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Risk Management in Open Innovation: Source, Identification, Assessment and Response

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Abstract: This paper addresses the uncertainties and risks involved in the open innovation process through strategic and network perspectives. The open innovation paradigm embeds the risks resulting from the porous boundaries of the firm and its mainstream literature emphasizes the reward side of this dilemma, whereas the negative impacts of knowledge flows are underestimate. Latest literature evinces that firms are still calibrating their levels of openness, thus balancing the related costs, benefits, risks and uncertainties. By employing a systematic literature review on the risk management procedures to open innovation we found three main clusters of risk management approaches: (1) Customer oriented, Outbound based, with firm level focus on the open-close dilemma; (2) Culture oriented, Experience based, with focus on individual problems of decision makers in two levels of analysis: individual level (e.g. personal perceptions), and aggregate level (e.g. cultural, institutional); (3) Knowledge oriented, Relationship based, with grounds on networks, stakeholder characteristics, and behavior in the alliances or connections. We conclude by compiling, under the risk management perspective, the sources of uncertainties, their related risks, assessment approaches, and responses to risks in each cluster.

Keywords: risk management; open innovation; risk; innovation; uncertainty.

1. Introduction

The external use of knowledge to innovate is not a contemporary practice, as at least the market and the materials are outside firm boundaries and a level of knowledge absorption in both sides of the value chain has ever been needed (Bogers, Chesbrough, & Moedas, 2018). However, the integration of external R&D is a more recent enlargement of the spectrum that ranges from closed innovation to the more prominent term, open innovation (Chesbrough, 2004). Open innovation involves the use of external and internal knowledge sources to accelerate internal innovation, and conversely, the use of external paths to markets for internal knowledge (Herzog & Leker, 2010). Firms acting in an environment of fast technological changes are often more dependent on external developing knowledge sources, as consequence of their eager to generate radical innovations, but more open initiatives are also found in more traditional industries (Brunswicker & Chesbrough, 2018).

However, the opening of R&D activities brings together all the risks resulting from a more permissive knowledge flow and whereas the most intuitive drawback is the knowledge leaking, there are several less recognized risks and uncertainties that constitute the main barriers for companies deep diving into open innovation (Alberti & Pizzurno, 2017; Toma, Secundo, & Passiante, 2018). The research mainstream emphasizes the reward side of this dilemma, and a few researchers have identified the negative impacts of external sourcing strategies, whether through reduced output or because improvements failed to exceed the cost of such strategies (Choi, Park, & Shim, 2018; Stefan & Bengtsson, 2017).

Dahlander and Gann (2010) and Faems *et al.*(2010) were the first to identify these effects. Indeed, the management field have traditionally focused on the success cases, thus risks and costs of external sources of innovation have been given secondary attention (Oliva *et al.*, 2019; Harvard Business Review Analytic Services, 2011). West and Bogers (2014) argue that the failures of open innovation are far underestimate because companies and consultants are proclaiming their successes and hiding their failures, thus making it difficult for researchers and managers to learn from the mistakes.

In addition, even the efficient level of openness and its results seems to be under trial by innovative firms (Thanasopon, Papadopoulos, & Vidgen, 2016; Veer, Lorenz, & Blind, 2016). Empirically, Chesbrough and Brunswicker (2014) found only modest satisfaction with the outcome of open innovation in a comprehensive study, recently reviewed (Brunswicker & Chesbrough, 2018), with 125 large corporations in Europe and in the U.S.A.

Various research streams, such as outsourcing of R&D, globalization of innovation, early supplier and user integrations, external technology commercialization and application, or the role and innovation of the business model, have contributed to the development of the open innovation field (Gassmann, 2006). In addition, open innovation may be analyzed in several levels, such as individuals, firms, dyads, networks, and even countries (van de Vrande, Vanhaverbeke, & Gassmann, 2010). Although various research streams have contributed to the explanation of the open innovation phenomenon and the different layers of analysis have added particular insights, the investigation of risks across the levels on the connections among the actors still demand further investigations. Particularly, while the literature has attempted to produce a collection of sources of risks and uncertainties, the managerial practices toward the new risks that arise when a firm increase its openness is less explored.

To address this gap, this paper answers to early scholars who claim for the addition of other fields in the open innovation body of knowledge (Henttonen & Lehtimäki, 2017) and uses the lenses of the network theory of stakeholders (Rowley, 1997). The stakeholder theory explain the relations between the groups of interest and a focal firm, whereas the network theory of stakeholder is a branch of this literature that considers the relationships are not one-to-one, or dyadic, but with and within groups (Neville & Menguc, 2006).

Finally, through this network approach this paper employs a systematic literature review on risks and uncertainties in open innovation to identify, aggregate, summarize, and analyze the perspectives of risk management in open innovation. In such manner, this paper provides a curatorship of main references on the topic, conciliate concepts for future scholars, and advance the discussion from descriptive approaches to managerial implications of open innovation risks.

2. Literature review

2.1. Open innovation

One of the paths for competitive advantage is innovation, frequently considered a key element of firm sustainable performance, thus a strategic capability to beat competition and for continually growth (McGrath, Tsai, Venkataraman, & MacMillan, 1996). From the many perspectives of innovation, such as the viewpoint of microeconomics, marketing, engineering, organization studies, and so on, innovators developed their ideas, products and business models internally and by themselves (Baregheh, Rowley, & Sambrook, 2009). However, on the turning to the 21st century, corporate phenomena such as spin-ins, spinouts, outsourcing R&D, and technology in-sourcing were observed by Chesbrough (2003) and Chesbrough & Crowther (2006) , and jointly called ‘open innovation’.

In the open innovation paradigm, firms collaborate with their environment from different points of view, which leads to external technology acquisition and exploitation, and conversely, the share of core competencies with other companies. Thus, the corporate limits become porous in open innovation, with a two-way innovation flow (Brunswicker & Chesbrough, 2018). In contrast to ‘closed innovation’, where firms innovate in house, open innovation deals instead with firm’s capability to deal with internal and external technology management tasks along the innovation process (Hsuan & Mahnke, 2011).

Not only big and high-tech companies are recognized in this paradigm, but also in other, less technology-intensive contexts as well as in SMEs (van de Vrande et al., 2010). Then, the exchange of knowledge is a central concept and claimed to offer a series of benefits, such as reducing time to market, cost and risk reduction, and improving access to specific expertise.

This mean that companies must develop capabilities to stablish stable and abundant collaborations with other actors (Baregheh et al., 2009). Also, that adopting open innovation approaches implies redefining the permission to cross the limits of organizations, allowing technological knowledge to become an exchangeable good itself, and the development of mechanisms and organization for inward and outward flows of technology (Fjeldstad, Snow, Miles, & Lettl, 2012; Gassmann, 2006).

In addition, the innovation process is not only technology based, and the same concept is applicable to processes, business models, and management practices, leading to a broader understanding of the 'open' concept (Veer et al., 2016). Indeed, a hot topic in the open innovation literature is the level and direction of openness, and empirical results have shown that firms are calibrating the exchange modus, thus their openness, by several parallel and frequently competitive tactics (Thanasopon et al., 2016). Corroborating to this, Chesbrough and Brunswicker (2014) found only modest satisfaction with the outcome of open innovation in a comprehensive study, recently reviewed (Brunswicker & Chesbrough, 2018), with 125 large corporations in Europe and in the U.S.A.

Hence, these findings remind scholars and practitioners that open innovation also embed negative effects, mostly stemmed from the porous boundaries of the firm and the two-way effect of openness, generally known as the open innovation dilemma: the more open the firm is, the greater the chance to receive knowledge, but the greater the chance to release it (Alexy, George, & Salter, 2013; Alexy & Reitzig, 2012; Dahlander & Gann, 2010).

2.2. Managing risks and uncertainties in open innovation

The open innovation dilemma implies that by adopting an open innovation paradigm a firm is exposed to new, or leverages existing, uncertainties and risks, thus open innovation is risky (Keizer, Vos, & Halman, 2005; Lang, Tesch, & Lindemann, 2017). However, the level of information differentiates uncertainties and risks, as for Galbraith (1973), uncertainty refers to the extent to which individuals, groups or organizations are informed about the future.

Thus, depending on the level of future acknowledge, there is a range from uncertainty (unknow future), to certainty (know future), with risks in between these extremes - and a recognition that perfectly known future is an abstraction (Schendel, 2007). In the innovation field there is a general accepted assumption that product and process ideation happens with high uncertainties and that while the future became more clear through the development phases, the earlier uncertainties turns into risks (Taran, Boer, & Lindgren, 2015; Teece, 2010). Advancing in this trend of thoughts, we may understand that prediction is a key driver of risk, and that the ability to turn uncertainty into risk is a managerial capability that strategy literature encloses in the risk management field (COSO, 2017; ISO, 2018; Oliva, 2016).

Because risks arise from uncertainties, complexity is a dimension that constrains the acknowledgement of future and consequently impact risks, being complexity the difficulty to understand a given process (Boer & During, 2001). From this concept, Taran, Boer, & Lindgren, (2013) developed a model related to innovation where risk is a function of uncertainty and complexity, hence, there is a risk in innovation when an understanding of the process and the possible outcomes of this process in the future is recognized.

Because the opening of R&D activities brings together the permissive knowledge flow, the most cited risk in open innovation is the knowledge leaking. However, Wu and Wu (2014) classified risks in five categories: technological, market, financial, collaboration, and institutional/regulatory. This approach led to a differentiation between risk and effect, in which knowledge leaking is actually the effect, and is mentioned either by the intellectual property viewpoint, thus institutional related, or by the free rider appropriation, thus collaborative related.

Considering the external interactions of open innovation, relational risks and opportunistic behavior plays a major role in risk management concerns (Barringer & Harrison, 2000). First studies on strategic alliances have addressed this issue through the trust and fairness concept (Das & Teng, 2001). Thus, the usual open innovation 'actor' is an stakeholder in a network which is also connected to others and subjected to conflicts and dilemmas (Reypens, Lievens, & Blazevic, 2016).

This lenses follow the scholars who have earlier acknowledge that collaboration happens within "actors who have the capabilities and values to self-organize, accumulate and share resources, protocols, processes, and infrastructures" (Fjeldstad, Snow, Miles, & Lettl, 2012, p.734). This approach is applicable to highlight the risks arising from the connections, such as the permissive knowledge flow, the cultural imbalance, and the motivations among the several actors that engage in jointly innovation (Schneider & Sachs, 2017).

As for the business management scope, many authors have limited and described its practices in a wide array from passive mitigation to a proactive strategy approaches (Hoyt & Liebenberg, 2011). However, some common attributions are the anticipation of events, identification of risks, alignment of risk appetite, seize the risk-opportunity trade-off, achieve efficiencies, and improve protocols (Beasley, Pagach, & Warr, 2008; Kloman, 1992).

From the risk management perspective, an innovative activity is considered risky if the likelihood of a bad result is considerable, the impact on the success of the innovative project is great, and if the ability of the team to influence it within the time and resource limits of the project is small (Keizer et al., 2005). In technological breakthrough projects, Halman and Keizer (1997) employed three dimensions: occurrence, impact and control, consonant with project management scholars (Ojasalo, 2009). The approach aims at gaining an integral overview of technological, business, and organizational risks (Keiser, Vos & Halman, 2005). On product innovation management, Keizer, Halman, & Song (2002) applied three phases: Risk identification, Risk assessment, and risk response development and control.

3. Methods

This paper employs a mixed method of bibliometric research and content analysis. While the former method addresses a quantitative perspective of the available literature, the latter aims to qualitatively examine the prominent papers on the topic.

3.1. Bibliometric and content analysis methods

According to Zupic & Čater (2015, p.430) "Bibliometric methods allow researchers to base their findings on aggregated bibliographic data produced by other scientists working in the field who express their opinions through citation, collaboration, and writing. When these data are aggregated and analyzed, insights into the field's structure, social networks, and topical interests can be put forward."

Indeed, there are correlations between scholar citations and other measures of influence or impact such as honors and laureateships. However, there are criticisms to the overvaluation of citations because this is a function of many factors, such as time, field, journal, type of article, reader style, and availability (Bornmann & Daniel, 2008).

In scientometrics, most used metrics are citations, co-citations, bibliographic coupling, and co-word. The unity of analysis may be any characteristic of a publication and the most usual are author, journal, keyword, year, and institution. (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011).

Content Analysis is a qualitative, objective, and systematic analysis of communication and may be applied to any symbolic material, usually texts (thus also called textual analysis) (Conley & Tosti-Kharas, 2014), to codify them into categories or groups according to a given criteria (Duriau, Reger, & Pfarrer, 2007; Verbeeten, Gamerschlag, & Möller, 2016). These

criteria are usually latent in the texts and are exposed after extensive readings and interpretative connections among their significance and concepts (Raich, Müller, & Abfalter, 2014). Therefore, for the analysis of research papers, categorizations are inductively selected after many looped readings and interactions of the whole paper collection (Conley & Tosti-Kharas, 2014; De Bakker, Groenewegen, & Den Hond, 2005).

3.2. Composition of the set of papers and methodological path

This paper jointly used two sources of bibliographic information, the Clarivate Analytics engine, Web of Science (WoS), and the Relx Group engine, Scopus. We opt to use both search engines as they are complementary for the most important databases and the number of papers involved is relatively small and recent (Cobo et al., 2011; Wallin, 2005).

We acknowledge that risk management characteristics are insipient and a search for "risk management" would not capture our intent because practices toward risks and uncertainties are not naturally labeled by authors. Thus, to compose the first selection of articles we searched for the terms 'open innovation' in association with 'risk' and 'uncertainty' for all years, with comprehensive term variations. This yielded 231 documents in the WoS and 340 documents in Scopus, leading to 131 and 132 peer-reviewed articles, respectively, and with an overlap of 77 papers. We used the Digital Object Identifier (DOI) as a key field to conciliate the lists and downloaded the 186 papers through the Crossref system.

The oldest retrieved paper was published in 2004, revealing the adherence to Chesbrough´s conceptualization at that year. As expected, we found a skewed curve of citations where the top 20 articles comprised 1365 citations in this first list, 71% of the total (Raan, 1996). After reading all the 186 papers we considered that 32 were unconditionally in the scope. We used the software Atlas.ti 8.3.20 to first manage the documents and later perform the content analysis, and the twin software VOSviewer 1.6.10 and CitNetExplorer 1.0.0 to aid our bibliometric research (van Eck & Waltman, 2010, 2014).

Bibliometric studies are valuable tools for the clearance of the superabundance of literature, however, there is always a "filter failure" associated with the criteria (Hood & Wilson, 2001) and a subjective factor is intrinsic (Bar-Ilan, 2008). We preferred quality over quantity, meaning adherence to the managerial approach of risks and uncertainties in open innovation.

Excluded articles were mainly because the words "risk" and "uncertainty" have a wide semantic in business so many scanned articles had completely different subjects. We preferred to face the semantic problem and qualitatively exclude mismatching papers than running the risk of missing an important reference. For instance, we found that searching strictly for "risk management" was not a good fit. Figure 1 shows the methodological path of this paper and depicts the main steps we proceeded to meet the three following objectives. These steps are subsequently detailed.

In the first step, to meet objective #1, we classified the papers by citation counts, then organized the references cited by the 32 papers to perform a citation and co-citation analysis and compose a citation map to find the references that built the body of knowledge of open innovation and risk management. In the second step, to meet objective #2, a total of 1828 backward citations were comprised after rejecting the overlaps. These papers were then clustered with a Visualization of Similarities (VOS) technique to allow an analysis of their theoretical grounds (Waltman, van Eck, & Noyons, 2010).

In addition, we tracked the following citing papers to perform a bibliometric coupling analysis in aggregate, to understand their theoretical influences (van Eck, Dekker, & den Berg, 2010; Wallin, 2005). A total of 3654 forward citations were comprised after rejecting the overlaps[i]. In the third step, to meet objective #3, we performed a content analysis of the 32

selected papers to compile their attributes and describe the conceptual differences and communalities of each cluster in consonance with the bibliometric results.

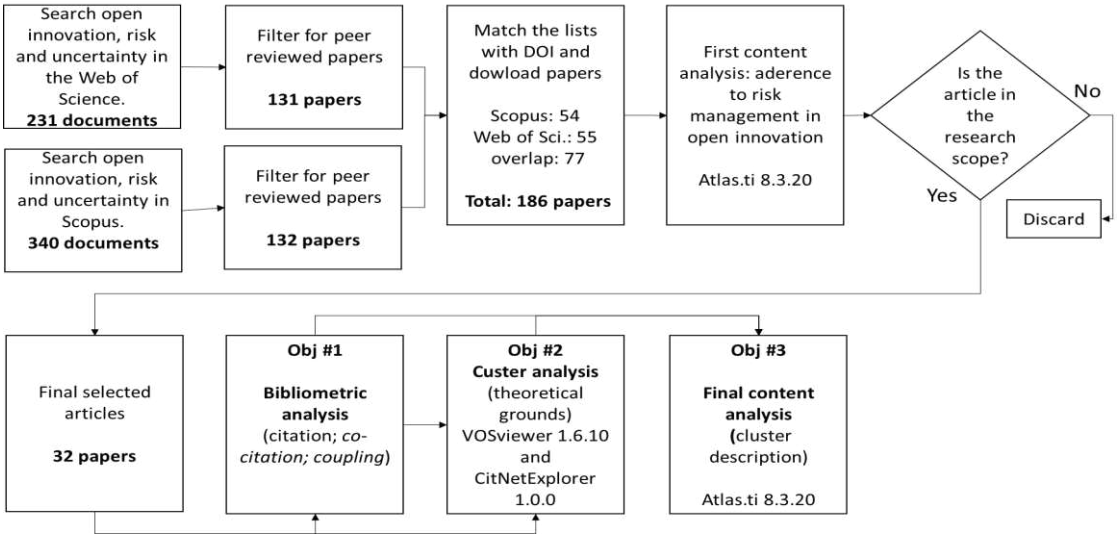

Figure 1 – The methodological path of this research paper.

4. Results and discussion

In this session, we present the results as a sequence of the three research objectives in Figure 1.

4.1. The body of knowledge of risk management in open innovation

We applied the citation technique to rank the 32 selected papers, hereon called the Body of Knowledge of Risk Management in Open Innovation (BoK-RM-OI). To minimize the filter failures and the overestimation of citations, we balanced citation and freshness. Thus, we present the top ten papers in two groups: the *Classic Works*, with maturity for citation, and the *Contemporary Papers*, published in 2017 and 2018. Table 1 depicts this collection of papers.

Table 1 – The body of knowledge of risk management in open innovation

Authors	Journal	Year	Citations[1]
	TOP 10 CLASSIC WORKS		
Chesbrough H.	Research Technology Management	2004	264
Enkel E., Kausch C., Gassmann O.	European Management Journal	2005	131
Alexy O., George G., Salter A.J.	Academy of Management Review	2013	113
Herzog P., Leker J.	International Journal of Technology Management	2010	67
Lampel J., Jha P.P., Bhalla A.	Academy of Management Perspectives	2012	31
Gould R.W.	Journal of Technology Management and Innovation	2012	30
Hsuan J., Mahnke V.	R and D Management	2011	29
Buganza T., Chiaroni D., Colombo G., Frattini F.	International Journal of Innovation Management	2011	18
Rayna T., Striukova L.	International Journal of Technology Management	2015	16
Rayna T., Striukova L.	International Journal of Technology Management	2010	15
	TOP 10 CONTEMPORARY PAPERS		
Malhotra A., Majchrzak A., Niemiec R.M.	Long Range Planning	2017	9
Stefan I., Bengtsson L.	Technological Forecasting and Social Change	2017	8
Agogué M., Berthet E., Fredberg T., et al.	Journal of Strategy and Management	2017	7
Aquilani B., Abbate T., Codini A., et al.	Knowledge Management Research and Practice	2017	3
Tranekjer T.L.	Business Process Management Journal	2017	1
Alberti F.G., Pizzurno E.	European Journal of Innovation Management	2017	1
Usai A., Scuotto V., Murray A., et al.	Journal of Knowledge Management	2018	1
Brockman P., Khurana I.K., Zhong R.I.	Research Policy	2018	1
Brunswicker S., Chesbrough H.	Research Technology Management	2018	1
Toma A., Secundo G., Passiante G.	Business Process Management Journal	2018	1

Note: [1]Total citations reported either by the Institute for Science Information (ISI) issued by the Web of Science (WoS), or by the Relx Group Scopus.

4.2. Theoretical grounds of risk management in open innovation

We organized the 1828 backward citations of the 32 selected papers to analyze the grounds where the Body of Knowledge of Risk Management in Open Innovation (BoK-RM-OI) was built on. Thus, references on methodologies (e.g. Yin (1994) "Case study research, design and methods"; Hair & Anderson (2010) "Multivariate data analysis"), and classic economics (e.g. Knight (1921) "Risk, uncertainty and profit"; and Coase (1937) "The nature of the firm") were considered apart. Table 2 summarizes the top 15 references.

We found the prominent presence of strategic management journals in the list, mainly regarding the concepts of learning, networks, alliances, and ecosystem. This was not a surprise and corroborates with our screening on the 'management' approach of risks and uncertainties.

In order to better understand the basis of the BoK-RM-OI, we performed a VOS clustering of the 32 papers based on their 1828 citations (Waltman et al., 2010). The VOS is useful to "analyze the intellectual structure of a scientific research field" and new unities are identifiable thru cluster analysis (Cobo et al., 2011, p.1384). Thus, for this technique the references on methodologies, economics, and other conceptual anchoring that were earlier extracted were invaluable and included because VOS groups the similarities and emphasizes the differences.

Table 2 – Top 15 theoretical grounds of risk management in open innovation[1]

Times cited	Author (year)	Title	Journal
18	Chesbrough (2003)	Open innovation: the new imperative for creating and profiting from technology	Book - Harvard press
16	Chesbrough, Vanhaverbeke & West (2006)	Open innovation: researching a new paradigm	Book - Oxford university press
13	Dahlander & Gann (2010)	How open is innovation?	Research Policy
12	Enkel (2010)	Attributes required for profiting from open innovation in networks	International Journal of Technology Management
11	Cohen & Levinthal (1990)	Absorptive capacity a new perspective on learning and innovation	Administrative Science Quarterly
11	Enkel, Gassmann & Chesbrough (2009)	Open R&D and open innovation: exploring the phenomenon	R&D Management
10	Teece (2010)	Business model, business strategy and innovation	Long Range Planning
9	von Hippel (1986)	Lead users: a source of novel product concepts	Management Science
9	Teece, Pisano & Shuen (1997)	Dynamic capabilities and strategic management	Strategic Management Journal
8	Knudsen & Mortensen (2011)	Some immediate - but negative - effects of openness on product development performance	Technovation
8	Laursen & Salter (2006)	Open for innovation: the role of openness in explaining innovation performance among uk manufacturing firms	Strategic Management Journal
8	West & Gallagher (2006)	Challenges of open innovation: the paradox of firm investment in open-source software	R&D Management
8	Adner (2006)	Match your innovation strategy to your innovation ecosystem	Harvard Business Review
7	Hamel (1991)	Competition for competence and interpartner learning within international strategic alliances	Strategic Management Journal
4	Cooke (1977)	Exchange and power in networks of interorganizational relations	Sociological Quarterly

Note: [1]References on methodologies (e.g. Yin (1994) "Case study research, design and methods"; Hair & Anderson (2010) "Multivariate data analysis"), and classic economics (e.g. Knight (1921) "Risk, uncertainty and profit"; and Coase (1937) "The nature of the firm") were considered apart.

Figure 1 depicts the map of references shared by the BoK-RM-OI and the three clusters generated by the VOS method with normalized co-citation count. A fourth cluster of 3 papers only, classified as miscellaneous, was extracted from the figure for better visualization. It is possible to recognize the main background papers and how they are intertwined to compose the later 32 selection, the BoK-RM-OI.

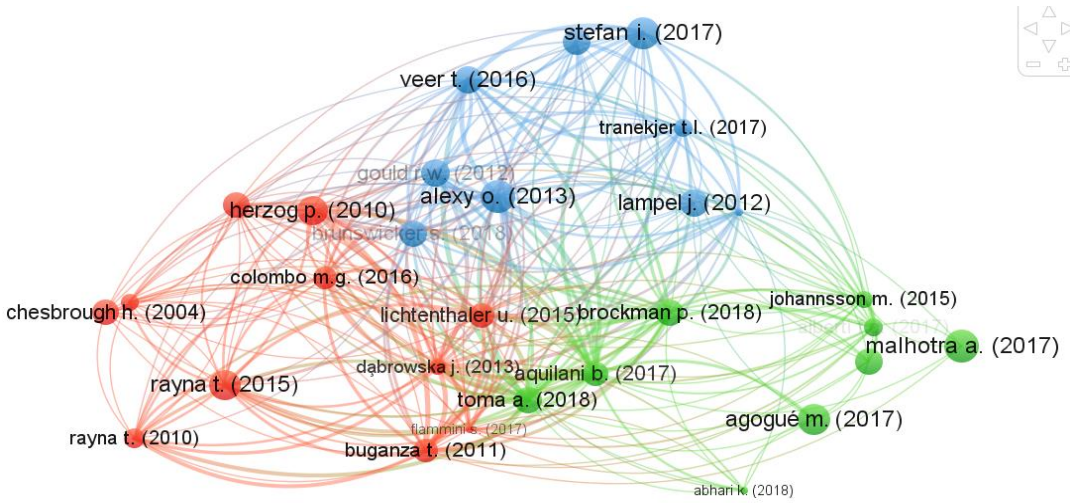

Figure 1 – Map of the references cited by the body of knowledge of risk management in open innovation. **Notes:** Circle sizes represent normalized citation counts within the 32 papers. Labels show first author only. Colors highlight the clusters of co-citation similarities (Waltman, van Eck, & Noyons, 2010).

The cohesion of the sources and the relationship pattern among the clusters is a quality measure of the first content analysis that led to the 32 papers out of the retrieved 186, meaning the selection is consistent with the knowledge of risk management in the open innovation field.

Table 3 – Cluster memberships and keyword dissimilarities[1]

link strength	Paper	Top keywords[2]	Occurrences in the cluster
CLUSTER 1 – RED COLOR (11 papers)		***Customer Oriented, Outbound based***	
103	(Dabrowska, Fiegenbaum, & Kutvonen, 2013)	outbound open innovation	7
98	(Buganza, Chiaroni, Colombo, & Frattini, 2011)	co creation	5
85	(Lichtenthaler, 2015)	open source innovation	4
75	(Herzog & Leker, 2010)	customer integration	3
64	(Colombo, Cumming, Mohammadi, et al., 2016)	open source	3
50	(Rayna & Striukova, 2015)	firm performance	3
49	(Rayna & Striukova, 2010)		
44	(Flammini, Arcese, Lucchetti, & Mortara, 2017)		
31	(Enkel, Kausch, & Gassmann, 2005)		
20	(Euchner, 2012)		
16	(H. Chesbrough, 2004)		
CLUSTER 2 – GREEN COLOR (9 papers)		***Culture oriented, Experience based***	
152	(Aquilani, Abbate, & Codini, 2017)	social	11
125	(Toma et al., 2018)	intermediary	6
83	(Brockman, Khurana, & Zhong, 2018)	knowledge	6
33	(Alberti & Pizzurno, 2017)	co innovation risk	5
25	(Johannsson et al., 2015)	cultural barrier	4
12	(Abhari, Davidson, & Xiao, 2018)	intellectual property	4
12	(Usai, Scuotto, Murray, Fiano, & Dezi, 2018)	open strategy formulation	3
11	(Agogué et al., 2017)		
5	(Malhotra, Majchrzak, & Niemiec, 2017)		
CLUSTER 3 – BLUE COLOR (9 papers)		***Knowledge oriented, Relationship based***	
105	(Alexy et al., 2013)	design competition	5
89	(Veer et al., 2016)	outsourcing r & d	5
70	(Gould, 2012)	r & d process	5
61	(Tranekjer, 2017)	actor engagement	5
58	(Stefan & Bengtsson, 2017)	stakeholder	4
50	(Lang et al., 2017)	strategic alliances	3
48	(Brunswicker & Chesbrough, 2018)	knowledge	3
29	(Hsuan & Mahnke, 2011)		
15	(Lampel, Jha, & Bhalla, 2012)		

Note: [1]Three papers did not fit the clusters and composed a 4th cluster of "miscellaneous" references. These papers are: Alexy & Reitzig (2012), Slowinski & Zerby (2008), and Thomas & Obal (2018). [2] The common keywords, such as 'open innovation' and 'risk', were extracted to highlight de dissimilarities among groups, and the list only show keywords with occurrences in more than 2 papers.

A following analysis of the clusters is summarized in Table 3, where the results of a co-citation of keywords is added for each cluster. For this later analysis, we opt for using the words attributed by the authors and by the database classifications. This approach is useful to uncover the concepts and theories that makes each cluster uniqueness (Ding, Chowdhury, & Foo, 2001). The common keywords, such as 'open innovation' and 'risk', were extracted to highlight de dissimilarities among groups, and the list show keywords with occurrences in more than 2 papers within the cluster.

4.3.Prominent arguments of risk management in the clusters

To analyze the perspectives of risk management in open innovation we performed a content analysis of the papers in each cluster to explore their differences based on Keizer et al. (2002) model of identification, assessment and response. We found the arguments presented in the papers well fitted into the cluster classifications and Table 3.

Cluster 1 - Customer Oriented, Outbound based

Cluster 1 aggregates papers with focus on market and customer integration on innovative activities, then publishing dates are older than other clusters with consequently higher citations. As a result of this more mature collection, the open-closed dilemma is heavier discussed in this cluster and papers focus on the firm level of analysis.

Table 4 – Risk management focus of Cluster 1: Customer Oriented, Outbound based

Source of uncertainty (concepts that aggregate the relevant complexities and unknown)
• Technical uncertainty • Market uncertainty • False negative • False positive
Risk identification (acknowledge of uncertainties and relevant realized risks)
• Internal bias in the openness perception • Loss of know-how and IP problems • Appropriability • Cultural gaps • Dependence on customers • Limitation to incremental innovations • Limitation to niche markets • Lack of resources for collaborators • Lack of skills of collaborators
Risk assessment (measures to acknowledge its occurrence, impact end/or control)
• Measure the stages outcomes (more stages than other clusters) • Balance with the higher risk of no customer insights at all • Assess support quality • Assess reliability of resources • Measure cross-cultural traces • Redefine the role of research. Redefine the metrics for innovation performance • Assess engagement and motivation (internally and externally) • Assess qualification of collaborators
Risk response (strategies, tactics and/or operations to manage risks)
• Startups as a source of learning (product and process) • Give more importance to business models • Venture capitals can help by pushing information and outcomes • Align target and perceived openness • Management of intellectual property • Careful selection of the internal project team and of the right customer • Maintaining long term relationship to customers • Overcome the not- invented-here syndrome • Try different levels of openness to find the right fit (interin strategies) • Management support: guidance by example practices and norms • Mass customization is a usual strategy for risk reduction • Patent pools reduce the risk IP and frictions

Considering the sources of uncertainty, there is a notable contribution of Chesbrough (2004) and the classification of technical and market uncertainties, with management implications on preventing false positive and false negative outlooks of innovation. Among the risks, there is a clear emphasis on the outside-in concerns, such as the drawbacks of customer bias and open source collaborators skills. The assessment of these risks includes more metrics for stages than other clusters, and qualification of collaborators with direct risk responses to offset them. Table 4 consolidates the findings on these 11 papers.

Cluster 2 - Culture oriented, Experience based

Cluster 2 is a collection of the latest papers and has the lowest citation count, in opposition to the first cluster. It deals with individual problems of decision makers and variates between the business environment (e.g. cultural, institutional) and its effect on individual levels of analysis (e.g. personal perceptions). Thus, is a cluster where uncertainties arise from human aspects in single or collective manner.

The risks range from the knowledge gaps created by personal interests to the lack of absorptive capacity, and assessments tend to be of sociological grounds, such as societal trust and collective fixation. The responses are also streamlined with cultural problems and most recommendations are related to training and sensibilization. Table 5 consolidates the findings on cluster 2.

Table 5 – Risk management focus of Cluster 2: Culture oriented, Experience based

Source of uncertainty (concepts that aggregate the relevant complexities and unknown)
• Individual (personal) interest • Intermediaries • Cultural norms (e.g. formal/informal contracts) • Institutional environment (e.g. law enforcement, transparency)
Risk identification (acknowledge of uncertainties and relevant realized risks)
• Individual risks: financial, IP right, social, and time. • Collective fixation and inertia • knowledge leak: technological, market, and managerial. • 'Not invented here' syndrome. • Lack of absorptive capacity • Risks of appropriation and opportunism (trust). • Schedule constraints • Legal barriers • Knowledge gaps • Asymmetric information • Hold up problems • Reputation and negative publicity
Risk assessment (measures to acknowledge its occurrence, impact end/or control)
• Measure individual experience and personal risk perception. • Assess collective fixation • Measure the level of societal trust
Risk response (strategies, tactics and/or operations to manage risks)
• Increase individual awareness in open innovation perceptions. • Use intermediaries: as problem solver, as broker for technology transfer, as network builder. • Share open issues instead of knowledge: questions and unsolved problems are easier to manage. • Overcome collective fixation. • Adapt the open model to the overall trust environment. • Mix formal and informal tools for IP protection

Cluster 3 - Knowledge oriented, Relationship based

The third cluster has average publication year and citation between the previous, and papers share the grounds on networks, relationships and knowledge. The uncertainties are sourced on partners - or newcomers to the network - and risks arise from actors, or stakeholders,

characteristics and behavior in the alliances or connections. Examples of risks are those related to low engagement of partners, such as unawareness or unwillingness to collaborate.

Consequently, the risk assessments are addressed to the actors in the innovation network, such as capabilities, commitment and governance. Hence, this cluster offers the more comprehensive collection of responses to risks, which are strategies such as selective revealing, formalization, and design competition, to name a few. Table 6 agregates the findings of the 9 papers in the cluster 3.

Table 6 – Risk management focus of Cluster 3: Knowledge oriented, Relationship based

Source of uncertainty (concepts that aggregate the relevant complexities and unknown)
• Partner characteristics (behavior, connections, interests) • Partner position in the network
Risk identification (acknowledge of uncertainties and relevant realized risks)
• Unawareness of partners. • Unwillingness to collaborate (power of actors and counterparts). • Low accountability of internal teams. • Knowledge leak. • Misappropriation. • Imbalance of competition v.s. collaboration behavior by actors. • Risk of early abandoned projects by others.
Risk assessment (measures to acknowledge its occurrence, impact end/or control)
• Measure if partners are in common ground. • Assess engagement and climate. • Assess the capabilities of newcomers. • Classify IP instruments and governance mechanisms.
Risk response (strategies, tactics and/or operations to manage risks)
• Selective revealing (issue spreading, agenda shaping, product enhancing, niche creating). • Reporting for high hierarchical level. • Optimization of management tasks: formalize the process as earlier as possible. • Engage stakeholders, consider competitive orientation. • Design competitions. • Cross industry collaboration. • Insertion of diverse actors (e.g. universities reduce friction and project abandonment). • Prefer intellectual property rights to contracts.

5. Conclusions

The opening of R&D activities incorporates the risks resulting from a more permissive knowledge flow and several risks and uncertainties compose barriers for a more open innovation adoption. This paper aimed at analyzing the presence and characteristics of the risk management approaches in the literature by a mixed method of bibliometric and content analysis. The small proportion of risk management papers reveled during the screening phase (32 out of 186 that deals with risks or uncertainties in open innovation), corroborates the usual avenue in strategy to focus on success cases and the findings of West and Boges (2014) that companies and consultants are proclaiming their successes and hiding their failures. Hence, one first contribution of this paper is to raise the awareness of this drawback side of open innovation, followed by a second contribution of appointing the responses to the listed risks.

To address the literature, this paper employed the lenses of the network theory of stakeholders to overcome the traditional levels of analysis and consider the relationships are not one-to-one, or dyadic, but with and within groups across the individual, firm, and institutional levels. This approach eventually shown to be adequate and led to interesting findings, such as different levels in the same clusters.

Findings considered three clusters in the body of knowledge of risk management in open innovation. The *customer oriented, outbound based* cluster, with firm level focus on the open-

close dilemma; the *culture oriented, experience based* cluster, with focus on individual problems of decision makers on the individual level (e.g. personal perceptions) and aggregate level of analysis (e.g. cultural, institutional); and the *knowledge oriented, relationship based cluster*, with grounds on networks and stakeholder characteristics and behavior in the alliances or connections.

The managerial implications are directly steamed from the employed model of analysis, namely the source-identification-assessment-response framework, and particularly the 'response' box is of management interest.

Finally, we recognize that bibliometric studies are sensitive to time and to the knowledge base where information is retrieved, therefore we opted to use two complementary search engines, the Web of Science and Scopus tools, and understand that citations are different in other databases. One main difficult we found was the directly assessment to risk management through keyword search, then the wider semantic of the words 'risk', 'uncertainty', and 'open innovation', led to large amount of papers. Also, the content analysis is always subjected to bias and analyses are qualitative and interpretative given the technique. We suggest further studies on the relatedness of these clusters to practices of risk management in other fields so insights and complementarities could be drawn upon.

6. References

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[i] This bibliometric coupling was performed on December 08, 2018. Bibliometric coupling is sensible to ongoing citations.