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# A systematic review of risk management in innovation-oriented firms

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**ABSTRACT**

Innovation and risk are inseparable. In fact, literature on innovation management often recommends that innovation-oriented firms must actively monitor, evaluate, analyze and treat future events in order to mitigate risks whenever possible. This approach is particularly important in emergent economies characterized by unstructured national innovation systems and constant economic and market instability. However, there has been no systematic effort to identify and categorize risks that potentially impact businesses based on innovation. Thus, we propose an interpretative framework of risk events with potential financial impact in innovation-oriented firms constructed and tested by means of a mixed studies review. The risk events were identified through a comprehensive systematic search and review of the published literature on risk and innovation. From the 115 works that were analyzed, it was possible to identify nine categories of risk events frequently associated with innovation-oriented businesses that may generate financial impacts. The proposed interpretative framework was tested in an empirical study with 13 innovation-oriented firms located in six Brazilian technological parks. Results from the empirical study suggest that managers found the proposed interpretative framework complete and comprehensive. Moreover, the empirical study signaled which risk events are more relevant for the Brazilian context. The proposed framework is a first necessary step for future development of ERM models applicable in innovation-intensive contexts.

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ERM; innovation; financial risk; technology parks



## 1. Introduction

Since the 1960s, innovation studies have evolved from a minor research interest in social sciences into a global, multifaceted phenomenon approached from multiple research perspectives that drives the strategic discourse on competition and productivity at the firm, region, and nation levels (Fagerberg and Verspagen 2009; Fagerberg, Fosaas, and Sapprasert 2012). Multiples definitions of innovation have been proposed over time, ranging from wide encompassing concepts such as generational socio-technological transformation and system innovation (Elzen and Wieczorek 2005; Geels 2005) to very specific operational definitions such as managerial innovation (Damanpour and Aravind 2011). In this paper, we opt for the middle ground, and focus our attention to innovation at the firm level. Most applied research about innovation at the firm level associate it with transformation of business opportunities into actual value; as such, innovation can be both a process and an outcome (Crossan and Apaydin

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2010; Nagano, Stefanovitz, and Vick 2014). In addition to this definition of innovation, the premises of this research are: (i) the fact that innovation and uncertainty are virtually inseparable (Bessant 2003; Adams, Bessant, and Phelps 2006; Hauser, Tellis, and Griffin 2006; Wong and Chin 2007), and (ii) the assumption that the way firms view and treat uncertainty (and, consequently, risks) impacts innovation-related decision-making (Meijer et al. 2006).

Among the many operational and conceptual definitions of risk, we adopt the view that risk arises from the effect of uncertainty on objectives (Aven 2010, 2011, 2012; Purdy 2010). As a consequence, risk is linked to the achievement of objectives, and is not necessarily defined in terms of probabilities (Aven 2011) – a definition that is particularly well suited to risk management in a business context. Instead, risk is defined in terms of uncertainty, which can have different natures and levels of intensity and, more importantly, cannot be ever fully eliminated by gathering knowledge (Meijer et al. 2006). Innovation-driven industries are often characterized by above-average uncertainty (Smits and Kuhlmann 2004; Lane and Maxfield 2005; Bullen, Fahey, and Kenway 2006) from multiple sources, such as policy and regulation, competition, suppliers, consumers, technology, and access to and availability of resources (Meijer et al. 2006). However, firms competing in risky innovation-driven industries must expeditiously make strategic decisions that are usually influenced by external variables beyond the control of the decision-maker (Hauser, Tellis, and Griffin 2006; Nagano, Stefanovitz, and Vick 2014). Independent of the type, source or nature of uncertainty, Bromiley et al. (2014) argue for the systematic adoption of Enterprise Risk Management (ERM) techniques and tools in order to at least partially reduce uncertainty. The ERM approach aims to identify, measure and control enterprise risks and has been touted as an essential tool for innovative companies (Haynee and Free 2014) that deal with the exploration of new and uncertain business opportunities (Bromiley et al. 2014). However, as both O'Connor, Ravichandran, and Robeson (2008) and Mu, Peng, and MacLachlan (2009) remark, there is a pressing need for more rigorous methodologies to guide the implementation of ERM in innovation-oriented firms.

The most popular ERM model is the one proposed by the Committee of Sponsoring Organizations of the Treadway Commission (COSO 2004), which is fairly generic and classifies risk according to nature of risk factors: external (economic, environmental, political, social, technological) or internal (infrastructure, personnel, processes, technology). An essential part of COSO's ERM model involves the identification of risk events, that is, events that may impact a firm's business. Although the term 'event' may suggest an episodic situation, it is well established in the literature about ERM that risk events may also refer to continuous activities, occurrences, or circumstances (Aven and Renn 2009; Aven 2010, 2012), including ongoing characteristics of firms and competitive environments.

ERM is usually associated with the financial industry (Bromiley et al. 2014). In fact, the use of ERM models in firms characterized by high technology and/or innovation intensity is strikingly unheard of, although it is particularly indicated for industries characterized by high volatility and strong entry barriers (Damodaran 2009). The absence of ERM applications in innovation-oriented firms may be related to the fact that it is often difficult to obtain past data to support the estimation of variability for expected returns (O'Connor, Ravichandran, and Robeson 2008). Risk analysis for technology-oriented firms are fairly established at the portfolio (e.g. SERIM, SRAM, BRisk, OBRiM) and project (e.g. Original Spiral Model, ProRisk, Riskit) levels (Keizer, Vos, and Halman 2005; Miorando 2010; Liu, Zhang, and Liu 2011). Besides, estimation and evaluation of systemic risk associated with the introduction of new technologies and innovations are also well developed topics (Koivisto et al. 2009; Bi, Huang, and Ye 2015; Yin, Liu, and Lin 2015), but in both cases the middle ground – that is, risks at the business level – is almost absent. As Bromiley et al. (2014) argue, ERM differs from such traditional risk management approaches because it proposes a holistic view of risk at the firm level, which includes governance- and strategic-related risks and, in line with the ISO 31,000 definition, considers risks as both threats and opportunities (Aven and Renn 2009; Purdy 2010; Aven 2011).

Previous researches have already investigated many facets of uncertainty in innovation-driven sectors and firms, such as internal aspects of firm organization and business strategy evolution and external market and economic influences (Bessant 2003; Nagano, Stefanovitz, and Vick 2014). Meijer, Hekkert, and Koppenjan (2007) studied the influence of uncertainty in technological entrepreneurship decision-making process, and concluded that political and technological uncertainties have a large effect

in the decision process. A substantial research stream has been devoted to understanding innovation success factors, whose presence or absence can be thought of as risk events (Nagano, Stefanovitz, and Vick 2014). For instance, Wong and Chin (2007) identified seven essential factors for successful innovation management, among which an innovation-oriented organizational culture can be highlighted. Studies focused on innovation success factors frequently mention uncertainty and risk, but an effective identification of risk events in innovative firms is absent from this literature.

Thus, the aim of this paper is to identify risk events with potential financial impact in innovation-oriented firms that have been previously mentioned in the scholarly literature on innovation by means of a systematic review. A systematic review is suitable for this task because it seeks to 'draw together all known knowledge on a topic area' (Grant and Booth 2009, 102). As a result, the main contribution of this paper is the proposal of a synthetizing interpretative framework of risk events that can support future development of ERM models for innovation-oriented firms. Additionally, an exploratory study with innovation-oriented firms located in Brazilian technology parks will provide a first empirical test of the interpretative framework of risk events, particularly regarding the comprehensiveness and completeness of the proposed framework as perceived by practitioners.



## 2. Methodological procedures

We conducted what Grant and Booth (2009) refer to as a mixed studies review combining a systematic literature review with qualitative empirical research. The systematic literature review is a structured, transparent and reproducible bibliographic research technique (Tranfield, Denyer, and Smart 2003) that 'seeks to systematically search for, appraise and synthesis research evidence' (Grant and Booth 2009, 102). The systematic approach to literature reviews has gained considerable attention in the last few years, especially among scholars dedicated to innovation studies (e.g. Crossan and Apaydin 2010; Medeiros, Cortimiglia, and Ribeiro 2014). In particular, systematic reviews allow for 'a conceptual consolidation across a fragmented field' (Crossan and Apaydin 2010, 1157), a description that fits the aims of our research. Based on the findings from the systematic literature review, we proposed a synthetizing framework of risk events for innovation-oriented firms. Next, we empirically tested the proposed framework through semi-structured interviews with board level managers from innovation-oriented firms located in Brazilian technology parks.

### *2.1. The systematic literature review*

A systematic literature review is based on a planned and structured process of identification, selection and evaluation of previous scholarly research and, as Grant and Booth (2009) point out, often adheres to specific guidelines for its conduction. In our research, we employed a four-step guideline inspired by Tranfield, Denyer, and Smart (2003) and Medeiros, Cortimiglia, and Ribeiro (2014): (i) research problem and keyword definition; (ii) selection of published studies; (iii) critical appraisement and evaluation; and (iv) synthesis of the results. Contrarily to Medeiros, Cortimiglia, and Ribeiro (2014), we opted against an intermediate step aimed at selecting specific sources (journals). Since the topic at hand is fragmented and mentions to risk events related to innovation can be implicit or indirect, we contend that there was no reason to limit our search to specific journals. When the review covers many different types of studies, it is sometimes referred to as systematic search and review (Grant and Booth 2009).

The research problem that guided our search and review was stated as: which are the risk events that can lead to financial impact in firms whose businesses are driven by innovation that have already been proposed and examined in published scholarly works dealing with innovation? Being aware that the research problem is wide in scope, we opted for comprehensive keywords that could capture innovation-related risk events even when those were mentioned implicitly or indirectly in the original works. As a result, we selected 'risk' and 'innovation' as search keywords and used the ISI Web of Knowledge's Social Sciences Citation Index (SSCI) database, one of the most inclusive repositories of applied research on social sciences. Our search covered a 10-year period from 2003 to 2014, was restricted to papers

written in English and published in academic journals. Such comprehensive search resulted in an initial sample of 5081 results. For comparison, we conducted another search in the same database using much more specific keywords: 'financial risk' combined with 'innovation'. This specific search resulted in only 48 papers. This result reinforced our claim for more extensive and systematic research on this topic. At the same time, it supported our assumption that many mentions to risk events in innovation studies are indirect or implicit.

Next, the initial sample of 5081 results was subjected to a number of filters, in order to eliminate papers with a very low probability of addressing the topics pertaining to our research problem. First, results that did not belong to 'Science and Technology' or 'Social Sciences' domains were discarded. We also restricted results based on the declared research areas ('business economics', 'engineering', 'public administration', 'operations research', 'management sciences', 'social sciences – other topics' and 'science and technology – other topics'). It is common practice in systematic reviews to focus in articles published in peer-reviewed journals, which are widely established as reliable sources of scholarly knowledge. Filtering is typical in systematic literature reviews, and similar approaches were employed by Crossan and Apaydin (2010) and Nicolás and Toval (2009). After filtering, the sample was reduced to 1496 papers.

A database with metadata from all 1496 papers was created in order to proceed with the selection of articles that dealt with the research problem. First, the titles and abstracts of all 1496 papers were independently analyzed by three researchers (the authors, plus a research assistant) in order to eliminate those that were clearly not related to the research problem. Each researcher independently assessed if a paper was relevant based on the title and abstract using a simple two-point scale: accept or reject. If at least two of the three researchers voted for rejection, it was excluded; otherwise, the paper in question was included in the final sample. Although the procedure initially called for analyzing only the title and abstract, in many cases the researchers had to read substantial parts of the articles in the sample in order to fully assess if the paper mentioned risk events related to innovation.

At the end of the selection procedure, 115 papers were retained (that is, voted for inclusion by at least two of three researchers) and subjected to full reading and analysis, which was again conducted independently by three researchers. Aspects considered for analysis included: research approach and strategy, theoretical background, methodological procedures, and type or characteristics of innovation. Similar to previous research on risk event identification (Bromiley et al. 2014; Etges and Souza 2014), the risk factors proposed in the COSO ERM model were used to inductively classify risk events. The COSO model suggests that organizations are submitted to external and internal risks that can be classified in the following thematic categories: economic, environmental, political, social, technological, infrastructure, personnel, processes, and technology. The three researchers independently identified and classified the risk events mentioned in the final sample of 115 papers in these categories, taking notes and registering the reasoning behind each classification.

The fourth and last step in our systematic review research scheme was the synthesis of the results, jointly conducted by the three researchers during four work meetings, which lasted approximately five hours each. In the first meeting, the notes registering the reasoning behind the identification and classification of each risk event using the COSO methodology factors were compared. Most of the time the independent classification by the researchers was similar, but in a number of instances it was necessary to debate and develop a consensus about the classification of a risk event. In the final three meetings, researchers inductively generated the categories of risk events that constitute our proposed interpretative framework. For this purpose, we adopted Auerbach and Silverstein (2003) guidelines for recursive and cyclical interpretative-oriented content analysis. First, inductive coding was employed to group similar risk events according to their characteristics and mechanics; as a result, the nine categories of risk events that constitute the framework were generated. Next, each individual risk event was reviewed in the light of the thematic categories of risk events and, if necessary, reclassified or discarded. Finally, individual risk events within each category were combined in order to minimize overlapping and duplication.

### 2.2. Exploratory multiple case-study

After developing a synthetizing framework of risk events with potential financial impact in innovation-oriented firms, we conducted an exploratory multiple case-study to investigate the completeness and comprehensiveness of these risk events according to managers of innovation-oriented firms located in technology parks in Brazil. We also probed for the existence of additional risk events that were not incorporated in our framework.

The research design for the empirical study consisted of multiple case studies with innovation-oriented firms. We screened potentially innovative firms by approaching firms located in technology parks, which usually host small or medium sized companies whose main competences involve knowledge creation and research (Chiochietta 2010). Additionally, Nanda and Rhodes-Kropf (2013) highlights the risks that firms located in technology parks normally face, especially those related to market acceptance of innovations. Firms were selected according to the following set of criteria: (i) firms should have a clear strategic orientation toward innovation, indirectly assessed from explicit public statements (e.g. as reported in investor prospectuses or technology park documents) and park managers' experience in dealing with the firms' strategy makers; (ii) firms should have already introduced at least one innovative product in the last three years; and (iii) firms should be located in technology parks. Moreover, we aimed at a broad coverage of industrial sectors, firm size and age. Based on these criteria and supported by technology parks' managers, 13 firms from six Brazilian technology parks were selected, as summarized in Figure 1.

For data collection, semi-structured individual interviews with at least one key executive for each company were employed. Semi-structured interviews were conducted between September and December 2014, by an average of two meetings for each executive. Face-to-face and telephone interviews were conducted; the average length of each meeting was one hour. The interview protocol consisted of two parts. The first part assessed firm innovativeness, while the second part investigated the presence and importance of risk events. The first part was based on the variables used in de Jong and Marsili's (2006) taxonomy of innovative firms. Figure 2 shows the description of the variables that inspired the guidelines for the first part of the interview. Additionally, interviewees described the firm in terms of age, number of employees, annual revenues, portfolio of products, number of innovation projects ongoing and concluded (including process innovations and patents filed), and previous use of governmental support for innovation efforts. Finally, respondents were asked about the firm's innovation strategy.

The second part of the interview protocol was focused on the presence and perceived importance of the risk events identified in the literature review, which are summarized in Figure 3. Interviewers first asked open questions about perceived risks that impact the respondent's business, and the risks

| Firm | Business Sector | Technology Park | Number of employees | Number of products | Interviewee | Received Federal Funding? | Years in Market |
|---|---|---|---|---|---|---|---|
| A | Industrial automation | Tecnovates | 3 | 1 | CEO | No | 2.5 |
| B | Ozone generators | Tecnovates | 2 | 1 | CEO | Yes | 4 |
| C | Consulting | Tecnovates | 3 | 4 | CEO | No | 2.5 |
| D | Consulting | Tecnovates | 3 | 2 | CEO | No | 3 |
| E | Radiopharmacy | Tecnopuc | 60 | 10 | CEO | Yes | 10 |
| F | Information Technology | Tecnoulbra | 50 | 1 | CFO | No | 3 |
| G | Advertising technology | Tecnounisc | 5 | 4 | CEO | No | 2 |
| H | Healthcare technology | Tecnopuc | 10 | 5 | CEO and CFO | No | 3 |
| I | Industrial Automation | Tecnounisc | 2 | 3 | CEO | No | 2 |
| J | Consulting | Tecnopuc | 2 | 3 | CFO | No | 1 |
| K | Information Technology | Tecnounisc | 2 | 1 | CEO | No | 1 |
| L | Consulting | Tecnosinos | 100 | 5 | CEO | No | 11 |
| M | Information Technology | Porto Digital | 350 | 6 | Innovation Manager | No | 10 |

**Figure 1.** Case study summary.

| Variable | Description |
|---|---|
| Innovation output | Questions involving measurable outputs of innovation generated, such as "Did the firm introduced a new or significantly improved product in the last three years?" |
| Innovation input | Questions involving measurable inputs for the generation process, such as "Does the firm has a specific budget for innovation?" |
| Sources of innovation | Questions dealing with the sources for innovation accessed by the firm, such as "Does the firm consults customers/suppliers for new ideas?" |
| Innovation strategy | Questions about aspects of innovation strategy, such as "Does the firm has documented plans describing timelines, roadmaps and targets for innovation-related projects?" |
| External orientation | Questions dealing with external partnerships and cooperation for innovation, such as "Does the firm maintain formal agreements with universities for joint development of innovation projects?" |

**Figure 2.** Interview protocol guidelines, first part: firm innovativeness.



spontaneously mentioned in the answers were noted and compared to the list of risk events identified beforehand. Next, interviewers addressed each risk event previously identified in the literature, asking if the interviewee agreed that it was a valid risk and requesting an estimate about the importance and potential impacts (both positive and negative). Finally, interviewers asked about additional risk events that were not included among those found in the literature review.

All interviews were recorded and transcribed for communicative validation and data analysis. Communicative validation was conducted by follow-up emails sent directly to the respondents, who were instructed to correct any misinformation and asked to help researchers to validate and clarify interpretations. Qualitative data from interviews and secondary sources was analyzed through cross-case content analysis aimed at finding patterns of commonality between the investigated dimensions. For this purpose, we used Bardin's (1977) meaning and enumeration rules for data codification according to previously identified categories, that is, the risk events in our proposed framework.

## 3. Results and discussion

Below we present the main results of our research. First, the results of the systematic literature review are presented in the form of an interpretative framework of risk events for innovation-oriented firms. Next, we present and discuss the results of an exploratory multiple case-study conducted to empirically test such framework.

### *3.1. Interpretative framework of risk events for innovation-oriented firms*

By means of a systematic literature search and review, we identified the risk events that can lead to financial impact in firms whose businesses are driven by innovation that have already been proposed and examined in published scholarly works on innovation studies. These risk events were classified in nine categories, as shown in Figure 3.

The first risk event reported in Figure 3 is Technical Knowledge Superior/Inferior Compared to Competitors. It deals with the presence or absence of adequate technical resources and competences for innovation. Among the reviewed works, 26 referred directly to this risk event, stating that technical knowledge is essential at every stage of the innovation generation process. First, superior technical knowledge during the idea generation stage can multiply opportunities for successful innovation (Hindle and Yencken 2004; Hayton 2006; Wang and Chen 2010). Next, during the innovation implementation stage, superior technical knowledge acts as the central pillar in product development projects (Smith, Collins, and Clark 2005; Wu 2008; Binneman and Steyn 2014). The Oslo Manual (OECD 2005)

| Risk Event Categories | Description | Source / COSO Factor | Count | References |
|---|---|---|---|---|
| Technical Knowledge Superior/Inferior Compared to Competitors | Technical knowledge, understood as the technical competence of all personnel directly involved with R&D activities, is widely regarded as essential for innovation development. Technical knowledge is also related to staff's motivation, heterogeneity, and ability to integrate multiple disciplines, backgrounds and worldviews. Finally, it is important to have intellectually capable employees that can efficiently gather and use market information to fuel the firm's innovation efforts. | Internal / Process and Personnel | 26 | (1) (3) (4) (8) (19) (20) (22) (38) (26) (28) (46) (48) (92) (52) (100) (101) (102) (67) (73) (87) (94) (39) (64) (75)(35) (86) |
| Innovation Strategy | An effective innovation strategy is essential to innovation-oriented businesses. In order to achieve it, the firm must: (i) associate its brand with innovation; (ii) associate and cooperate with external partners; (iii) capitalize innovation output through patents; (iv) monitor emergent technologies; (v) plan its innovation activities; and (vi) employ a performance management system to track the result of its innovation strategy. | Internal / Process | 32 | (38) (67) (41) (43)(80) (81) (92) (70) (83) (94) (99) (71) (31) (24) (78) (7) (64) (17) (49) (103) (25) (44) (80) (47) (9) (84) (54) (90) (13) (38) (66) (76) |
| Technology Management | This risk event is related to the following technology-related firm competences: (i) technology development; (ii) technology integration; (iii) technology monitoring; (iv) technology acquisition; (v) technology diversification; and (vi) technology exploitation. | Internal / Technology | 16 | (10) (12) (28) (33) (42)(53) (77) (99) (4) (97) (54) (103) (72) (55) (92) (96) |
| Governmental Incentives & Policies | Innovation often requires access to governmental funding. Similarly, government policies foster collaborative efforts for technology development and exploitation. Finally, governmental action can promote innovation by directing governmental purchases, offering tax breaks for innovative firms, and helping to create markets for innovation outputs. | External / Political | 16 | (53) (36) (97) (101) (57) (62) (63) (104) (84) (11) (17) (96) (58) (102) (81) (91) |
| Risk Profile | Given the inherent risky nature of innovation, it is important for both managers and operational staff to develop a risk-oriented profile in order to cope with the uncertainties of innovation projects. | Internal / Personnel | 8 | (32) (34) (40) (67) (81) (56) (68) (80) |
| Flexible and Innovation-oriented Management | Managers and managerial practices must be flexible in order to create a work environment that encourages intrapreneurship. Moreover, managers must ally technical and market knowledge and actively pursue external events that can lead to new innovation opportunities. The development team must be aligned with company objectives, and innovation practices that promote effective knowledge management must be implemented. Finally, the firm must implement management practices and strategies that foster trust and longtime commitment by creating perspectives of financial safety and career growth for all employees. | Internal / Process | 28 | (23) (24) (80) (75) (176) (89) (93) (23) (30) (50) (100) (65) (14) (26) (98) (60) (77) (61) (98) (2) (16) (86) (51) (5) (73) (54) (69) (27) |
| Geographic Location & External Relationships | Innovation-oriented firms are often geographically located in regions that concentrate technological development initiatives, such as technology parks, incubators, research centers and universities. Successful innovation projects may benefit from positive external relationships with such actors characterized by trust, transparency, and integration. The role of suppliers as important sources for innovation is also frequently highlighted. | External / Political | 13 | (53) (98) (105) (58) (104) (6) (53) (45) (54) (74) (82) (17) (18) |
| Size & Maturity | This risk event is related to a firm's technical and managerial maturity. Often such maturity is related to size and age, as managerial resources in most startups and new ventures are shared among areas and activities. Large firms normally generate expectations among customers for new innovation projects and may dedicate more resources to innovation development projects. | Internal / Infrastructure | 12 | (15) (17) (46) (98) (96) (21) (95) (79) (29) (88) (105) (106) |
| Creativity | Creativity is essential to innovation. Successful development of innovative solutions require an ability to "think outside the box", mixing ideas and insights from different areas and sources. Both individual and group creativity must be developed and fostered in an environment that rewards experimentation, problem-solving, and constant learning. | Internal / Personnel | 2 | (59) (85) |

| | | | |
|---|---|---|---|
| (1) Smith et al. (2005) | (28) Roco (2005) | (56) Elston & Audretsch (2010) | (83) Wu et al. (2007) |
| (2) Greve (2003) | (29) Sharma & Lacey (2004) | (57) Tait & Chataway (2007) | (84) Leyden & Link (2004) |
| (3) Baum & Silverman (2004) | (30) Wu et al. (2010) | (58) Chen et al. (2010) | (85) Ahlin et al. (2014) |
| (4) Sorescu et al. (2003) | (31) Li et al. (2005) | (59) Chen & Huang (2010) | (86) Ouimet & Zarutskie (2014) |
| (5) Langerak et al. (2004) | (32) Ghadim et al. (2005) | (60) Keizer & Halman (2007) | (87) Binneman & Steyn (2014) |
| (6) Veugelers & Cassiman (2004) | (33) Leten et al. (2007) | (61) Molina-Morales et al. (2011) | (88) Apreda et al. (2014) |
| (7) Adner (2006) | (34) Dewett (2007) | (62) Khalil & Ezzat (2005) | (89) Chen et al. (2014) |
| (8) Leiponen & Helfat (2010) | (35) Reich and Paz (2008) | (63) Dahlstorm et al. (2003) | (90) Herz et al. (2014) |
| (9) Gurhan-Canli & Batra (2004) | (36) Link & Scott (2010) | (64) Lazonick & Mazzucato (2013) | (91) Yang et al. (2014) |
| (10) Kostoff et al. (2004) | (38) Sommer et al. (2009) | (65) Arvanitis & Stucki (2012) | (92) Baumann & Heine (2013) |
| (11) O'Brien (2003) | (39) Sethi & Sethi (2009) | (66) Unger & Eppinger (2011) | (93) Turnipseed and Turnipseed 2013 |
| (12) Garcia-Vega (2006) | (40) Lopez et al. (2008) | (67) Li et al. (2010) | (94) Mazzucato (2013) |
| (13) Salomo et al. (2007) | (41) Yanadori & Marler (2006) | (68) O'connor et al. (2007) | (95) Pesamaa et al. (2013) |
| (14) Cooper (2003) | (42) Stirling (2007) | (69) Ottenbacher & Harrington (2010) | (96) Mata & Woerter (2013) |
| (15) Cefis & Marsili (2006) | (43) Frishammar & Horte (2007) | (70) Mazzucato & Tancioni (2008) | (97) Rodrigues (2013) |
| (16) Alpkan et al. (2010) | (44) Perez-Luno et al. (2011) | (71) Murro (2013) | (98) Pacns (2010) |
| (17) Song et al. (2008) | (45) Pisano (2010) | (72) Wells et al. (2010) | (99) Prasanth (2005) |
| (18) Hoetcht & Trott (2006) | (46) Johnson (2010) | (73) Lindsay & Hopkins (2010) | (100) Wu (2008) |
| (19) Hewitt-Dundas (2006) | (47) Romero & Molina (2011) | (74) Hall et al. (2014) | (101) Nuur et al. (2009) |
| (20) Hayton (2005) | (48) Alquier & Tignol (2006) | (75) Hutchison-Krupat & Chao (2014) | (102) Frenkel (2003) |
| (21) Ravasi & Turati (2005) | (49) Hsu (2009) | (76) Ilevbare et al. (2014) | (103) Srinivasan et al.(2008) |
| (22) Hindle & Yencken (2004) | (50) Xue (2007) | (77) Shin & Lee (2013) | (104) Bienkowska et al.(2010) |
| (23) Caldwell & O'reilly (2003) | (51) Leeders et al. (2007) | (78) Schmiele (2013) | (105) Fontana & Nesta (2009) |
| (24) Rammer et al. (2009) | (52) Wang & Chen (2010) | (79) Cohen at al. (2013) | (106) Bruneel et al.(2012) |
| (25) Lhuillery & Pfister (2009) | (53) Lukach et al. (2007) | (80) Van Bossuyt et al. (2012) | |
| (26) Peeters & Potterie (2006) | (54) Keizer et al. (2005) | (81) Löfqvist (2012) | |
| (27) Chao & Kavadias (2008) | (55) Hortinha et al. (2011) | (82) Chemarin & Orset (2011) | |

**Figure 3. Proposed interpretative framework of risk events.**

stresses the high importance of this risk event by emphasizing the primary role of scientific knowledge and engineering capabilities in innovation-oriented firms.

Another widely mentioned risk event regards Technology Management; more specifically, the existence or absence of firm competences dealing with technology acquisition, development, integration, monitoring, diversification, and exploitation. Among the reviewed works, 16 referred to technology-related risks. Both this risk event and the aforementioned technical knowledge risk event impact an innovation-oriented firm's ability to field multidisciplinary work teams (Li et al. 2005; Lazonick and Mazzucato 2013; Binneman and Steyn 2014) focused on developing a portfolio of innovative solutions (Garcia-Vega 2006; Leten, Belderbos, and Van Looy 2007; Srinivasan, Lilien, and Rangaswamy 2008) to address a varied demand and, by doing so, to contribute to firm performance (Hortinha, Lages, and Lages 2011; Welbourne, Neck, and Meyer 2012). Besides, the Technology Management risk event may influence the development of an adequate technology orientation focused on customers (Langerak, Hultink, and Robben 2004; Baumann and Heine 2013). In other words, technological competences must allow the firm to keep its rate of innovation development on pace with market demand in order to minimize failures for late or early market entry (Huang, Chou, and Lee 2010; Wells et al. 2010) and to avoid exposure to disruptive innovation (Christensen 1997; Christensen and Reynor 2003).

Results also highlight the importance of the risk event Innovation Strategy: 32 of the reviewed works mention it. The majority of these studies suggest that a strong commitment to innovation by top management is the starting point of a cohesive firm strategy that emphasizes and rewards risk taking and experimentation, two key antecedents of change acceptance and innovative behavior. Moreover, the reviewed works indicate a strong link between the existence of a clear innovation-oriented strategy, were the main goals, values, mission, and vision are oriented to develop new products, services, or processes and positive innovation performance, especially in terms of aligning innovation outcomes with market demand (Adner 2006; Frishammar and Åke Hörte 2007). Innovation Strategy also deals with innovation performance monitoring and reward mechanisms that promote (or at least do not penalize) non-conformity to current business practices (Wan, Chin, and Lee 2003; Meijer 2006; Wong and Chin 2007), thus paving the way for increased firm flexibility and adaptability (Kelley 2009). Finally, the Innovation Strategy risk event also refers to the integration between two other important risk events (Technology Management and Technical Knowledge) and strategic objectives (Li et al. 2005; Hortinha, Lages, and Lages2011).

Given the high uncertainty that characterizes innovation-intensive competitive environments, it is only natural to consider the risk factor Governmental Incentives & Policies, mentioned in 16 of the reviewed works. For the authors that addressed suck risk events, governments often need to promote public policies to support innovation-oriented businesses through direct funding and other political and regulatory incentives (Chen, Hsu, and Huang 2010; Link and Scott 2010; Murro 2013), as innovative activity is widely regarded as a central component of local and regional economic development (O'Brien 2003; Khalil and Ezzat 2005; Freeman and Soete 2008). Absence of governmental incentives directly impact innovation strategy at all levels, as sources of funding, collaboration opportunities, and technology acquisition and exploration venues are all impacted.

In a similar vein, 13 authors addressed the risk event Geographic Location & External Relationships. Literature suggests that firm location and its capability to generate and maintain a solid network of relationships are important elements to build successful innovative businesses (Salomo, Weise, and Gemünden 2007; Kelley 2009; Lhuillery and Pfister 2009; Demirbag and Glaister 2010; Schmiele 2013), particularly in the case of firms that have limited resources or capabilities to develop their own internal R&D activities (Rammer, Czarnitzki, and Spielkamp 2009). Moreover, this risk event recognizes the benefits, in terms of innovation output and outcome, of establishing positive links with universities and research institutes (Veugelers and Cassiman 2005; Pisano 2010).

Focusing on the internal boundaries of the firm, many authors report that an adequate work environment is paramount for successful innovation-oriented businesses, and that such an environment is often based on flexible managerial practices (Keizer and Halman 2007; Molina-Moraes, Martínez-Fernández, and Torlò 2011) that establish, cement or promote a positive culture for innovation (Caldwell

and O'Reilly 2003). In fact, we found 28 authors that directly addressed what we called the Flexible and Innovation-oriented Management risk event. Flexible managerial practices that promote innovation include the existence of adequate organizational structures as well as both control and resource allocation mechanisms that foster, recognize and reward idea generation and experimentation-based problem-solving activities (Greve 2003; Chiesa et al. 2009; Alpkan et al. 2010), firm-wide creativity and experimentation (Turnipseed and Turnipseed 2013) and employee empowerment (Sundbo 1996).

Finally, a number of individual characteristics that lead or promote innovation can be subsumed into the risk event categories Creativity (three mentions among reviewed works) and Risk Profile (eight mentions). The results suggest leaders of innovation-oriented firms must be comfortable with risks and ambiguity (Dewett 2007; Cabrales et al. 2008; Van Bossuyt et al. 2012) in order to guide the company around traditional systems and mechanisms that may act as barriers to new ideas, change, and experimentation (Talke 2007). Besides, the reviewed literature suggests that both individual and team creativity is highly correlated with successful innovation (Chen and Huang 2010; Ahlin, Drnovšek, and Hisrich 2014).



### *3.2. Risk event validation*

In this section, we present and discuss the results of an exploratory study with innovation-oriented firms located in Brazilian technology parks aimed at testing the completeness and comprehensiveness of our proposed interpretative framework in a real-life context. We investigated the presence and perceived impact of the risk events that constitute our tentative framework of risk events for innovation-oriented firms and inquired about the existence of additional risk events that were not captured in the framework.

The first risk event in our framework is Technical Knowledge Superior/Inferior Compared to Competitors. Indeed, given the high uncertainty that often characterizes innovation activities, the ability to create new solutions by using employees' technical knowledge is positively related to a firm's innovation output, particularly if technical abilities are heterogeneous (Smith, Collins, and Clark 2005) and located at the boundaries of science (Leiponen and Helfat 2010). Interviewees unanimously agreed with this view. In fact, one of the respondents claimed that 'successful innovation-oriented firms are usually loaded with technical talent', while another argued that 'superior technical talent from different backgrounds is even better, so they can all switch functions and perform each other's tasks'. Besides, managers stated that the presence of superior technical knowledge mitigates risks associated with rework (especially in new product development teams) and market acceptance of product innovation. The reason for that, according to one of the interviewees, is that superior technical knowledge allows firms to 'get it right since the initial stages of the innovation process, to screen out which ideas will ultimately yield positive returns'. This last proposition seems to be well supported by existing literature (Hindle and Yencken 2004). Moreover, approximately two-thirds of the managers interviewed argued that effective idea generation and selection requires not only superior technical knowledge, but also creativity and the capability to detect market needs and to translate them into technical propositions that can be tested and analyzed. This interpretation is consistent with the assertion by Caldwell and O'Reilly (2003) that innovation is the result of two complementary processes: (i) generation of good new ideas, based on creativity; and (ii) introduction and implementation of change, based on technical capabilities.

Another insight from the empirical study is that most respondents understand that the risk events Technology Management and Size & Maturity are related, since larger and more mature companies tend to invest comparatively more in internal R&D efforts than small and medium-sized firms. All nine interviewees that manage small firms stressed that they would like to support internal development teams, but are unable due to lack of capital. As one respondent put it, 'I simply can't maintain dedicated PhDs doing research and development, so I have to open up to the market in order to acquire technology and collaborate with universities to develop new solutions'. By doing so, the impact of financial losses due to unsuccessful innovations becomes larger, since revenues are shared with partners. A manager from a small company summarized this well: 'the smaller we are, the smaller our margin of error'. The work by Mata and Woerter (2013) supports this view. According to the authors, external innovation

implies in higher risks for smaller companies, mainly because revenues and profits must be shared with external collaborators.

Regarding the Technology Management risk event, all respondents recognized the importance of technology development capabilities, but six of the 14 alerted that technology development must be closely linked to the overall firm strategy in order to avoid generating innovation that is not aligned with the firm's core competences. In general, respondents seemed aware that a balance between internal and external innovation activities must be achieved, especially for small and medium firms. As the manager for firm I commented, 'we can't do all the research by ourselves, so we are here [at the Technology Park] to be close to the University labs'. On the other side, managers from firms with larger and more formal innovation structures (i.e. firms E, L and M) considered the existence of a dedicated R&D team a critical success factor for innovation, especially product innovation. This perception is grounded in existing literature; for instance, Sorescu, Chandy, and Prabhu (2003) highlighted how financial success of innovation and internal R&D capabilities are related.

As a counterpoint, one interviewee strongly disagreed with the assertion that firm size plays such a large role in determining innovation success; instead, he believes that internal and external relationships are the key, and that relational capabilities are independent of firm size or maturity. In this sense, even managers from the larger firms investigated reported that their internal R&D efforts are complemented by external innovation activities, mostly collaboration projects with research institutes and universities. This finding is consistent with the recent popularity of open innovation approaches, which according to Chesbrough (2003) is a potential success factor in the contemporary business environment. However, when the issue of open innovation was explicitly raised during the interviews, respondents were almost universally critical. In the words of an interviewee, 'open innovation is such a beautiful concept in theory, and policy makers seem to like it very much. Maybe it works in the United States, or Europe. However, the Brazilian practice is different: we still see most partners as potential competitors, and projects in partnership with universities and governmental research institutes as nuisances that generate more bureaucratic work than useful results'. These results seem in concordance with previous research on collaborative innovation in Brazil, such as Freitas, Marques, and Silva (2013) and Silva et al. (2013).

Empirical insights about risks and collaboration between firms, research institutes and universities were particularly interesting given the fact that the companies investigated were all located in technology parks associated with universities. In this sense, most respondents fully agreed with the observation by Bigliardi et al. (2005) that firms located in technology parks tend to absorb more resources from the environment if they operate in segments aligned with the park's focus. In fact, the park that hosts firms E and J is clearly oriented toward Information Technology and Life Sciences, and both respondents considered the park structure and the easy access to universities' resources as key success factors for their innovation activities. Conversely, the manager for firm H, located in the same park but operating in a different segment, argued that being in the park is positive only because it entails a certain level of cost reduction given the easiness of access to qualified labor, administrative facilities and fiscal deductions.

Respondents also signaled agreement with Demirbag and Glaister (2010), who argue that geographical location impacts innovation risks besides firms' participation in technology parks, as every firm must account for local culture. Interviewees were unanimous in declaring that the average Brazilian businessman is trained to manage traditional businesses, and usually lack entrepreneurship and innovation-related skills. In this sense, and considering that innovation success can be related to individual entrepreneurship attitude and behavior (Dewett 2007; Lopez et al. 2008; Van Bossuyt et al. 2012), respondents agreed that managers with a risk-prone decision-making profile are required in Brazilian innovation-oriented firms. Similar results were obtained in a previous exploratory research by Etges and Souza (2014): all of the ten top managers of innovative firms located in a Brazilian technology park investigated were found to have a risk-prone profile and to recognize the opportunity nature of risks in sectors where innovation is a competitive requirement.

Respondents also offered insightful observation about innovation strategy risks. First of all, they unanimously agreed that formulating and implementing an innovation strategy is the most important element for success for innovation-oriented firms. Furthermore, six of the 14 interviewees mentioned that an innovation strategy must encompass not only traditional areas of technology management (i.e. R&D, product development, intellectual propriety rights), but also operations and marketing, so to associate the firm's brand with novelty and innovation, as Salomo, Weise, and Gemünden (2007) observed. However, respondents were also adamant that elaborating an innovation strategy is extremely challenging, especially in a fast changing competitive context such as the Brazilian one. Respondents referred to something akin to Adner's (2006) innovation system concept, mentioning that Brazilian firms' innovation strategies are too often dependent on too many aspects that are outside of the organization's reach. By learning to systematically assess risks, managers of innovative firms may be able to set more realistic expectations and estimations for their innovation strategies. Similarly, risk management allows the elaboration of adequate contingency plans.

A central component of a successful innovation strategy is organizational management style. In this sense, all interviewees strongly agreed that the risk factor Flexible and Innovation-oriented Management plays a very important role in innovation-oriented firms. Respondents singled out aspects such as 'management must be tolerant of mistakes, especially when new things are being tried and tested' and 'managers should support experimentation and even reward failure, if said failure generates learning'. Both these aspects were highlighted also in previous literature; specifically, Alpkan et al. (2010) showed how management tolerance and support leads to increased innovative capabilities, and Caldwell and O'Reilly (2003) investigated the impact of flexible management practices in response velocity. Among respondents, 11 out of 14 mentioned specific management tools and practices that, according to them, are aimed at creating a supportive environment for innovation within their companies: horizontal management approaches, work time flexibility, specific physical environments dedicated to creating and testing ideas, and reward mechanisms for generating new ideas and successful innovation projects. Six respondents contended that reward mechanisms based on salary improvements or financial bonuses are somewhat rare due to specific restrictions in Brazilian labor regulations. Interestingly, managers were generally pessimistic of non-monetary reward mechanisms.

Finally, when asked about local, regional, and national instruments of innovation policy, most interviewees (10 out of 14) stressed the obstacles for accessing investment capital, which in Brazil (and most emergent national innovation systems) is concentrated in public banks. Some of the respondents were very vocal in their complaints against the complexity of the procedures put forth by government funding agencies. As one interviewee described, 'we won a public grant, but the evaluation and implementation processes took so long that the project we submitted did not make sense anymore, as the technology we wanted to develop was already being introduced in the market and demand had changed'. The majority of respondents (9 out of 14) agreed that public incentives are necessary and can be a factor of success, especially for small firms, as pointed out by authors such as Tait and Chataway (2007) and Link and Scott (2010), but they would like to see more credit options from private institutions and venture capital funds.

At the end of the interviews, respondents were asked if they would like to suggest risk events that were not part of the proposed interpretative framework. No new risk events were mentioned, but most respondents (8 out of 14) emphasized how important it is, for practitioners, to fully understand the political and cultural specificities of the Brazilian innovation system, which points out for the perceived importance of contextual risk events such as Governmental Incentives & Policies and Geographical Location & External Relationships that characterize the national and regional innovation systems. A number of issues that illustrate this point were mentioned, such as the characteristics of higher education in Brazil, the profile of the Brazilian labor force, and the emergence of entrepreneurship, especially among lower classes. Besides, all respondents declared strong interest in ERM model implementation, as none of the firms investigated had systematic tools to manage risks associated with innovation in place.

## 4. Conclusions

Innovation and risk are inseparable. For this reason, models and guidelines that allow enterprise-level risks to be analyzed and managed in innovative businesses are necessary (Leiponen and Helfat 2010). However, models and guidelines for ERM are still fairly generic, with limited discussion about specific aspects of operational implementation (Caron, Vanthienen, and Baesens 2013; Cagliano, Grimaldi, and Rafaele 2015) and restricted to traditional management environments (Bromiley et al. 2014), whose characteristics are rather different from those of firms that strongly rely on innovation. As such, innovation-related risk management requires procedures, models, techniques and tools to address complex and ambiguous risks, whose management cannot be the sole province of the focal firm; in other words, requiring a shift toward risk governance (Van Asselt and Renn 2015). This paper presents a first theoretical contribution on this topic, in the form of a systematic literature search and review, combined with an exploratory study with Brazilian innovation-oriented firms located in technology parks. The result, an interpretative framework of risk events for innovation-oriented, is a first step for a future integrative operational model of ERM applicable in innovative contexts.

Nine categories of risk events were identified from the analysis of the existent literature on risk management and innovation: Technical Knowledge Superior/Inferior Compared to Competitors; Innovation Strategy; Technology Management; Governmental Incentives & Policies; Individual Risk Profile; Flexible and Innovation-oriented Management; Geographic Location & External Relationships; Size & Maturity; and Creativity. These risk events were compared to those on the widely renowned COSO ERM model. Finally, the completeness and comprehensiveness of the proposed framework was tested in an exploratory study with innovation-oriented firms located in Brazilian technology parks. The importance attributed to Governmental Incentives & Policy and Technical Knowledge is a very relevant specific result of the case studies, as it highlights key issues that entrepreneurs and innovation managers must develop in new projects and companies. Obviously, it should be noticed that the empirical study was conducted in Brazilian firms only, whose innovative performance is somewhat hindered by a still incipient and immature national innovation system. As a consequence, it is not possible to generalize results from such a limited empirical study. Instead, results are only a first test of the proposed framework and partial evidence of the importance that managers attribute to the identification, analysis and treatment of risks commonly present in innovation-oriented firms.

The risk event identification generated insights about the relevance of ERM to innovative companies that can be useful for practitioners. Innovation is related to the creation and application of technical knowledge to support the development of solutions that are both novel and better than the existing ones (Teece 1986). Although a generic innovation process can be conceptualized (Bernstein and Singh 2006; Tidd, Bessant, and Pavitt 2008), each individual firm develops a unique instance of it given its peculiar assortment of competences, resources, processes, routines, characteristics, and determinants of innovative capability (Cooper 2003; OECD 2005; Teece 2007; Crossan and Apaydin 2010). Thus, it becomes relevant to identify competences and resources that can be continuously analyzed and managed in order to support the identification and exploration of opportunities from the risks inherent to each firm's innovation process (Mu, Peng, and MacLachlan 2009).

COSO highlights the importance of identifying risk events related to a firm's core business in order to structure an ERM approach. Bromiley et al. (2014) supports this assertion by showing how risk events can be linked to technical and corporate business impacts. When the effects of risks are analyzed in an innovation-oriented context, a dual approach is recommended: on the one side, opportunities and beneficial impacts derived from the risk should be exploited; on the other side, negative impacts must be mitigated (Freeman and Soete 2008; Purdy 2010). Risk identification is the first step toward these ends. As Kaplan and Garrick (1981, 12) put it, 'awareness of risk reduces risk'. In innovative firms, risk event identification is also relevant because innovation often requires a high level of interaction between customers and producers as well as between internal and external sources of ideas, competences, and resources (OECD 2005). One of the key practical contributions of our research is the proposition that the identification of common risks can be thought of as an alternative to success factor analysis

for innovation-oriented companies. In other words, identification and management of risk events is the essential first step in a proactive approach to improve risk management and generate positive innovation performance.

The sheer number of published works that were identified in our systematic review underlines the theoretical relevance of the topic at hand. However, none of these works went so far as to propose an ERM model for innovation-oriented companies. Thus, the proposition and testing an ERM model for innovation-oriented firms can be a viable venue for new research. To be useful for practitioners and decision-makers, such model should recommend different tools and techniques according to each specific situation, to be adaptable and flexible, and should be able to generate quantitative indicators of riskto qualify decision-making and allow scenario building and evaluation.

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No potential conflict of interest was reported by the authors.

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