords-Plus (Curators' Keywords)	Articles
1	Innovation	838	Performance	1929
2	Knowledge Management	521	Absorptive-Capacity	1858
3	Absorptive Capacity	400	Innovation	1324
4	Open Innovation	375	Research-And-Development	1002
5	Knowledge	338	Knowledge	916
6	Performance	222	Perspective	879
7	Knowledge Transfer	190	Competitive Advantage	848
8	Knowledge Sharing	181	Management	840
9	Learning	161	Firm	798
10	Organizational Learning	137	Capabilities	651

Table 6. Ten Most Frequently Cited Manuscripts.

Manuscript	Citations
Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128–152	2063
Chesbrough, H W. (2003), Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.	1163
Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. Academy of management review, 27(2), 185–203.	1025
Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. Strategic management journal, 461–477.	844
Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of management, 17(1), 99–120.	839
Grant, R. M. (1996). Toward a knowledge-based theory of the firm. Strategic management journal, 17(S2), 109–122.	761
Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. Organization science, 3(3), 383–397.	758
Alavi, M., & Leidner, D. E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS quarterly, 107–136.	703
March, J. G. (1991). Exploration and exploitation in organizational learning. Organization science, 2(1), 71–87.	640
Nonaka, I., & Takeuchi, H. (1995). The knowledge-creating company: How Japanese companies create the dynamics of innovation. Oxford university press.	590

4.2. Authors' Co-Citation Analysis

As a second step in our analysis, we developed an Author's Co-citation analysis.

This analysis helps in identifying how the various authors are linked in the academic literature. In order to better identify the vertices of the network, we have adopted the Salton Similarity Index [101] among the various options that were provided by the software.

The following Figure 2 reports the results of this analysis in a Fruchterman–Reinghold diagram.

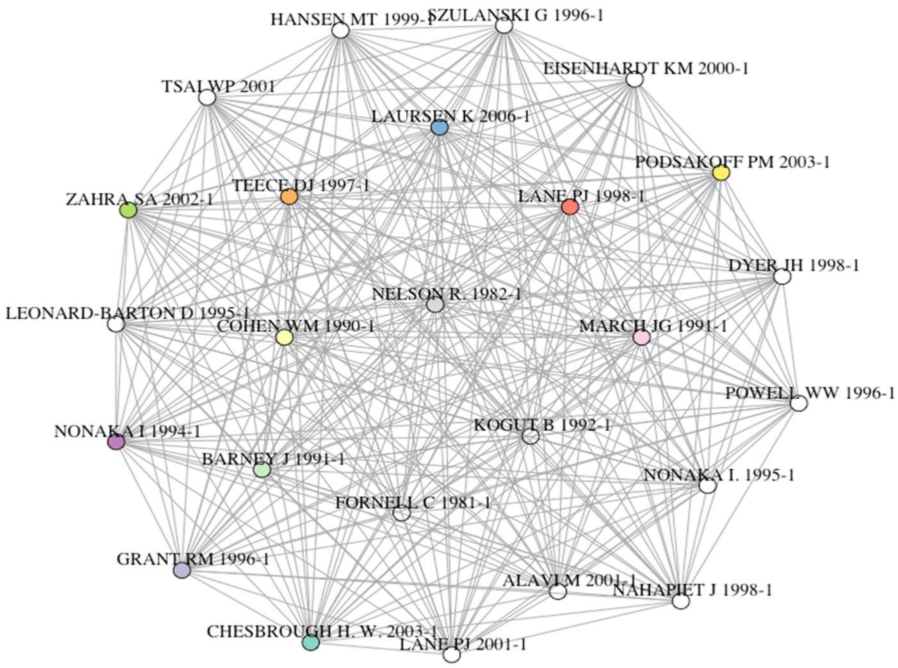

Figure 2. The co-citation network of the first 25 most cited contributes in the corpus.

The first thing to notice it is that the network is quite similar to a circle diagram showing that the kernel of the literature in this corpus is tightly connected.

At the same time, it is interesting to notice how in the center of the graph—i.e., the most co-cited work in this network as the Fruchterman–Reinghold algorithm minimizes the distance among each vertex and those that it is more strongly tied to—we found the article of Nelson and Winter on the Population Ecology of the Organizations (this is outside of the corpus). This article highlights the need to confront the turbulent times with a more flexible set of competences as those that a company can reach adopting only the Open-Innovation Paradigm.

Another interesting point is the centrality of the 1981 article by Fornell and Lacker on the evaluation of Structural Equation Models with unobservable latents showing that most of the literature in this fields adopts this methodology, or, at the very least, acknowledge the need to take into consideration the problem of the error in measuring unobservable factors.

As a whole, this network has 117941 vertices (every cited reference) and it is in general quite sparse (Degree centralization of 0.2%), showing hints of a classic core-periphery behavior where only a limited part of the literature is really making an impact on the field where most of the literature is just marginally present.

In order to study the kernel of this network, we limited the research to those articles with more than 10 co-citation as a way to purge out of the network all of the links between articles that are only marginally co-cited—i.e., the periphery. We get a new network composed of 4790 vertices with a density of 74.22%. If we consider only those articles that have been cited by at least 118 other publications—i.e., they have been cited in the 0.1% of the whole corpus—we get a strong core that is composed of 148 manuscripts with a density of 98.32%.

Confronting this list with the first 50 more relevant articles on Complex Systems and Open Innovation, as for the Google Scholar ranking, we have found that none of these articles are in the core of the field. It follows that the authors in the Open-Innovation fields do not see the Complex System Theory as one of the main topics/theories to factor in in their researches. This was expected after the preliminary phase, as the interaction between the two fields had been found in a mere 10% of whole corpus of papers, and, as this network shows a core-periphery structure, this is usually not big enough for the topic to have entered the core.

4.3. Keywords Co-Occurrence Analysis

In order to avoid the potential issues with the co-citation analysis depending more on the year of publication than on the true relevance of the article, we have carried on a Co-occurrence Analysis of the keywords that are used to describe the manuscripts in the corpus.

The following Figure 3 shows the plot of the Fruchterman–Reinghold diagram of the 50 most used curator's keywords in the corpus. In this case, the plot is less shaped as a circle than the previous one showing several rings of co-occurrence.

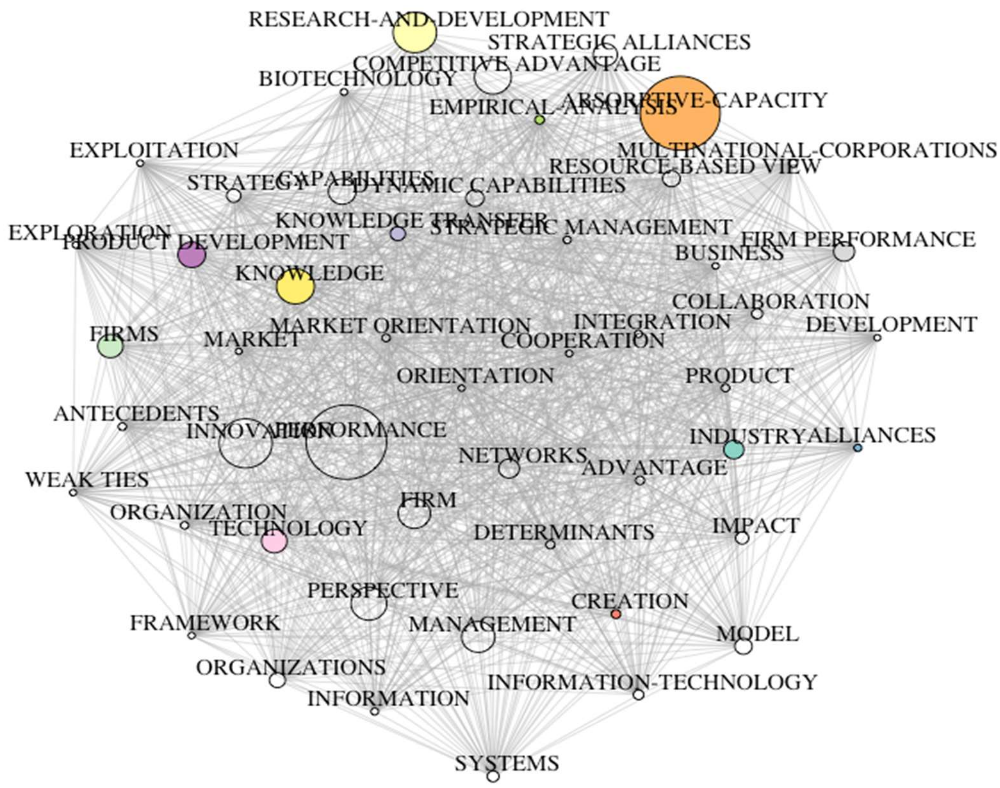

Figure 3. The co-occurrence network of the first 50 most used curator's keywords in the corpus.

It is relevant to note that at the center of the plot we find the keywords on "market" and "market orientation". In the lower part of the diagram, at the edge, there is the keyword "System" that is near to other system thinking keywords, like "model" and "creation", and near other keywords as "performance", "management", and "information".

At the same time, we have to notice how the "System" keyword is far from other keywords as "Strategic Management", "Firm Performance", "Integration", and "R&D", but even some other related to empirical fields related to the research on open innovation as "Biotechnology" or the more generic "Empirical Analysis".

Analyzing the whole network while using the tools of Social Network Analysis, we still find a quite sparse network with a density of only 0.85%. We investigate a reduction of the 5093 nodes in order to understand if there's a core-periphery structure.

As before, we look into the keywords appearing no less than 5 times (the 0.1% of the whole set) and we get a network of 1168 keywords with a density of a little more than 9%, if we look into the keywords appearing no less than 25 times (the 0.5% of the whole set), we get a network of 294 keywords with a density of a little more than 40%. This shows that the curator's keywords are not shaped as a core-periphery, but, instead, they have a slower degradation in the degree centrality. In this network, there are some keywords that are related to the Complexity Systems. Some of the keywords that are used that can be surely related to the Complex System Perspective are reported in the next Table 7 at the next page.

Table 7. Some Keywords used and their frequency.

Keywords	#	Keywords	#
Systems	2779	Involuntary	12
System	240	System Process Innovations	12
Complexity	198	Complex Networks	11
Adaptation	130	System Quality	11
Emergence	106	System Strength	11
Coevolution	101	Adaptive Systems Perspective	10
Complex	72	Complexity Science	10
Loosely Coupled Systems	54	Emergent	10
Complexity Theory	53	Exaptation	10
Entropy	46	System Characteristics	10
Systems-Development	44	Systematic-Risk	10
System Usage	31	Systems Competition	10
Interorganizational Systems	27	Systems Implications	10
Interorganizational Systems	27	Systems-Approach	10
Systems Success	23	System Implementation	8
Complex-Systems	21	Systems Integration	8
System Dynamics	21	Interactions	7
System Success	21	Systems Biology	7
System Reform	20	Autopoiesis	6
Context-Emergent Turnover	13	Systems Thinking	6
Systems Research	13		

The table highlights, how, after the first keyword— "System" —there is a steep descent to a mere 240 ties for the Complex System's Keywords; please note that, as each manuscript has usually more than two keywords, the number of keywords co-occurrences is usually higher than the number of manuscripts indexed with them.

These Keywords are representative of several aspects of Complex System Theory as Adaptation, Emergence, but even some of the other topics as Coevolution and Autopoiesis find a way in this corpus of manuscripts.

At the same time, we have to admit that most of the Keywords appear only in a bunch of manuscripts, as more than half of them have a number of ties lower than 20.

5. Discussion

The results of our exploration process have shown that even if Open Innovation and Complex Systems are theoretically related they are only rarely used together in academic literature.

The tight theoretical link between the two fields highlights that managers could be able to improve their performances in Open Innovation Networks when they acknowledge that, instead of trying to control the outcome of the interactions, they should, instead, acknowledge the main strengths of the

Complex Systems as the auto-regulation and they should focus their efforts in adapting to the other players' behaviors.

Moreover, if managers are able to leverage the interactions between Complex Systems and Open Innovation they can understand that the more disruptive innovations are, often, an emergent new property of the whole system so they can be leveraged in other sub-systems (i.e., at the meso-level).

At the same time, our article shows that there is still much work to do for this interesting perspective to make a dent into this field of research.

None of the main authors of the System Thinking perspective has found a way in the core of the network of the most cited works, but this is not really relevant, as, as highlighted in the first part of the research project, only 10% of the studies have made an explicit connection between the two topics and, in a core-periphery network structure 10% is a too small size to enter the network's core.

Some more positive results are coming out of the keywords utilization shown in the Table 7. We have to remember that these are the keywords provided by the experts working for Web of Science not those provided by the authors.

This is not a casual choice, as these keywords are based on the content and on the structure of the manuscripts and they are not influenced by publication biases or some other agenda by the authors.

The research of this paper is partly limited by two main research design issues:

- we choose not to limit the corpus to only the article citing the Open Innovation; and,
- we do not cover the whole abstract.

With regard to the first limitation, this has been a proper decision to help identify the part of the streams lying at the boundary of the open innovation to explore, thanks to the co-citation and the co-occurrence, some potential new fields to focus on in future researches.

Moreover, the analysis of the corpus has shown that the Absorptive Capacity and the Knowledge Management sub-streams create two small groups of keywords, which, while still being connected to the others, are still clearly identifiable looking at the graphs.

On the other side, we could analyze the abstracts and the titles using dimensionality reduction techniques, such as Multidimensional Scaling (MDS), Correspondence Analysis (CA), or Multiple Correspondence Analysis (MCA) in order to map the conceptual structure of a framework using the word co-occurrences.

In future research, we will study this corpus with MCA and K-means clustering to identify clusters of documents that express common concepts, but this research goes beyond the scope of this first paper on this corpus of manuscripts. This more in-depth study of the intersection between the Complex Systems topic and its components, or dimensions, may be able to provide a clearer and more effective description of the interactions between the fields.

This more in-depth research goes beyond the scope of this work that is to explore if, and how, the various aspects of the complex systems perspective have been adopted by the scholar of the Open Innovation field as a way to identify new potential knowledge gaps by changing the general perspective on these activities.

Another limitation in this article, which could be used to develop further researches, is that we do not take into account the different relevance of the various sources (i.e., its Impact Factor) for the research community, an aspect that we have not considered in this work that could be useful to have a clearer picture of the evolution dynamics of the interaction between the two research fields.

Author Contributions: Conceptualization, M.T., O.P.; Methodology, M.T., P.S. and O.P.; Software, M.T.; Validation, O.P., P.S.; Formal Analysis, M.T.; Data Curation, P.S.; Writing-Original Draft Preparation, M.T., O.P., P.S.; Writing-Review & Editing, M.T. In general, the work is a shared effort, but the authors have been the main contributors of the following sections. M.T.: Sections 1, 2.1, 2.3 and 4.1, Appendix C; O.P.: Sections 3 and 4.2, Appendix A; P.S.: Sections 2.2 and 4.3, Appendix C. All the other sections have been the results of a shared effort.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The step by step process to create the corpus of Open Innovation literature (first part).

Seed	Citation Model	Articles		Duplicates	Corpus Dimension
		Before Refinement	After Refinement		
OI1	1	924	308	0	308
	2	275	114	11	411
	3	73	43	21	433
	4	69	27	19	441
	5	63	24	6	459
OI2	1	336	120	9	570
	2	3	1	0	571
	3	2	2	0	573
	4	2	1	0	574
	5	1	1	0	575
OI3	1	2,094	1,341	250	1,666
	2	29	17	3	1,680
	3	10	3	0	1,683
	4	8	2	0	1,685
	5	7	0	0	1,685
OI4	1	545	286	74	1,749
	2	4	0	0	1,749
	3	1	0	0	1,749
	4	1	0	0	1,749
	5	N/A	N/A	N/A	1,749
OI5	1	470	219	57	1,816
	2	3	0	0	1,816
	3	1	0	0	1,816
	4	1	0	0	1,816
	5	N/A	N/A	N/A	1,816
AC1	1	8	2	0	1,818
	2	N/A	N/A	N/A	1,818
	3	N/A	N/A	N/A	1,818
	4	N/A	N/A	N/A	1,818
	5	N/A	N/A	N/A	1,818
AC2	1	2,969	1,541	214	3,145
	2	17	6	0	3,151
	3	14	4	2	3,153
	4	7	1	0	3,154
	5	4	0	0	3,154
AC3	1	1,807	1,086	430	3,810
	2	4	2	0	3,812
	3	2	1	1	3,812
	4	1	0	0	3,812
	5	N/A	N/A	N/A	3,812
AC4	1	1,451	771	430	4,235
	2	4	1	0	4,236
	3	3	2	1	4,237
	4	2	0	0	4,237
	5	2	2	1	4,238
AC5	1	777	465	271	4,432
	2	7	6	4	4,434
	3	1	1	1	4,434
	4	1	1	0	4,435
	5	1	1	1	4,435

Appendix B

The step by step process to create the corpus of Open Innovation literature (second part).

Seed	Citation Model	Articles		Duplicates	Corpus Dimension
		Before Refinement	After Refinement		
KM1	1	2,888	713	0	713
	2	208	55	0	768
	3	9	2	0	770
	4	8	2	0	772
	5	8	1	0	773
KM2	1	1,348	603	24	1,352
	2	12	4	2	1,356
	3	8	2	0	1,358
	4	2	2	0	1,360
	5	2	2	0	1,362
KM3	1	297	27	8	1,381
	2	1	0	0	1,381
	3	N/A	N/A	N/A	1,381
	4	N/A	N/A	N/A	1,381
	5	N/A	N/A	N/A	1,381
KM4	1	1,095	335	136	1,580
	2	7	2	0	1,582
	3	5	0	0	1,582
	4	3	1	1	1,582
	5	2	1	1	1,582
KM5	1	427	118	55	1,645
	2	10	2	1	1,646
	3	2	1	0	1,647
	4	N/A	N/A	N/A	1,647
	5	N/A	N/A	N/A	1,647

Appendix C

The program code used to refine and study the corpus.

```
# Bibliometric Analyses For JOITMC
# OI in System Thinking Perspective
#
# First of all define a work directory
setwd(dir = "/Users/mariotani/Dropbox/research/Conferenze/soitmc/")
# We install the needed libraries
install.packages("dplyr",
            "factoextra",
            "FactoMineR",
            "ggplot2",
            "igraph",
            "Matrix",
            "rscopus",
```

```
            “SnowballC”,
            “stringr”)
install.packages(“bibliometrix”)
library(dplyr)
library(factoextra)
library(FactoMineR)
library(ggplot2)
library(igraph)
library(Matrix)
library(rscopus)
library(SnowballC)
library(stringr)
library(bibliometrix)

#read all the data in a DF
#we need to use two different DF asa consequence of the reset
c_1 <- readFiles(“0001-500.bib”,
            “0501-1000.bib”,
            “1001-1500.bib”,
            “1501-2000.bib”,
            “2001-2500.bib”,
            “2501-3000.bib”,
            “3001-3500.bib”,
            “3501-4000.bib”,
            “4001-4435.bib”)
c_2 <- readFiles(“seconda ricerca 1-500.bib”,
            “seconda ricerca 501-1000.bib”,
            “seconda ricerca 1001-1500.bib”,
            “seconda ricerca 1501-1647.bib”)
corpus_1 <- convert2df(c_1, dbsource=“isi”, format = “bibtex”)
corpus_2 <- convert2df(c_2, dbsource=“isi”, format = “bibtex”)
#we use rbind() and duplicatedMatching() to eliminate the duplicates from the corpus
corpus_duplicate <- rbind(corpus_1, corpus_2)
corpus <- duplicatedMatching(corpus_duplicate, Field = “UT”)
rm(c_1)
rm(c_2)
rm(corpus_1)
rm(corpus_2)
rm(corpus_duplicate)
```

```
# First Analysis, a description of the Network
# We use the biblioAnalysis() function to extract a first analysis of the corpus.
results <- biblioAnalysis(corpus, sep = “;”)
summary(results)
# We plot the articles by year graph
table(results$Years)
#We identify the ten most relevant keywords defined by the authors
head(results$DE, n=10)
#We identify the ten most relevant keywords defined by the curators
head(results$ID, n=10)
# We look into the corpus to identify the most cited articles
CR <- citations(corpus, field = “article”, sep = “.  “)
cbind(CR$Cited[1:10])
#Step 2 - The Co-Citation Analysis
# In order to comprehend the links between the articles
#we proceed to make a Co-citation network
#The first step is to create a bi-partite network of the authors
#cited in the references of the
#corpus’ manuscripts
NetMatrix <- biblioNetwork(corpus, analysis = “co-citation”,
                network = “references”, sep = “.  “)
rm(results)
#plot authors’ similarity (first 20 authors)
net=networkPlot(NetMatrix, weighted=NULL, n = 25, Title = “Co-Citation Network”,
           type = “fruchterman”, size=5,remove.multiple=TRUE)

#we analize the network using igraph functions
net <- graph.adjacency(NetMatrix,mode=“undirected”,weighted=NULL)
V(net)$id <- colnames(NetMatrix)
net <- simplify(net, remove.loops = T)
networkSize <- vcount(net)
networkDensity=edge_density(net, loops = FALSE)
# we reduce the network to those articles that have more than 5 citations
# 1.  redefine functions from package Matrix
diag <- Matrix::diag
colSums <-Matrix::colSums
# 2.  delete not linked vertices
ind=which(Matrix::colSums(NetMatrix)-Matrix::diag(NetMatrix)>0)
NET=NetMatrix[ind,ind]
```

```
dim(NET)

# 2.  delete vertices with less than 5 co-citations
n = 5
NET2 <- NET[diag(NET)>=n,diag(NET)>=n]
dim(NET2)
core.network <- graph.adjacency(NET2,mode="undirected",weighted="null")
core.network <- simplify(core.network, remove.multiple = T, remove.loops = T)
edge_density(core.network, loops = FALSE)

# 3.  delete vertices with less than 0.1% of co-citations
n = 118
NET3 <- NET[diag(NET)>=n,diag(NET)>=n]
dim(NET3)
core.network2 <- graph.adjacency(NET3,mode="undirected",weighted="null")
core.network2 <- simplify(core.network2, remove.multiple = T, remove.loops = T)
edge_density(core.network2, loops = FALSE)
colnames(NET3)
#removing not anymore useful objects
rm(net, NET, NET2, NET3, core.network, core.network2, colSums, diag, ind, n)

#Step 3 - The Co-occurrence Analysis
# In order to comprehend the links between the articles we proceed to make a
Co-occurrence network
#The first step is to create a bi-partite network of the keywords used in the
corpus' manuscripts
NetMatrix2 <- biblioNetwork(corpus, analysis = "co-occurrences", network = "keywords",
                  sep = ";")
NetMatrix3 <- biblioNetwork(corpus, analysis = "co-occurrences",
                  network = author_keywords", sep = ";")
#plot keywords network (first 50 keywords)
net=networkPlot(NetMatrix2, normalize="association", weighted=NULL, n = 50,
          Title = "Keyword Co-occurrences", type = "fruchterman",
          size=T, edgesize = 0.4, labelsize=1, remove.multiple=TRUE)
          net=networkPlot(NetMatrix3, normalize="association", weighted=NULL,
          n = 50, Title = "Keyword Co-occurrences", type = "fruchterman",
          size=T, edgesize = 0.4, labelsize=1, remove.multiple=TRUE)
#we analize the networks using igraph functions
net <- graph.adjacency(NetMatrix2,mode="undirected",weighted=NULL)
V(net)$id <- colnames(NetMatrix)
net <- simplify(net, remove.loops = T)
```

```
vcount(net)
edge_density(net, loops = FALSE)

# 1.  redefine functions from package Matrix
diag <- Matrix::diag
colSums <-Matrix::colSums
# 2.  delete not linked vertices
ind=which(Matrix::colSums(NetMatrix2)-Matrix::diag(NetMatrix2)>0)
NET=NetMatrix2[ind,ind]
dim(NET)

# 2.  delete vertices appearing less than 5 times
n = 5
NET2 <- NET[diag(NET)>=n,diag(NET)>=n]
dim(NET2)
core.network <- graph.adjacency(NET2,mode="undirected",weighted="null")
core.network <- simplify(core.network, remove.multiple = T, remove.loops = T)
edge_density(core.network, loops = FALSE)

# 2.  delete vertices with less than 50 co-citations
n = 25
NET3 <- NET[diag(NET)>=n,diag(NET)>=n]
dim(NET3)
core.network2 <- graph.adjacency(NET3,mode="undirected",weighted="null")
core.network2 <- simplify(core.network2, remove.multiple = T, remove.loops = T)
edge_density(core.network2, loops = FALSE)

# 3.  look for the Complex System Keywords
# 1.  Save all the keywords in a file
x <- sort(colnames(NET))
write(x, file="./ckw.txt")
# we have looked in the keywords and extracted those clearly related with
# Complex System Theory
sum(NET[colnames(NET) == "COMPLEX-SYSTEMS"])
sum(NET[colnames(NET) == "COMPLEX"])
sum(NET[colnames(NET) == "COMPLEXITY"])
sum(NET[colnames(NET) == "EMERGENCE"])
sum(NET[colnames(NET) == "ADAPTATION"])
sum(NET[colnames(NET) == "AUTONOMOUS"])
sum(NET[colnames(NET) == "ADAPTIVE SYSTEMS PERSPECTIVE"])
```

```
sum(NET[colnames(NET) == “AUTOPOIESIS”])
sum(NET[colnames(NET) == “COEVOLUTION”])
sum(NET[colnames(NET) == “COMPLEX NETWORKS”])
sum(NET[colnames(NET) == “COMPLEXITY SCIENCE”])
sum(NET[colnames(NET) == “COMPLEXITY THEORY”])
sum(NET[colnames(NET) == “CONTEXT-EMERGENT TURNOVER”])
sum(NET[colnames(NET) == “EMERGENT”])
sum(NET[colnames(NET) == “ENTROPY”])
sum(NET[colnames(NET) == “EXAPTATION”])
sum(NET[colnames(NET) == “SYSTEM”])
sum(NET[colnames(NET) == “SYSTEMS”])
sum(NET[colnames(NET) == “INTERACTIONS”])
sum(NET[colnames(NET) == “INTERORGANIZATIONAL SYSTEMS”])
sum(NET[colnames(NET) == “INVOLUNTARY”])
sum(NET[colnames(NET) == “LOOSELY COUPLED SYSTEMS”])
sum(NET[colnames(NET) == “INTERORGANIZATIONAL SYSTEMS”])
sum(NET[colnames(NET) == “SYSTEM CHARACTERISTICS”])
sum(NET[colnames(NET) == “SYSTEM DYNAMICS”])
sum(NET[colnames(NET) == “SYSTEM IMPLEMENTATION”])
sum(NET[colnames(NET) == “SYSTEM PROCESS INNOVATIONS”])
sum(NET[colnames(NET) == “SYSTEM QUALITY”])
sum(NET[colnames(NET) == “SYSTEM REFORM”])
sum(NET[colnames(NET) == “SYSTEM STRENGTH”])
sum(NET[colnames(NET) == “SYSTEM SUCCESS”])
sum(NET[colnames(NET) == “SYSTEM USAGE”])
sum(NET[colnames(NET) == “SYSTEMATIC-RISK”])
sum(NET[colnames(NET) == “SYSTEMS BIOLOGY”])
sum(NET[colnames(NET) == “SYSTEMS COMPETITION”])
sum(NET[colnames(NET) == “SYSTEMS IMPLICATIONS”])
sum(NET[colnames(NET) == “SYSTEMS INTEGRATION”])
sum(NET[colnames(NET) == “SYSTEMS RESEARCH”])
sum(NET[colnames(NET) == “SYSTEMS SUCCESS”])
sum(NET[colnames(NET) == “SYSTEMS THINKING”])
sum(NET[colnames(NET) == “SYSTEMS-APPROACH”])
sum(NET[colnames(NET) == “SYSTEMS-DEVELOPMENT”])
```

References

1. Hacklin, F.; Raurich, V.; Marxt, C. Implications of technological convergence on innovation trajectories: The case of ICT industry. *Int. J. Innov. Technol. Manag.* **2005**, *2*, 313–330. [CrossRef]

2. Hacklin, F.; Marxt, C.; Fahrni, F. Coevolutionary cycles of convergence: An extrapolation from the ICT industry. *Technol. Forecast. Soc. Chang.* **2009**, *76*, 723–736. [CrossRef]
3. Curran, C.S.; Leker, J. Patent indicators for monitoring convergence–examples from NFF and ICT. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 256–273. [CrossRef]
4. Powell, W.W.; Grodal, S. Networks of innovators. In *The Oxford Handbook of Innovation*; Fagerberg, J., Mowery, D.C., Nelson, R.R., Eds.; Oxford University Press: New York, NY, USA, 2005; pp. 56–85.
5. Dyer, J.H.; Singh, H. The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. *Acad. Manag. Rev.* **1998**, *23*, 660–679. [CrossRef]
6. Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business Press: Brighton, MA, USA, 2003.
7. McMaster, M.D. Organizing for Innovation: Technology and Intelligent Capacities. *Long Range Plan.* **1997**, *30*, 799–802. [CrossRef]
8. Herschel, R.T.; Nemati, H.; Steiger, D. Tacit to explicit knowledge conversion: Knowledge exchange protocols. *J. Knowl. Manag.* **2001**, *5*, 107–116. [CrossRef]
9. Nonaka, I.; Takeuchi, H. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*; Oxford University Press: Oxford, UK, 1995.
10. Barney, J.B. Strategic factor markets: Expectations, luck, and business strategy. *Manag. Sci.* **1986**, *32*, 1231–1241. [CrossRef]
11. Amit, R.; Schoemaker, P.J. Strategic assets and organizational rent. *Strateg. Manag. J.* **1993**, *14*, 33–46. [CrossRef]
12. Barney, J.B. *Gaining and Sustaining Competitive Advantage*, 3rd ed.; Prentice-Hall: Upper Saddle River, NJ, USA, 2007.
13. Peteraf, M.A. The cornerstones of competitive advantage: A resource-based view. *Strateg. Manag. J.* **1993**, *14*, 179–191. [CrossRef]
14. Hoyt, J.; Huq, F. From arms-length to collaborative relationships in the supply chain: An evolutionary process. *Int. J. Phys. Distrib. Logist. Manag.* **2000**, *30*, 750–764. [CrossRef]
15. Bharadwaj, S.; Menon, A. Making Innovation Happen in Organizations: Individual Creativity Mechanisms, Organizational Creativity Mechanisms or Both? *J. Prod. Innov. Manag.* **2000**, *17*, 424–434. [CrossRef]
16. Donald, M. *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition*; Harvard University Press: Boston, MA, USA, 1991.
17. Weitzman, M.L. *Recombinant Growth*; Harvard University Press: Boston, MA, USA, 1996.
18. Polanyi, M. *The Tacit Dimension*; Doubleday and Co.: New York, NY, USA, 1966.
19. Brown, J.S.; Duguid, P. Knowledge and organization: A social-practice perspective. *Organ. Sci.* **2001**, *12*, 198–213. [CrossRef]
20. Walloth, C. Emergent Nested Systems. In *Emergent Nested Systems: A Theory of Understanding and Influencing Complex Systems as Well as Case Studies in Urban Systems*; Springer International Publishing: Cham, Switzerland, 2016.
21. Moran, P.; Ghoshal, S. Markets, firms, and the process of economic development. *Acad. Manag. Rev.* **1999**, *24*, 390–412. [CrossRef]
22. Von Bertalanffy, L. *General System Theory*; Braziller: New York, NY, USA, 1968.
23. Atay, F.M.; Jost, J. On the emergence of complex systems on the basis of the coordination of complex behaviors of their elements: Synchronization and complexity. *Complexity* **2004**, *10*, 17–22. [CrossRef]
24. Desouza, K.C. Facilitating tacit knowledge exchange. *Commun. ACM* **2003**, *46*, 85–88. [CrossRef]
25. Dooley, K.J. A complex adaptive systems model of organization change. *Nonlinear Dyn. Psychol. Life Sci.* **1997**, *1*, 69–97. [CrossRef]
26. Day, G.S. The Capabilities of Market-Driven Organizations. *J. Mark.* **1994**, *58*, 37–52. [CrossRef]
27. Verhees, F.J.; Meulenberg, M.T. Market orientation, innovativeness, product innovation, and performance in small firms. *J. Small Bus. Manag.* **2004**, *42*, 134–154. [CrossRef]
28. Shapiro, B.P. What the Hell Is 'Market Oriented'? *Harv. Bus. Rev.* **1988**, *66*, 119–125.
29. Jaworski, B.J.; Kohli, A.K. Market orientation: Antecedents and consequences. *J. Mark.* **1993**, *57*, 53–70. [CrossRef]
30. De Luca, L.M.; Verona, G.; Vicari, S. Market orientation and R&D effectiveness in High-Technology firms: An empirical investigation in the biotechnology industry. *J. Prod. Innov. Manag.* **2010**, *27*, 299–320.

31. Williamson, O.E. Markets and hierarchies: Some elementary considerations. *Am. Econ. Rev.* **1973**, *63*, 316–325.
32. Williamson, O.E. The economics of organization: The transaction cost approach. *Am. J. Sociol.* **1981**, *87*, 548–577. [CrossRef]
33. Williamson, O.E. Credible commitments: Using hostages to support exchange. *Am. Econ. Rev.* **1983**, *73*, 519–540.
34. Ireland, R.D.; Hitt, M.A.; Vaidyanath, D. Alliance management as a source of competitive advantage. *J. Manag.* **2002**, *28*, 413–446. [CrossRef]
35. Hamel, G.; Prahalad, C.K. *Competing for the Future*; Harvard Business Press: Brighton, MA, USA, 1996.
36. Johannessen, J.A.; Olsen, B.; Olaisen, J. Organizing for innovation. *Long Range Plan.* **1997**, *30*, 96–109. [CrossRef]
37. Kogut, B.; Zander, U. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organ. Sci.* **1992**, *3*, 383–397. [CrossRef]
38. Grant, R.M. Toward a knowledge-based theory of the firm. *Strateg. Manag. J.* **1996**, *17*, 109–122. [CrossRef]
39. Wernerfelt, B. A resource-based view of the firm. *Strateg. Manag. J.* **1984**, *5*, 171–180. [CrossRef]
40. Gulati, R. Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strateg. Manag. J.* **1999**, *20*, 397–420. [CrossRef]
41. Kale, P.; Dyer, J.H.; Singh, H. Alliance capability, stock market response, and long-term alliance success: The role of the alliance function. *Strateg. Manag. J.* **2002**, *23*, 747–767. [CrossRef]
42. Dyer, J.H.; Hatch, N.W. Relation-specific capabilities and barriers to knowledge transfers: Creating advantage through network relationships. *Strateg. Manag. J.* **2006**, *27*, 701–719. [CrossRef]
43. Garud, R.; Rappa, M.A. A socio-cognitive model of technology evolution: The case of cochlear implants. *Organ. Sci.* **1994**, *5*, 344–362. [CrossRef]
44. Shapiro, D.L.; Sheppard, B.H.; Cheraskin, L. Business on a handshake. *Negot. J.* **1992**, *8*, 365–377. [CrossRef]
45. Barney, J.B.; Hansen, M.H. Trustworthiness as a source of competitive advantage. *Strateg. Manag. J.* **1994**, *15*, 175–190. [CrossRef]
46. Kogut, B.; Shan, W.; Walker, G. The make-or-cooperate decision in the context of an industry network. In *Networks and Organizations*; Nohria, N., Eccles, R., Eds.; Harvard University Press: Boston, MA, USA, 1992; pp. 348–365.
47. Raub, W.; Weesie, J. Reputation and efficiency in social interactions: An example of network effects. *Am. J. Sociol.* **1990**, *96*, 626–654. [CrossRef]
48. Burt, R.S.; Knez, M. Kinds of third-party effects on trust. *Ration. Soc.* **1995**, *7*, 255–292. [CrossRef]
49. Remneland-Wikhamn, B.; Wikhamn, W. Open innovation in practice: Diffusion of knowledge and use in Swedish bio-pharmaceutical firms. *Int. J. Bus. Innov. Res.* **2014**, *8*, 137–153. [CrossRef]
50. Gewald, H.; Birkle, M. Open Innovation in the German SME Sector. Development and Test of a Diffusion Model. *Prog. Mach. Syst.* **2012**, *1*, 52–63.
51. Chesbrough, H.W. Why companies should have open business models. *MIT Sloan Manag. Rev.* **2007**, *48*, 22.
52. Gassmann, O.; Enkel, E. Towards a theory of open innovation: Three core process archetypes. In Proceedings of the RADMA Conference, Lissabon, Portugal, 7–9 July 2004.
53. Quaratino, L.; Serio, L. L'innovazione Aperta: La Prospettiva Dell'innovazione Aperta e le Nuove Logiche Organizzative e Gestionali. Available online: https://apeiron.iulm.it/handle/10808/1096#.W3d8V-gzZPY (accessed on 18 August 2018).
54. Belussi, F.; Sammarra, A.; Sedita, S.R. Learning at the boundaries in an "Open Regional Innovation System": A focus on firms' innovation strategies in the Emilia Romagna life science industry. *Res. Policy* **2010**, *39*, 710–721. [CrossRef]
55. Huizingh, E.K. Towards successful e-business strategies: A hierarchy of three management models. *J. Mark. Manag.* **2002**, *18*, 721–747. [CrossRef]
56. Huizingh, E.K. Open innovation: State of the art and future perspectives. *Technovation* **2011**, *31*, 2–9. [CrossRef]
57. Lichtenthaler, U.; Lichtenthaler, E. A capability-based framework for open innovation: Complementing absorptive capacity. *J. Manag. Stud.* **2009**, *46*, 1315–1338. [CrossRef]
58. Tomlinson, P.R. Cooperative ties and innovation:some new evidence for UK manufacturing. *Res. Policy* **2010**, *39*, 762–775. [CrossRef]

59. Laursen, K.; Salter, A. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strateg. Manag. J.* **2006**, *27*, 131–150. [CrossRef]
60. Van de Vrande, V.; de Jong, J.P.J.; Vanhaverbeke, W.; de Rochemont, M. Open innovation in SMEs: Trends, motives and management challenges. *Technovation* **2009**, *29*, 423–437. [CrossRef]
61. Teece, D.J. Profiting from technological innovation: Implications for integration collaboration, licensing and public policy. *Res. Policy* **1986**, *15*, 285–305. [CrossRef]
62. Keupp, M.M.; Gassmann, O. Determinants and archetype users of open innovation. *R&D Manag.* **2009**, *39*, 331–341.
63. Chesbrough, H.W.; Crowther, A.K. Beyond high-tech: Early adopters of Open Innovation in other industries. *R&D Manag.* **2006**, *36*, 229–236.
64. Gassmann, O. Open in gup the innovation process: Towards an agenda. *R&D Manag.* **2006**, *36*, 223–228.
65. Cohen, W.M.; Levinthal, D.A. Absorptive capacity: A new perspective on learning and innovation. *Adm. Sci. Q.* **1990**, *35*, 128–152. [CrossRef]
66. Gassmann, O.; Enkel, E.; Chesbrough, H. The future of open innovation. *R&D Manag.* **2010**, *40*, 213–221.
67. Chiaroni, D.; Chiesa, V.; Frattini, F. The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm. *Technovation* **2011**, *31*, 34–43. [CrossRef]
68. Bar-Yam, Y. *Dynamics of Complex Systems*; Addison-Wesley: Reading, MA, USA, 1997; Volume 213.
69. Ackoff, R.L. Towards a system of systems concepts. *Manag. Sci.* **1971**, *17*, 661–671. [CrossRef]
70. Gell-Mann, M. Complex adaptive systems. In *Systems Thinking*; Midgley, G., Ed.; Sage Publications: New York, NY, USA, 1994.
71. Holland, J.H. *Hidden Order: How Adaptation Builds Complexity*; Addison-Wesley: Reading, UK, 1995.
72. Luhmann, N. *Social Systems*; Stanford University Press: Redwood City, CA, USA, 1995.
73. Allen, D. A set of core principles and tools? *J. Ind. Ecol.* **2000**, *4*, 1–2. [CrossRef]
74. Boulding, K.E. *Economics as a Science*; McGraw-Hill: New York, NY, USA, 1970.
75. Kickert, W.J.; Klijn, E.H.; Koppenjan, J.F. (Eds.) *Managing Complex Networks: Strategies for the Public Sector*; Sage: London, UK, 1997.
76. Meek, J.W.; De Ladurantey, J.; Newell, W.H. Complex systems, governance and policy administration consequences. *Emerg. Complex. Organ.* **2007**, *9*, 24.
77. Ellis, B. Complexity in practice: Understanding primary care as a complex adaptive system. *J. Innov. Health Inform.* **2010**, *18*, 135–140. [CrossRef]
78. Beer, S. *Brain of the Firm: A Development in Management Cybernetics*; Herder and Herder: New York, NY, USA, 1972.
79. Beer, S. *The Heart of Enterprise*; Wiley: Chichester, UK, 1979.
80. Sterman, J.D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*; Irwin/McGraw-Hill: Boston, MA, USA, 2000.
81. Senge, P.M. *The Fifth Discipline: The Art and Practice of the Learning Organization*; Doubleday/Currency: New York, NY, USA, 1990.
82. Senge, P.M.; Sterman, J.D. Systems thinking and organizational learning: Acting locally and thinking globally in the organization of the future. *Eur. J. Oper. Res.* **1992**, *59*, 137–150. [CrossRef]
83. Dominici, G.; Levanti, G. The Complex System Theory for the Analysis of Inter-Firm Networks: A Literature Overview and Theoretic Framework. *Int. Bus. Res.* **2011**, *4*, 31–37. [CrossRef]
84. Baum, J.A.; McKelvey, B. Whole-part coevolutionary competition in organizations. In *Variations in Organization Science: In Honor of Donald T. Campbell*; Baum, J.A.C., McKelvey, B., Eds.; SAGE: London, UK, 1999; pp. 113–135.
85. Stacey, R.D. *Complexity and Management*; Routledge: London, UK, 2002.
86. Batty, M.; Torrens, P.M. Modelling complexity: The limits to prediction. *Cybergeo Eur. J. Geogr.* **2001**. [CrossRef]
87. Mitleton-Kelly, E. *Complex Systems and Evolutionary Perspectives on Organisations: The Application of Complexity Theory to Organisations*; Elsevier Science Ltd.: Amsterdam, The Netherlands, 2003.
88. McCarthy, I.P.; Rakotobe-Joel, T.; Frizelle, G. Complex systems theory: Implications and promises for manufacturing organisations. *Int. J. Manuf. Technol. Manag.* **2000**, *2*, 559–579. [CrossRef]
89. Goldstein, J. Emergence in complex systems. In *The Sage Handbook of Complexity and Management*; Sage Publications: New York, NY, USA, 2011.

90. Kaufmann, S.A. *The Origins of Order: Self-Organization and Selection in Evolution*; Oxford University Press: Oxford, UK, 1993.
91. Arthur, W.B. Competing technologies, increasing returns, and lock-in by historical events. *Econ. J.* **1989**, *99*, 116–131. [CrossRef]
92. Bertschinger, N.; Olbrich, E.; Ay, N.; Jost, J. Information and closure in systems theory. In *Explorations in the Complexity of Possible Life. Proceedings of the 7th German Workshop of Artificial Life*; Artmann, S., Dittrich, P., Eds.; IOS Press: Amsterdam, The Netherlands, 2006; pp. 9–21.
93. Anderson, P. Perspective: Complexity theory and organization science. *Organ. Sci.* **1999**, *10*, 216–232. [CrossRef]
94. Lewin, A.Y.; Volberda, H.W. Prolegomena on coevolution: A framework for research on strategy and new organizational forms. *Organ. Sci.* **1999**, *10*, 519–534. [CrossRef]
95. Volberda, H.W.; Lewin, A.Y. Co-evolutionary dynamics within and between firms: From evolution to co-evolution. *J. Manag. Stud.* **2003**, *40*, 2111–2136. [CrossRef]
96. Gell-Mann, M. *The Quark and the Jaguar: Adventures in the Simple and the Comple*; W. H. Freeman: New York, NY, USA, 1994.
97. Allen, P.M. *Cities and Regions as Self-Organizing Systems: Model of Complexity*; Environmental Problems & Social Dynamics Series; Gordon and Breach Science Publishing: Philadelphia, PA, USA, 1997; Volume 1.
98. McKelvey, B. Perspective—Quasi-natural organization science. *Organ. Sci.* **1997**, *8*, 351–380. [CrossRef]
99. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*; Pearson Education: Harlow, UK, 2009.
100. Aria, M.; Cuccurullo, C. *bibliometrix*: An R-tool for comprehensive science mapping analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
101. Hamers, L. Similarity measures in scientometric research: The Jaccard index versus Salton's cosine formula. *Inf. Process. Manag.* **1989**, *25*, 315–318. [CrossRef]