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Social Network Analysis based Keyword Analysis of ISPIM Research Topics

Teemu Santonen*

Laurea University of Applied Sciences,
Vanha maantie 9, 02650 Espoo, Finland.
E-mail: teemu.santonen@laurea.fi

Steffen Conn

ISPIM
PO Box 18, Worsley, Manchester M28 1XP
E-mail: conn@ispim.org
* Corresponding author

Abstract: The usefulness of keywords and keyword networks as a fundamental carrier of knowledge has been recognized but the prior studies identifying and analyzing innovation management research topics and their evolution at ISPIM have not addressed the Social Network Analysis (SNA) viewpoint. Therefore this study evaluates the network structure of ISPIM research topics from the SNA point of view. By applying SNA to the ISPIM keyword and research topic data from 2009 to 2014 full academic paper publications (N=1081), this study is explicitly modelling how the different keywords are inter-linked with each other. By analyzing various centrality measures, the importance of a particular keyword within the whole ISPIM network are determined. As a result the contemporary body of knowledge of innovation management research is described and visualized as keyword networks. Implications for future innovation management research are discussed.

Keywords: ISPIM, Social Network Analysis, Scientometrics, Keyword analysis, Research topic

1 Introduction

Science by definition builds on previous knowledge, which evolves over time, refines and develops knowledge and serves as a foundation for further research. Thus, in-depth understanding of the structure of scientific knowledge in any research domains including innovation management is vital. Scientific conference proceedings as a relevant and important knowledge source have been recognized but also criticized (Lisée, et al. 2008; Drott 1995). Many authors argue that conference proceedings and journal articles can be considered as complimentary communication channels (González-Albo and Bordons, 2011; Butler and Visser 2006; Godin, 1998). Importantly Montesi and Mackenzie (2008) suggested that conference proceedings can demonstrate an ability to innovate and propose new ideas. Since ISPIM is among the leading research communities (Bourdieu, 2004) focusing on the innovation management research topic (Baregheh et al. 2009), we argue that ISPIM proceedings are a good platform to identify and evaluate how different innovation management research topic are interlinked with each other.

1.1 Objectives of the study

Santonen and Ritala (2014) recently analysed the co-authorships relations within the ISPIM community and we now have a good understanding about the underlying structure of the author collaboration network within the ISPIM. According to their study *"ISPIM co-author network is constructed from multiple sub-networks with one or several key actors in a central network positions, and from a large number of isolated co-authorship pairs or groups"*. Furthermore, their results also suggests *"tight clustering based on geographical and institutional boundaries"* but in such a way that *"the high performing authors span these boundaries via significantly different strategies"*. Moreover, Santonen and Conn (2015a, 2015b) identified and later on verified TOP50 innovation management research topics by applying popularity-based scientometrics analysis (Choi et al, 2011) to ISPIM full academic papers. As a result, the TOP50 list was populated by research topics, where keywords can be derived from the mainstream innovation classifications such as product, process, market, organizational keywords based on Schumpeter's (1934) typology or Chesbrough's open innovation (Chesbrough and Bogers, 2014) as an example. Importantly most of the ISPIM publications seemed to follow traditional innovation management research themes and portray a kind of "incremental innovation" research approach.

However, these prior ISPIM studies have not described the keyword network structure of ISPIM publications from the Social Network Analysis (SNA) point of view (Borgatti et al., 1992) which is the main goal of this study. By applying Social Network Analysis (SNA) methods to the ISPIM keyword data, we are conducting scientometrics study (Santonen and Conn, 2015a) and explicitly modelling how the different keywords are inter-linked with each other (e.g. Motter et. al. 1999, Hori et. al, 2004).

This paper is organised as follows. Following this introduction we discuss the theoretical foundations of our study. In third section, we present our research methodology and define the key measures. Fourth, we present our results and then finally, we conclude with our findings and discussion of theoretical and practical implications.

2. Theoretical background -- Scientometrics as a Research Method

Most typically the literature reviews in management research have been based on narrative reviews (McLean, 2005) instead of more rigorous research methods such as a systematic literature review (Becheikh et al., 2006), meta-analysis (Tornatzky and Klein, 1982) or scientometrics (Larivière et al. 2012). In this study we follow scientometrics approach, which is closely related to bibliometrics (Pritchard, 1969) and informetrics (Nacke, 1979). Each of these overlapping terms – scientometrics, bibliometrics and informetrics – have well documented history and are utilizing similar methodologies (Hood and Wilson, 2001). Basically, scientometrics can be defined as the quantitative study of science and technology (Van Raan, 1998).

Recently Santonen and Conn (2015) illustrated a comprehensive framework for classifying various types and combinations of scientometrics studies. According to them studies identifying and evaluating research communities can be classified as "popularity-based" or "social network analysis -based" studies (later also SNA) (Choi et al, 2011). Popularity-based studies are typically mainly analyzing frequency of keywords or other related terms, which have been derived from the context of the research community whereas network-based studies are instead focusing on the relationships via publications, which most typically are based on co-authorship (Su and Lee, 2012), citation/co-citation networks (Pilkington and Meredith, 2009) or keywords (Yi and Choi, 2011). However, typically SNA studies have mainly focused on co-authorship or citation relations and covered various types of scientific communities (Newman 2001, Morlacchi et. al. 2005, Vidgen et. al. 2007) also including innovation communities such as global open innovation research (Su and Lee 2012), and the ISPIM community (Santonen and Ritala, 2014).

Importantly, the usefulness of keywords and keyword networks as a fundamental carrier of knowledge has been recognized (Su and Lee, 2010) and related methodologies have been developed (Yi and Choi, 2011). Recently Santonen and Conn (2015a, 2015b) applied popularity-based scientometrics analysis (Choi et al, 2011) to ISPIM publications and identified the main research topics and their evolution at ISPIM (Santonen and Conn, 2015b). However, these recent ISPIM related studies have clear limitations since they are not addressing the social network analysis viewpoint. Therefore, we argue that there is a clear research gap, which this study is addressing. As a result by following Santonen and Conn (2015a) classification of scientometrics studies, we are only focusing on the content based view in context of social network analysis by using ISPIM full academic paper keywords as data source.

3 Research methodology

The unit of analysis in this study is a keyword presented in an ISPIM full academic paper. We limit our time span to publications from 2009 to 2014 due more robust data and retain the comparability to prior studies by Santonen and Conn (2015a, 2015b). In all, our dataset included a total of 1081 full academic papers. In SNA studies a node can refer to any kind of actor within a network, but in this study it is referring to a keyword. Node ties a.k.a. links within ISPIM publication keywords are calculated and visualized via standard methodology and tools of social network analysis (e.g. Wasserman and Faust, 1994; Borgatti et al., 2013) including centrality measures such as "degree centrality" and "betweenness centrality" which helps determining the importance of a particular keyword within the whole ISPIM network (Wassermann and Faust, 1994). "Degree centrality", Betweenness centrality" are defined as follows (Santonen and Ritala, 2014):

Degree centrality = "*Calculates how many direct connections each node has with other nodes in the network showing how linked each node is to other nodes. Basically this measure can be seen as a measure for analysing node's activity or involvement in a network. A high degree centrality indicates that the node has a central position in the network among other nodes (indicating e.g. a "hub" or otherwise relevant position).*"

Betweenness centrality = "*is used for investigating the structural position of a particular node between clusters of nodes in a network. Therefore it can be interpreted as measuring the nodes based on their position and role as a gatekeeper between two or more independent components. Such nodes may be in a structurally powerful position because* *they might be able to exploit their gatekeeper role for the purposes of knowledge and resource sharing between the separate parts of the network, for example."*

An analysis of network components is also conducted. According to Hawe et. al. (2004), a component is a part of a network in which all nodes are directly or indirectly connected by at least one connection. Thus, the component analysis will reveal those keyword and research topic groups within the whole network which are internally connected, but separate from each other. Component analysis will reveal the number of components during the different ISPIM events and in a dataset which includes all ISPIM full academic paper. Furthermore, "component ratio" is also calculated, which get value 1 when every keyword is an isolate and value 0 when all keywords are connected and there is only one component. Finally, cohesion measure "density" which is defined as number of links in the network expressed as a proportion of the number possible (Borgatti et al. 2013) is also calculated.

4 Results

4.1 Network cohesion and comparison of different events

In Table 1 we have compared how the network cohesion measures are varying between the single ISPIM events and "ALL events" measure which combines all individual events into one dataset.

Table 1 Network cohesion comparison between years 2009 to 2014 and ALL when author defined keywords as used as nodes.

Event	Avg Degree	Density	Components	Component Ratio	Main component share
2009_06	6.54	0.014	20	0.042	80.4%
2009_12	6.96	0.025	15	0.050	75.7%
2010_06	6.74	0.015	8	0.016	92.2%
2010_12	6.67	0.031	10	0.041	68.5%
2011_06	6.81	0.012	20	0.035	79.3%
2011_12	6.41	0.029	16	0.067	66.1%
2012_06	7.19	0.011	22	0.031	81.7%
2013_06	7.27	0.011	15	0.021	87.3%
2013_12	7.06	0.017	18	0.041	78.5%
2014_06	7.55	0.010	18	0.023	89.6%
ALL events	9.74	0.003	30	0.009	96.0%

As a result the average degree (i.e. average number of links per keyword), appears to be increasing slightly over time (correlation 0.727, sig. 0.017). In 2009 summer conference on the average a single keyword has 6.54 links, whereas in 2014 summer event the number of links has increased to 7.55 links. To reveal the network structure more in-depth, an analysis of network components was conducted. As a result, the largest component a.k.a. main component is covering substantially share of the all keywords in each event. On the average in the case of summer conferences the main component is including 85 percent of all keywords whereas in the winter conferences the average remains also high (72 percent), but significantly less than in the summer. When all events are combined into one dataset, the main component is covering nearly all keywords (96 percent). These results indicate that keywords at ISPIM are highly connected and forming solid thematic ensemble.

4.2 Keyword connections in full network

In Table 2 we have ranked the TOP25 keywords based on the "degree centrality" and "betweeness centrality" measures in which degree centrality is indicating how many links each keyword has, while betweeness centrality value is typically interpreted as a gatekeeping role (Borgatti et al. 2013).

Table 2 TOP 25 Keywords ranked by degree centrality and betweeness centrality.

	Keyword	Degree centrality		Keyword	Betweenness centrality
1	Innovation	1 164	1	Innovation	1 408 432
2	Open innovation	925	2	Open innovation	1 001 091
3	Innovation management	479	3	Innovation management	540 250
4	Collaboration	335	4	Small and medium sized enterprises	232 780
5	Small and medium sized enterprises	282	5	Collaboration	232 094
6	Case study	222	6	Case study	186 051
7	Research and development	220	7	Sustainability	175 092
8	Business model	216	8	Innovation process	166 709
9	New product development	200	9	New product development	148 326
10	Innovation process	183	10	Business model	142 580
11	Sustainability	175	11	Service innovation	133 621
12	Strategy	172	12	Business model innovation	119 892
13	Service innovation	160	13	Research and development	109 432
14	Network	143	14	Entrepreneurship	107 987
15	Living lab	142	15	Product innovation	92 591
16	Business model innovation	141	16	Knowledge management	85 204
17	Creativity	140	17	Technology transfer	83 601
18	Knowledge management	137	18	Radical innovation	83 398
19	Co-creation	136	19	Dynamic capability	80 921
20	Technology transfer	125	20	Creativity	79 404
21	Absorptive capacity	122	21	Innovation performance	77 533
22	Dynamic capability	121	22	Co-creation	76 539
23	Entrepreneurship	112	23	Absorptive capacity	74 111
24	Radical innovation	109	24	Foresight	71 232
25	Patent	103	25	Network	69 380

Not surprisingly *"innovation"* keyword is the top ranking keyword both in terms of degree (1164) and betweeness (1408432) centrality measure values. However it is closely followed by *"open innovation"* keyword with degree (925) and betweeness (1001091) centrality measure values. Almost as a clear number three is the *"Innovation management"* keyword (degree = 479, betweeness = 540250). *"Collaboration"* and *"small and medium* *sized enterprises (SMEs)"* are changing position four and five depending centrality measure while *"case study"* keeps the position six in the case of both measures. Other popular keywords in TOP10 are *"research and development"*, *"business model"*, *"sustainability"*, *"new product development"* and *"innovation process"* which are gradually loosing popularity as well as all the other remaining TOP25 keywords.

4.3 Visualizing keyword connections in full network

As seen in Figure 1, making a clear visualization of ISPIM keyword network is somewhat a difficult task due the high connectivity and large number of keywords.

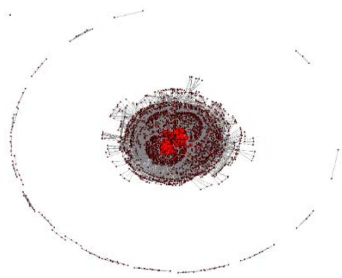

Figure 1 Full ISPIM keyword network

Dichotomizing is a common data transformation process in social network analysis methodology which converts valued data to binary data with respect to a threshold value (Borgatti et al. 2013). However, dichotomizing is not without the critics and since the results of the analysis are depending on the choice of threshold value (Thomas and Blitzstein, 2011). First, a set of network images varying the threshold value from "greater than 1" to "greater than 10" were visualized. Then the threshold value "greater than 4", which retained as much as possible of information but was still easily interpretable, was selected to be displayed in Figure 2.

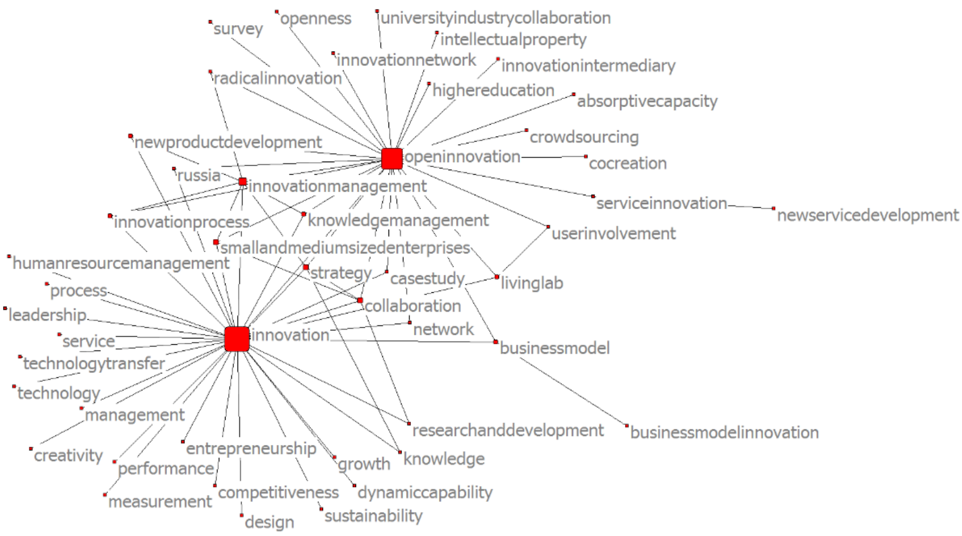

Figure 2 Dichotomized ISPIM keyword network (threshold greater than 4)

Basically the Figure 2 illustrates the dual core structure of ISPIM keyword network in which “Innovation” and “Open innovation” are the two dominant keywords outperforming clearly all the other keywords. There is a logical relationship between these two keywords which can be summarized as follows: All open innovation studies are innovation studies, but all innovation studies are not necessarily open innovation studies. Furthermore, all “innovation” and “open innovation” studies are also “innovation management” studies, which was found to be the third dominant keyword. In Figure 3 we presented the open innovation studies relative share during 2009 to 2014, which on the average is 19.9 percent.

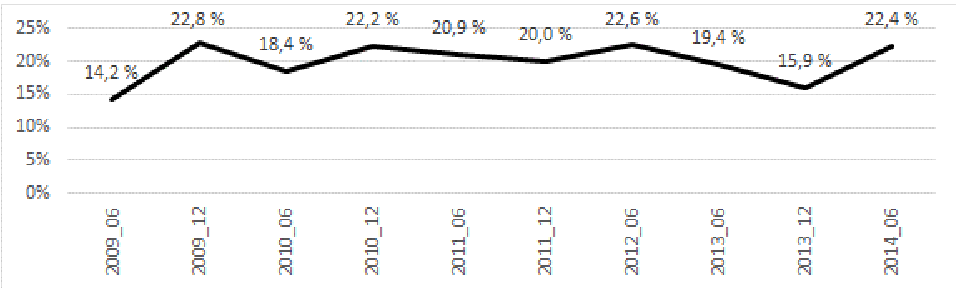

Figure 3 Open innovation studies relative share between 2009 to 2014

4.4 In-depth keyword connection analysis

In order reveal the possible latent keyword network structure which might be hindered because of the above three dominant keywords, additional analysis were conducted after following data management processes:

- First, “innovation management” keyword was removed since it is not providing any structural value
- Second, the dataset was then divided into “innovation” and “open innovation” dataset in which these two keywords were removed. As a result we had new “Innovation” and “open innovation” dataset which could be used to evaluate the keyword connection within these main research topic.

Relating component structure we observed somewhat similar results as in the case of full dataset. In “Innovation” dataset (N=865 full academic papers) which is interpreted as “non-open innovation studies” (i.e “open innovation” keywords was not included in any of these publications), the main component is covering 93.0 percent of all keywords, which is only 3 percent less than in the case of full dataset. In the case of “Open innovation” dataset (N=216 full academic papers), main component covers 54.3 percent of all keywords, which is indicating a bit more scattered research focus then in the case of “innovation” dataset. Anyhow, the above results provides even stronger validation that keywords in ISPIM are forming highly connected research themes.

In Figure 4 we have illustrated “Innovation” dataset TOP25 nodes based on betweenness centrality measure (dichotomized threshold value is set as greater than 1). whereas Figure 5 illustrates “Open Innovation” dataset TOP25 nodes and Table 3 present comparison of TOP 25 **“**Innovation” and “Open innovation” dataset keywords ranked by betweeness centrality. As a result, *“Collaboration”* is clearly the top ranking keyword in the *“Innovation”* dataset and *“Network”* the top ranking keyword in the *“Open* *innovation"* dataset. In all 10 out of 25 keyword (40 percent) were same in the both datasets indicating similar and overlapping research interest between *"Innovation"* (a.k.a non-open innovation)" and *"Open innovation"* research streams.

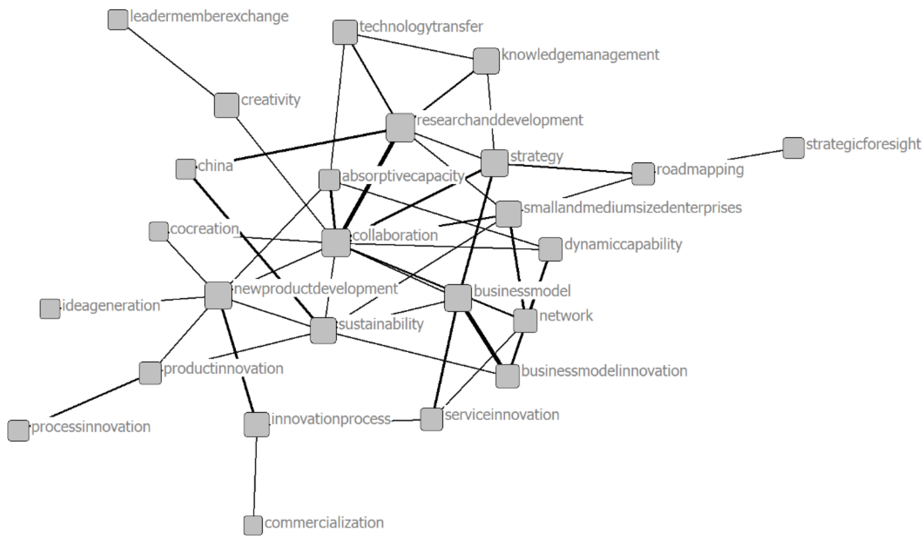

Figure 4 Innovation keyword network, TOP25 nodes based on betweenness centrality measure (dichotomized threshold value is greater than 1)

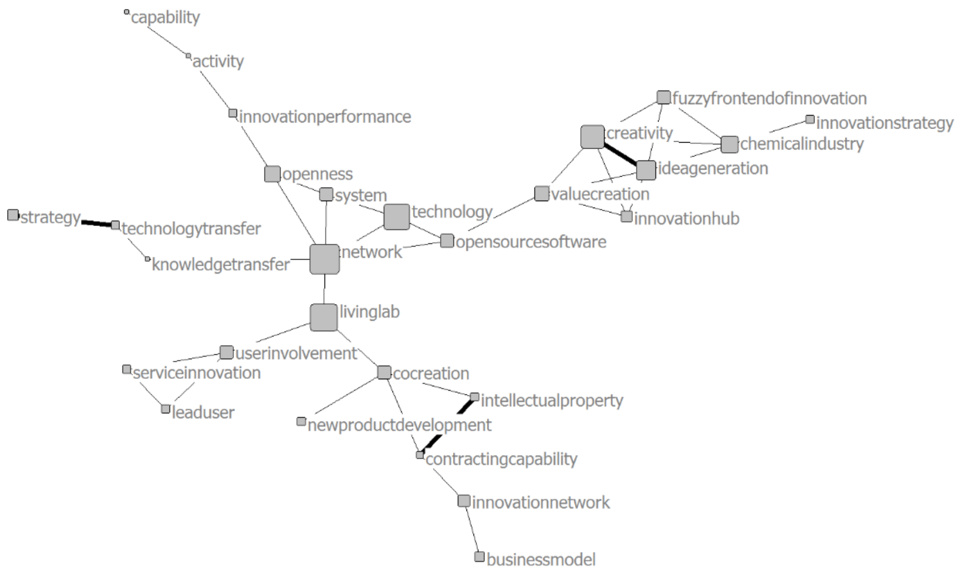

Figure 5 Open innovation keyword network, TOP25 nodes based on betweenness centrality measure

Table 3 TOP 25 **"**Innovation" and "Open innovation" dataset keywords ranked by betweeness centrality.

	Innovation dataset	Betweenness centrality		Open Innovation dataset	Betweenness centrality
1	Collaboration	7 888	1	Network	7 640
2	Research and development	4 733	2	Living lab	5 881
3	New product development	4 704	3	Open source software	4 011
4	Business model	3 638	4	Value creation	3 538
5	Strategy	3 417	5	Co-creation	3 383
6	Small and medium sized enterprises	2 719	6	Technology	2 003
7	Sustainability	2 565	7	Openness	1 953
8	Knowledge management	2 444	8	Contracting capability	1 715
9	Technology transfer	1 930	9	Innovation network	1 564
10	Creativity	1 797	10	Creativity	1 549
11	Innovation process	1 787	11	Knowledge transfer	1 540
12	Dynamic capability	1 694	12	Technology transfer	1 419
13	Business model innovation	1 617	13	Innovation performance	1 292
14	Network	1 519	14	User involvement	1 286
15	Service innovation	1 461	15	Idea generation	1 105
16	Roadmapping	1 381	16	Chemical industry	1 008
17	Product innovation	1 247	17	New product development	730
18	Absorptive capacity	1 058	18	Strategy	591
19	Strategic foresight	1 012	19	Activity	588
20	Process innovation	1 010	20	Business model	447
21	Leader member exchange	947	21	Capability	444
22	China	927	22	Intellectual property	387
23	Idea generation	862	23	Innovation strategy	298
24	Co-creation	821	24	System	264
25	Commercialization	812	25	Fuzzy front end of innovation; Innovation hub; Lead user; Service innovation	150

5 Conclusions

The usefulness of keywords and keyword networks as a fundamental carrier of knowledge has been recognized in prior studies. Therefore in this study we evaluated the network structure of ISPIM full academic paper keywords from 2009 to 2014 and identified how the different keywords were inter-linked with each other. As a result the contemporary body of knowledge of innovation management research was described and visualized as various keyword networks. Our results revealed that the keywords at ISPIM are highly connected and forming solid thematic ensemble. It appeared that ISPIM keyword network was grounded on the dual core structure in which *"Innovation"* and *"Open innovation"* were the two dominant keywords outperforming clearly all the other keywords. This influence was furthermore reinforced with the third popular "innovation management" keyword.

To eliminate the dominance of these keywords and to reveal the latent keyword network structure in-depth network analysis were conducted by splitting the dataset in *"Innovation"* and *"Open innovation"* datasets. The comparison of these two separate datasets revealed multiple common keywords in the both TOP25 keyword ranking list including *"New product development"*, *"Business model"*, *"Strategy"*, *"Knowledge transfer"*, *"Technology transfer"*, *"Creativity"*, *"Network"*, *"Service innovation"*, *"Co-creation"* and *"Idea generation"* suggesting similar research interest in both keyword datasets.

Interestingly *"Collaboration"* was found to be the most important keyword in *"Innovation"* dataset while also *"Absorptive capacity"* and *"Dynamic capability"* keywords appeared on the TOP25 list. Logically collaboration can be linked to "Collaborative innovation" which is referred as a creation of innovations across firm boundaries through the sharing of ideas, knowledge, expertise, and opportunities (Miles, Miles, and Snow, 2005). Furthermore, Teece, et. al (1997) define *"Dynamic capability"* as "the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" and *"Absorptive capacity"*, is related to the acquisition of knowledge from external sources (Smith et al. 2005) and "the ability of a firm to recognize the value of new information, assimilate, and apply to commercial ends" (Cohen and Levinthal, 1990, p. 128). All these three terms are addressing the similar issues as "Open innovation" term (Chesbrough and Bogers, 2014), which was found the be the second dominant term right after *"Innovation"* term and even outperforming generic *"Innovation management"* term.

As argued in prior studies (Huizingh 2011), the use of outside knowledge as a driver for innovation, did not originate from the open innovation paradigm but from a rich stream of various research paradigms such as the above mentioned terms, supporting critical arguments that "open innovation" is actually "old wine in new bottles" (Trott and Hartmann, 2009). Furthermore, Huizingh (2011) predicted in his "Open innovation: State of the art and future perspectives" – paper that *"open innovation is on its way to become innovation since it will become fully integrated in innovation management practices"*. Based on our observations, we can empirically support Huizingh's prediction since *"Open innovation"* and *"Innovation"* were the most dominant keywords and the separated dataset's TOP25 keyword list shared 40 percent of common keywords. The Huizingh's suggested integration process in our opinion has clearly started. Furthermore it is suggested that "collaboration" will be the dominant research angle in innovation research, but it will have multiple embodiments which can be addressed various topics.

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