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Types and traps: R&D consortia and developmental pitfalls.

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Abstract

Managing innovation requires two distinctive sets of organizational abilities: the ability to push the technological frontier and create new knowledge, and the ability to refine existing technologies and deliver products into market. While both are essential to survival, they are generally seen as conflicting strategies. In this conceptual paper, we focus on R&D collaboration as a strategy to solve the dilemma of exploration and exploitation. We suggest that cooperative R&D organizations are distinguishable by their initial strategic intent, to either explore new knowledge or exploit existing capabilities, but face similar tensions described in individual organizations when attempting to simultaneously pursue high levels of both activities. Cooperative R&D bodies are, hence, a unique sampling frame. Like individual firms,

cooperative R&D organizations suffer similar pressures in moving innovations from lab to market. But differently, they add a political dimension: to successfully operate, managers must champion innovations against different organizational systems, strategic contexts and time horizons. We suggest that managers are called upon not only to reconcile conflicting expectations of member companies; they are also looked to for creating organizational linkages to support multiple structures, and strategies. Otherwise, we risk observing a plethora of organizations getting stuck in the middle of local peaks.

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When the solution to the dilemma of exploration and exploitation itself becomes a problem.

Towards a conceptual model in collaborative R&D entities.

ABSTRACT

Managing innovation requires two distinctive sets of organizational abilities: the ability to push the technological frontier and create new knowledge, and the ability to refine existing technologies and deliver products into market. While both are essential to survival, they are generally seen as conflicting strategies. In this conceptual paper, we focus on R&D collaboration as a strategy to solve the dilemma of exploration and exploitation. We suggest that cooperative R&D organizations are distinguishable by their initial strategic intent, to either explore new knowledge or exploit existing capabilities, but face similar tensions described in individual organizations when attempting to simultaneously pursue high levels of both activities. Cooperative R&D bodies are, hence, a unique sampling frame. Like individual firms, cooperative R&D organizations suffer similar pressures in moving innovations from lab to market. But differently, they add a political dimension: to successfully operate, managers must champion innovations against different organizational systems, strategic contexts and time horizons. We suggest that managers are called upon not only to reconcile conflicting expectations of member companies; they are also looked to for creating organizational linkages to support multiple structures, and strategies. Otherwise, we risk observing a plethora of organizations getting *stuck in the middle* of local peaks.

Keywords:
Exploration and exploitation, ambidexterity, spatial separation, R&D consortia, innovation and change.

INTRODUCTION

To survive and prosper when attempting to innovate, organizations are expected to navigate throughout several tensions. As suggested by Eisenhardt (2000), paradoxes or tensions in organizations appear in many forms. Although prevailing categorizations appropriately cover the tensions that may arise in stand-alone organizations, little research focuses on the interplay between organizational design, tensions and integration mechanisms and the influence they have in exploration and exploitation outcomes in cooperative R&D entities.

The scholarly literature has used the conceptual distinction between exploration and exploitation to indicate the hazards of innovation in a wide range of organizational studies (He & Wong, 2004), including organizational design (Jansen, Tempelaar, van den Bosch, & Volberda, 2009; Menguc & Auh, 2010; Rivkin & Siggelkow, 2003; Siggelkow & Levinthal, 2003), organizational learning (Beckman, 2006; Levinthal & March, 1993; Lichtenthaler, 2009), organizational change and adaptation (Brion, Mothe, & Sabatier, 2010; Brown & Eisenhardt, 1997; Gibson & Birkinshaw, 2004; Tushman & O'Reilly, 1996) and new product development (Andriopoulos & Lewis, 2009; de Visser, de Weerd-Nederhof, Faems, Song, van Looy, & Visscher, 2010). From an organizational perspective, exploration is associated with variation, scanning, creativity, path breaking, and recombination; where exploitation is

associated with selection, adaptation, routines and structures (He & Wong, 2004; Zollo & Winter, 2002). Via exploration, organizations seek out new alternatives to effectively respond to new challenges (March, 1994: 47). Via exploitation, they seek to refine existing capabilities and technologies to implement options that prove effective (March, 1991, 1994).

This distinction creates the need for a structural balancing act within the organization to survive and prosper. Prior studies provided evidence for the idea that ambidextrous (as opposed to focused) organizations are better equipped to succeed in a dynamic environment (He & Wong, 2004; Tushman & O'Reilly, 1996). Ambidextrous organizations achieve alignment and efficiency around current core products, while remaining adaptive enough to manage disruptive innovations to assure long-term survival (Christensen, Raynor, & Anthony, 2003).

However, the problem remains that balancing acts are difficult and expensive to sustain (Gibson & Birkinshaw, 2004; Levinthal & March, 1993). The ability to create and profit from innovation requires the existence of two different spaces, each one demanding its own structure, strategy, people and culture (O'Reilly & Tushman, 2007). Where expanding the technological frontier (exploration) requires extensive research spending, experimentation, and flexible and fluid structures; transforming ideas into products (exploitation) requires efficiency, control and coordination between many functions, including R&D, production and marketing (Miotti & Sachwald, 2003: 1493). Exploration and exploitation have also different profitability structures (Puhan, 2008). Where exploitative activities can boost the probability of short-term success as "innovations move along the traditional performance trajectory" (Christensen et al., 2003: 3), if not combined with explorative activities, it may constrain the organizational ability to shape future markets and succeed in the long-term (Jansen, 2008). This potentially creates a managerial dilemma for organizations, which involves the dual search for certainty and flexibility in a context where both logics compete for resources and strategic focus (Smith & Tushman, 2005). Not surprisingly, organizations are increasingly experiencing conflicting demands as a result of creating and maintaining "dual structures" to master both foci (Lavie & Rosenkopf, 2006; Mc Namara & Baden-Fuller, 2007).

More recently, the literature has suggested that inter-firm collaborative alliances and consortia can overcome the limits of the individual firms in encompassing incremental (exploration) and radical (exploitation) innovations (Grant & Baden-Fuller, 2004; Rothaermel & Deeds, 2004). The literature has termed this co-specialization strategy as spatial separation (Christensen, 1997; Levitt & March, 1988), and more recently, interorganizational

ambidexterity (Puhan, 2008). Collaborative forms enable participant firms to focus on core competences that are critical to defend a unique position in the market (Prahalad & Hamel, 1990), while facilitating the absorption of new, external knowledge (Dyer & Singh, 1998; Teece & Pisano, 1994). Furthermore, as the costs and risks of research and development mount, these collaborative organizations, whether called R&D alliances, R&D consortia or strategic partnerships, have emerged as a functional instrument for enhancing innovativeness and economic performance in firms, while significantly reducing these risks (Dodgson, Mathews, & Kastelle, 2006; Gulati, Nohria, & Zaheer, 2000; Mathews, 2002).

Research aim

Of particular interest of this paper is an examination of the role played by R&D consortia in solving the dilemma of exploration and exploitation (Christensen, 1997; Lavie & Rosenkopf, 2006) from a theoretical perspective. We aim to understand the relationships between the characteristics of the R&D consortia, the role they have in enhancing R&D activities linked to exploration and exploitation, and their potential managerial tensions or tradeoffs. To develop our conceptual framework, we build upon Koza and Lewin's (1998, 1999, 2000) conceptualization of three types of strategic alliances, namely learning, business and hybrid, to propose a similar model of R&D consortia.

As our starting point, we define an R&D consortium as a legal entity formed by a group of autonomous organizations linked by cooperation agreements conducting associated research and development activities (Doz, Olk, & Ring, 2000; Mothe & Quelin, 2001). We argue that R&D consortia are distinguishable by their initial strategic intent, to either explore new knowledge or exploit existing capabilities (Koza & Lewin, 1998, 2000), but face similar tensions described in individual organizations when attempting to simultaneously pursue high levels of both activities, in spite of having a larger potential set of available skills and resources coming from participating firms (Hoang & Rothaermel, 2010; Lavie & Rosenkopf, 2006). Cooperative R&D bodies are, hence, a unique sampling frame. Like individual firms, cooperative R&D organizations suffer similar pressures to moving innovations from lab to market (Lubatkin, Simsek, Ling, & Veiga, 2006; Markham, 2002). But differently, they add a political dimension: to successfully operate, managers must champion innovations against different organizational systems, strategic contexts and time horizons (Hoang & Rothaermel, 2010).

Expanding on the model, we explain the risks associated with executing two strategies which initially appear incompatible or at least competing and elaborate on the concept of *stuck in the middle* (O'Reilly & Tushman, 2007; Porter, 1980; Raisch & Birkinshaw, 2008).

We suggest that when a cooperative R&D organization is forced to move upstream (forward) or downstream (backward) in the product development process under a situation of resource and capabilities constraints, it risks mismanaging both strategies and destroying value (Markides & Charitou, 2004). We also suggest that each form has embedded associated risks or tradeoffs that need to be considered when launching a specific type of collaborative organization.

In this paper, we do not address public policies issues, which are often associated with the role that governments and national innovation systems have played in promoting technology programs to enhance innovation and competitiveness (Busom & Fernández-Ribas, 2008; Klette, Møen, & Griliches, 2000; Tikoria, Banwet, & Deshmukh, 2010). Instead, we choose to concentrate on the managerial problems associated with articulating contradictory organizational demands in an R&D consortium setting. As such, this paper will focus more on the tensions rather than on the benefits of each type of R&D consortia. In doing so, we implicitly recognize the key role that successful R&D consortia has had in many countries to advance technologies that could not have been addressed by individual firms, such as the cases of Microelectronics and Computer Technology Corporation (MCC) (Peck, 1986), Semiconductor Manufacturing Technology (SEMATECH) and the Center for Advanced Television Studies (CATS) in the U.S. (Irwin & Klenow, 1996; Link, Teece, & Finan, 1996), the Very Large Scale Integrated (VLSI) circuits TRA, and the Opt-Electronics Applied System TRA in Japan (Aldrich & Sasaki, 1995; Sakakibara, 1997), the Laptop, then New, PC Consortium in Taiwan (Mathews, 2002), and EUREKA in Europe (Mothe & Quelin, 2000). The practical implication of this model is that organizational theory can be linked more closely to the design of cooperative R&D entities. In that sense, we consider our model as an intermediate step in the development of a more complex model that could account for design issues that incorporates the mediator role of integrating or conjoint mechanisms as enabler for a better coordination between organizations and across incremental and radical innovations.

This paper is organized as follows. We begin with a brief revision of the exploration and exploitation motives for firms to participate in a consortium. Next, we describe the types of R&D consortia, to then categorize the traps or tensions that are associated with each type. In the final section, conclusions are presented.

TOWARDS A TAXONOMY OF R&D CONSORTIA

Motives for participating in R&D consortia

The literature indicates that the design of R&D consortia is largely determined by the objectives and expectations of the participating firms, and this variation may lead to differences in their outcomes (Dacin, Hitt, & Levitas, 1997; Gomes-Casseres, Hagedoorn, & Jaffe, 2006). Koza and Lewin (1998: 256) suggested that a firm's motives to participate in cooperative R&D "can be distinguished in terms of its motivation to exploit an existing capability or to explore for new opportunities".

The literature displays an impressive list of exploration to exploitation motives for why firms enter into cooperative relations (Nielsen, 2010). Where the former are associated with the firm's decision to improve its ability to recognize, assimilate and apply new, external, knowledge to commercial ends (Cohen & Levinthal, 1990; Gulati, 1998, 1999); gain access to attractive yet unfamiliar business (Contractor & Lorange, 1988); and diversify its portfolio of products and services while hedging the risk of being either locked into old technologies or products or locked-out of critical new technologies (Branstetter & Sakakibara, 2002; Miotti & Sachwald, 2003). The latter are linked to the firm's decision to gain access to complementary resources and capabilities difficult to find in open markets (Khanna, Gulati, & Nohria, 1998; Koza & Lewin, 2000; Powell, Koput, & Smith-Doerr, 1996); increase market power (Hagedoorn, Link, & Vonortas, 2000; Porter & Fuller, 1986); and reduce the costs of innovation via economies of scale and scope, whilst avoiding the risks of full-scale merger (Contractor & Lorange, 2002).

An R&D consortium is also a powerful mechanism to restore socially optimal levels of R&D investment (Spence, 1984), and correct failures in the R&D market associated with imperfect appropriability (e.g. high spillovers), and asymmetric information that provide a disincentive for firms to undertake individual R&D projects (Katz, 1986). These incentive problems involve the strategic decision of the firm to interact with public and private actors (Binenbaum, 2008). The firm's decision to participate in an R&D consortium is then an organizational response to market and environmental dynamics. The economic globalization and the internationalization of the intellectual property protection, among other contextual changes, has laid pressure on firms to simultaneously meet large-scale and local needs, while the active role of triggering entities (e.g. national and local governments via subsidies and regulations, universities and local agencies) has provided them with the necessary funding to downsize the risks (Contractor & Lorange, 2002; Mowery, Oxley, & Silverman, 1998).

Types of R&D consortia

The literature suggests that collaborative organizations cannot be treated in a uniform fashion. Following the pioneering work of Koza and Lewin (1998, 1999, 2000), it has been argued that cooperative forms provide participating firms with separate specialized structures in either the discovery of new technologies or the commercialization of new products. For example, Rosenkopf and Nerkar (2001) observed that exploration outside the organizational borders brought firms with radical and broader use of technological streams far beyond their traditional markets, enlarging their business opportunities; and Rothaermel (2001) described an integrated product development path including technology venture alliances (exploration) and market venture alliances (exploitation) in the pharmaceutical industry to the benefit of major incumbents, who seem to survive and prosper in spite of the most radical changes in technology.

Expanding upon the framework of learning, business and hybrid alliances (Koza & Lewin, 2000), major aspects of R&D collaborative initiatives are discussed hereafter to suggest a model of R&D consortia.

Learning Cooperative R&D Organizations

Learning cooperative R&D organizations (LCOs) are established to explore territories where technologies are either immature or very expensive to develop (Rothaermel & Deeds, 2004). As such, LCOs put a very marked emphasis on the research ("R") components of the innovation process, "enabling partners to share tacit knowledge and develop new knowledge" (Lavie & Rosenkopf, 2006: 799). Six common blueprints are predominant in learning-like R&D consortia. First, the formation of LCOs follows an **engineered, designed pattern**, that is, it is driven by the action of a triggering entity (Doz et al., 2000; Hall, 1972). Triggering entities act as innovator catalysts; they actively bring together partners around a common subject and procure initial funding to encourage collaborative endeavors. Although the literature suggests "that triggering entities may be individuals, firms, agencies of governments, or environmental events" (Doz et al., 2000: 241), a significant impact in the emergence of collaborative partnerships comes from public R&D supported programs (Arranz & Fernández de Arroyabe, 2008). As such, R&D consortia "are then expected to recruit enough industry participants and financial contributors to become self-sustaining" (Aldrich & Sasaki, 1995: 303).

Second, parties view collaboration as a **learning** rather than a commercial platform. Their aim is "the expansion of generic-knowledge research, rather than the development of

patentable or commercialized products" (Aldrich & Sasaki, 1995: 303), so that they serve the needs of firms to more effectively share complementary knowledge, increase their awareness of R&D, and train their research staff (Branstetter & Sakakibara, 2002; Sakakibara, 1997).

Third, their activities are concentrated more **over the first stages** of the innovation cycle, between joint facilities and member firms, and between public and private organizations as they tend to place fewer restrictions on the members' participation (Aldrich & Sasaki, 1995). The emphasis here of the R&D consortia is more focused on precompetitive research rather than on the diffusion of existing knowledge to firms so they can prepare for integrating new technologies (Mothe & Quelin, 2001).

Fourth, given the nature of the task, cooperation agreements **involve a broad variety of organizations**, including suppliers or customers (vertical), universities and research institutes (institutional cooperation), and competitors (horizontal) (Belderbos, Carree, Diederen, Lokshin, & Veugelers, 2004). When working with competitors, though, firms collaborate in distant space opportunities from their current markets leading to generic discoveries in order to avoid potential leaks of knowledge not readily protected (Baum, Calabrese, & Silverman, 2000; Miotti & Sachwald, 2003).

Fifth, learning as opposed to other forms of collaborative organizations, are commonly implemented as **open-ended**, **less specific**, cooperative development ventures. Moreover, LCOs memberships vary over time –as certain members leave and others join-, and these variations lead to changes in the R&D consortium's goals over time (Evan & Olk, 1990).

Finally, LCOs show patterns of an **organic** rather than a mechanic organizational form (Burns & Stalker, 1961). They promote explorative outcomes (e.g. patents, publications) as a result of having loosely coupled structures, decentralized units, informal relations and flexible boundaries as opposed to more hierarchical structures, centralized decision-making process and formal controls and communication channels that are used in business oriented R&D consortia to decrease the risk of undesired spillovers and information leaks (He & Wong, 2004; Jansen, Van Den Bosch, & Volberda, 2006). Thus, in situations with a single or dominant demand that privileges exploration functions, learning compared to business R&D consortia will tend to have a looser structure intended to facilitate creativity, capability development and long-term growth (Nielsen, 2010).

Business Cooperative R&D Organizations

The primary intent for business cooperative R&D organizations (BCOs) is to help founding firms to establish a successful commercial position in a new market or sustain a competitive

position in an existing market. Subsequently, they are concentrated more in applied research (product development and prototype/pilot plants) and commercialization stages (Lavie & Rosenkopf, 2006). Exploitation-like R&D consortia show six distinctive features. First, they follow an **emergent pattern** which is reflected in the interest of founder members to limit partnerships to a similar type of entities and to direct most funding to respond to common threats or to changes in the environment (i.e. technology) affecting their competitive position (Doz et al., 2000). As suggested by Katz (1986), this situation is linked to the degree of development of the industry. In competitive industries firms are "more motivated to form R&D consortia to ease the subsequent product market competition" (Sakakibara & Dodgson, 2003: 234); and therefore improve their position in the market, while using cooperative agreements to reduce duplicative R&D expenditures (see also Irwin & Klenow, 1996).

Second, they are conceived as **functional instruments** (Mathews, 2002). Partnerships are typically undertaken to work in a singular project and often of limited duration, hence terminated after reaching their goals or when key members abandon the R&D consortia.

Third, their work is focused on research with a **commercial application**. BCOs occur further down the innovation chain, "when firms collaborate by pooling technology and funds to commercialize or coproduce a product" (Aldrich & Sasaki, 1995: 303). The strength of BCOs is, hence, in the diffusion of existing rather than in the creation of new, technologies across partners (Dodgson et al., 2006: 96).

Fourth, given the need to use complementary as opposed to similar capabilities, BCOs tend to **restrict horizontal relationships** and the incorporation of newcomers into the group. Where direct competitors are brought together by strong common business interests to combine complementary, but scarce, resources or capabilities "which results in the joint creation of unique new products, services, or technologies (Dyer & Singh, 1998: 662), vertical relationships are far more frequent. Since, by definition, relationships with both suppliers and customers provide insightful technological and product information directly from the market, and by extension, comprise far less risk of opportunistic behaviors compared to horizontal cooperation, they may serve better to enhance exploitative rather than explorative innovation (Arranz & Fernández de Arroyabe, 2008: 97).

Fifth, BCOs are **designed to minimize opportunistic behaviors** among members, thereby organized around well-defined contracts and measurable operational objectives (Koza & Lewin, 2000; Nielsen, 2010). BCOs perform only research that is protected via equity agreements (Hagedoorn et al., 2000).

Finally, a BCO displays a more rigid formal, hierarchical structure than its counterpart the LCO, aimed to promote a rapid transit of the new technology to the market (Jansen et al., 2006). Thus, in situations with a single or dominant demand that privileges exploitation functions, business compared to learning R&D consortia will tend to have a vertical, centralized structure, arranged in a cascade of authority and communication relations, intended to facilitate execution and short-term growth (Perretti & Negro, 2006).

Hybrid Cooperative R&D Organizations

A third basic form involves hybrid or ambidextrous cooperative R&D organizations (HCOs), which connect companies that seek to simultaneously maximize opportunities for both value creation and value capturing (Koza & Lewin, 2000: 149). HCOs combine properties from both learning and business collaborative organizations, and features of ambidextrous organizations. Accordingly, a high level of partner involvement is far more essential for hybrid organizations due to the fact that they seek a major transformation outcome in multiple time horizons (Koza & Lewin, 2000: 149). As a result of concentrating the efforts in the development and commercialization of new technologies, by using hybrid forms, partner firms can benefit from economies of scale and scope that arise from the combination of specific assets to develop a major blockbuster, securing new, future, revenues "to increase the odds of dramatic gains" (Koza & Lewin, 2000: 149).

Although from a theoretical perspective it can be assumed that HCOs effectively combine all the features of both learning and business R&D consortia, in practical terms it is very unlikely. Henceforth, we have more questions than certainties in this regard. To our recollection, the formal literature on R&D consortia does not provide examples of hybrid cases, and in most situations, a focused strategy is suggested (e.g. Branstetter & Sakakibara, 2002; Mathews, 2002; Rothaermel & Deeds, 2004) and, in others cases where exploration and exploitation outcomes are observed as result of strategic partnerships, the examples are more representatives of individual firm/supplier relationships (often in the form of a cluster) –as in the cases of Samsung Electronics in Korea or Ericsson in China (Dodgson et al., 2006)-, vendor/customer relationships –as in the case of SupplyChainCo in the U.S. (Im & Rai, 2008), or a more general form of alliance between independent firms (Holmqvist, 2004; Kale & Singh, 2007; Lavie & Rosenkopf, 2006). A potential explanation for this situation may be found in the fact that although the research agenda in an R&D consortium is implemented on the basis of specific projects approved by the board of directors, and members share the initial costs associated with each program, successful projects are often carry out under more specific modalities, which in many cases imply that the R&D

consortium creates an alliance or a separate firm to commercialize promising projects (Aldrich & Sasaki, 1995; Mothe & Quelin, 2001). In that sense, more often, R&D consortia focus more on the earlier (e.g. basic research, pilot testing) as opposed to the later (e.g. commercialization) stages in the development chain. We can summarize these concerns around the following three issues:

First, if learning outcomes in more restricted business operations are inhibited by narrowly defined domain consensus, unrealistic expectations of continuity or over-engineering of structure (Doz et al., 2000), business operations will likely suffer from a lack of focus if an R&D consortium wants to search for a new, radical innovation. The problem is whether an R&D consortium can effectively balance both exploration and exploitation without losing momentum in one activity.

Second, the literature on organizational theory suggests that ambidextrous as opposed to focused organizations are better equipped to succeed in a dynamic environment (Gibson & Birkinshaw, 2004; He & Wong, 2004; Tushman & O'Reilly, 1996). However, it is not clear whether a problem that is very complex for individual firms can be effectively tackled by a *supracorporate*, more complex entity that is not completely detached from its parent firms (Evan & Olk, 1990), especially considering the political dimensions of an R&D consortium (Hoang & Rothaermel, 2010).

Finally, it has been suggested that performance can be improved through learning (March, 1991). Therefore, the question to pose is whether an R&D consortium that is positioned to perform one activity at a time can learn to become ambidextrous. And if so, what are the mechanisms used to facilitate this process?

These concerns prompt us to suggest that under determined circumstances, the solution to the dilemma of exploration and exploitation itself becomes a problem and the search for ambidexterity may impinge on the survival of an R&D consortium. In the following section, we deepen our understanding of these issues to identify traps or tensions associated with each form that may transform an R&D consortium into a dysfunctional instrument.

For a brief description of cooperative R&D organizations, see Table 1:

Insert Table 1 about here

Associated traps and tensions in R&D consortia

Collaborative R&D projects are critical to innovation and growth, but often plagued by organizational challenges (Chao, Lichtendahl, & Grushka-Cockayne, 2011). From a general perspective, managerial problems in cooperative forms encompass: organizational design (Aggarwal & Hsu, 2009; Ireland, Hitt, & Vaidyanath, 2002); legal issues (Hagedoorn et al., 2000); resourcing (Evan & Olk, 1990); membership involvement and turnover (Belderbos et al., 2004; Mothe & Quelin, 2001); decision making (Aldrich & Sasaki, 1995; Branstetter & Sakakibara, 2002); convergence of interests and governance structure (Gulati, 1998; Linnarsson & Werr, 2004); opportunistic behaviors, holdups and underinvestment (Binenbaum, 2008; Heiman & Nickerson, 2004); and producing and evaluating outputs (Link et al., 1996; Sakakibara & Dodgson, 2003).

From a more specific perspective, and consistent with the view put forth by Koza and Lewin (2000: 148), we suggest that each R&D cooperative arrangement embodies a unique level of risk/return tradeoffs for the parties and demands a specific set of management process. Like other types of organizations, collaborative organizations are specific purpose instruments. Even though there are, a priori, many ways of designing an organization, but once that decision is taken, the investments made in a specific design itself becomes specific and irreversible, constraining future decisions (Eriksen, 2006; Gresov & Drazin, 1997).

Furthermore, tensions between exploration and exploitation are more likely to escalate destructively and negatively impact outcomes in an R&D consortium setting as opposed to the case of an individual firm given the nature of collaborative arrangements (Alic, 1990; Hagedoorn et al., 2000). As observed by Nielsen (2010: 685), while individual firms “may control the internal balance between exploration and exploitation by adjusting aspirations, beliefs, feedback, incentives, and socialization or selection processes”; in cooperative forms, partners different perceptions about how much to dedicate to one or another activity may lead to strategic misfits, unless resolved through a process of common adaptation, suboptimal solutions and a higher predisposition to failure. The need to develop multi-level structural linkages in R&D consortia to solve divergence of interests across its multiple efforts at both the intra and the extra-organization units becomes, thus, paramount to the realization of superior performance, while preventing high instability and group disbandment (Linnarsson & Werr, 2004).

Managing R&D collaboration raises an additional and long visited dilemma for the parties: opening the venue to value creation in collaborative forms, creates favorable

conditions to opportunistic behaviors, exposing valuable and unprotected knowledge to expropriation (Heiman & Nickerson, 2004). Opportunist behaviors impact more strongly on business R&D consortia than others, as LCOs are established to exchange less delicate information without irreversible involvement and in far-from-market areas leading to generic discoveries (Mothe & Quelin, 2001).

Another source of tension emerges when an R&D consortium is incapable of successfully readapting its configuration to changes occurring in the member firms. Changes occur at two levels. At the consortium level, membership composition changes over time, as certain members leave and others join (Mothe & Quelin, 2001). This requires an extra effort from consortium managers not only to actively engage in promotional activities aimed to recruit new members but also to then settle and harmonize common interests between the old order and the expectations of the new members (Evan & Olk, 1990). There are also changes at the individual firm level. For example, a change in the ownership or at the top management level of a member firm can lead to a change in the corporate strategy, impacting the firm's propensity to collaborate. In that sense, tensions in R&D consortia emerge not only from differences in management styles between partners (Kumar & Nti, 1998); they also appear because member firms shift their strategies due to problems derived from "cultural differences, organizational challenges and competitive difficulties" (Reuer, 2000: 5).

Membership involvement and turnover occur more frequently on learning R&D consortia than others, as they often cover more general, non-equity agreements, and therefore, are more flexible instruments to allow the participation of new firms. However, changes in membership composition are more frequent in LCOs –as the diversity and lack of domain similarities (e.g. a minimum level of relevant factual knowledge, skills and technical proficiency, size, target market and time orientations) between partners characteristic of LCOs may cause more repeated conflicts than in other types of consortia (Provan & Kenis, 2007)-, the consequences for BCOs are more catastrophic. Business, and by association hybrid, R&D consortia are dependent upon the strong commitment of the partners and combine R&D skills and resources through equity joint ownership (Hagedoorn et al., 2000). Once a member leaves, the entity is subsequently terminated. The same reasoning is applicable for their projects. If certain learning R&D consortia projects "are not successful, they can be terminated with only a relatively small loss compared to the loss that would be incurred when a research [business] corporation is dissolved" (Hagedoorn et al., 2000: 570 [word in parentheses is not in the original.]).

Finally, complex arrangements are more difficult to manage, and then the costs and benefits are not equally shared. As complexity escalates, for example in the case of ambidextrous or dual oriented R&D consortia, so too does the costs of maintaining connections among mature and revolutionary technologies (Tushman & Nadler, 1978; Van Looy, Martens, & Debackere, 2005). An ambidextrous formation of consortia benefits large (as opposed to small) firms, given the restrictions on funding, lack of slack resources and small margin for error typically associated with small firms (Lin, Yang, & Demirkan, 2007).

The preceding arguments suggest that a consortium is, then, at risk of becoming "stuck in the middle" (O'Reilly & Tushman, 2007; Porter, 1980) when the tensions that are intrinsic to high levels of exploration and exploitation become unmanageable (He & Wong, 2004). Put differently, the need to strive for an effective balance between exploration and exploitation must be weighed against the potential costs and alignment problems to deal with different logics (Cegarra-Navarro & Dewhurst, 2007), particularly considering that R&D consortia tend to magnify the inherent problems of research found in stand-alone organizations (Ghemawat & Costa, 1993; Peck, 1986).

Figure 1 depicts each type of R&D consortium and associated risks or potential traps:

Insert Figure 1 about here

Trap 1: misfit trap

The current literature argues that, whatever their source, tensions inevitably diminish the organizational fit, and lead towards unstable relationships, negatively impacting performance (Kumar & Nti, 1998; Siggelkow & Levinthal, 2003). For instance, Porter (1996: 70) suggested that structures, systems and processes require to reflect the tradeoffs rules, so organizations could focus on core competencies, critical resources and key success factors. For Gulati and Puranam (2009) inconsistencies between formal and informal structures inevitably create internal fit problems, enhancing the hazards of organizational mortality, although conflicts can be a stimulant to ambidexterity. However, in complex systems, such as R&D consortia, the notion of internal fit, that is, the call for consistency between organizational elements (i.e. strategy, structure and activities) needs to be balanced with the notion of external fit, that is, the need for consistency between organizational design and environmental conditions (Siggelkow & Levinthal, 2003). In this context, Siggelkow (2001: 838) observed that a tightly coupled, ambidextrous organizations may have even more difficulties to adapting to such changes, since "coupling requires a firm to modify many choices simultaneously, an inherently difficult task".

Expanding the notion of fit beyond the firm level, it can be inferred that an R&D consortium attempting to pursue an ambidextrous position under either a resource constrained scenario (Cao, Gedajlovic, & Zhang, 2009) or lacking broad management skills and abilities to develop learning mechanisms to sustain both foci (O'Reilly & Tushman, 2007) may suffer effort dispersion in fragmentary activities, leading to a negative circle of unfinished projects (Copani, Bosani, Tosatti, & Azevedo, 2006).

Furthermore, the managerial failure to adequately respond and adapt to internal and external conflicting demands may preclude the termination of an R&D consortium. We use the term *misfit trap* (Tiwana, Bharadwaj, & Sambamurthy, 2004) in the setting of R&D consortia to refer to alignment problems between the organizational design and both internal and external demands that negatively impact on performance. Where internal demands are associated with conflicts in the relationship between organizational structure and the role of research (i.e. how much exploration versus how much exploitation); in this setting, external demands are associated with changes in the environmental conditions (i.e. technology, regulations), and at the membership composition of the consortia.

Traps 2 and 3: Competency and learning traps

However, vicious cycles or traps (Andriopoulos & Lewis, 2009) have also been extensively described in organizations whose strategic tendency is to exclusively focus on exploitation activities, a propensity known as “competency trap” (Leonard-Barton, 1992) and in which past success and the promise of immediate returns lead management to strategic persistence (Audia, Locke, & Smith, 2000), driving out explorative activity (O'Reilly & Tushman, 2007), or, conversely, in organizations that focus on exploration activities, a trend named “failure trap” (Levinthal & March, 1993), and in which unsuccessful past results in knowledge creation lead to a continuous changing in searching options in which exploration drives out exploitation (Gupta, Smith, & Shalley, 2006).

Trap 4: Consensus trap

The nature of collaboration may also engender a complementary failure type, which resembles the idea of a *consensus trap* described by Fiorino (1997). Consensus traps emerge from two distinguishing characteristics of R&D consortia referred to Evan and Olk (1990). First, as mentioned above, an R&D consortium represents a *supracorporate* organization that is not entirely detached from its member firms (Evan & Olk, 1990: 40). This strategic and legal attachment creates tensions between the goals of a consortium and those of its members: while a consortium manager must invite all interested parties to provide inputs relevant to the objectives of the consortium, he/she must also control for the different needs of each parent

firm. His/her job is to develop an efficient decision-making procedure to arrive at consensus quickly, while reducing the internal conflicts that affect performance (Provan & Kenis, 2007). Subsequently, managers are obliged to continuously rely on consultation and negotiation processes to set and execute a research agenda. To put it differently, in this borderless organization, members need to develop a shared understanding of the direction in which the relationship must go to compete successfully.

Second, as suggested above, in its life-span, an R&D consortium is likely to experience membership losses, and as a result, consortium managers may need to recruit new members to replace members who have left or to help the consortium to grow, which in turn will alter the balance of power (Evan & Olk, 1990: 43). Essentially, to successfully conduct an R&D consortium, managers have to actively battle against the desire for control and involvement of each individual member, manage different expectations and time horizons as well as control for the "agreed" specifications to be delivered, on time and on budget. Consensus traps arise, thus, from the inability of the participating firms to commit to optimal decisions or due to the shifts in their preferences or composition, which in turn may create a vicious circle of dysfunctional behaviors inside a consortium.

We suggest that a consensus trap may affect all three types of R&D consortia, although we recognize that the effects may be more pervasive in a business oriented –and, by association, also a hybrid- consortium as the critical element in those two types are related to effective R&D project execution. To illustrate the factor that a consensus trap will still affect all three, but also to recognize that the inability to manage this or any other trap described in this paper may produce equally negative results, we introduce a fourth type of R&D consortium, which we called dysfunctional or "stuck in the middle".

To sum up, in the setting of a collaborative R&D organization, the conflicting pressures which arise from the clash of the opposing logics of exploration and exploitation produce the emergence of four types of traps. In other words, to expropriate and modify Schumpeter´s phrase, all three types of collaborative R&D forms described by Koza and Lewin (2000) have embedded the germ of "destructive destruction"; in other words, the potential to become dysfunctional or "stuck in the middle".

CONCLUSION

Studies report that a large fraction of R&D cooperative forms do not accomplish their original goals and many are disbanded (Das & Teng, 2000; Podolny & Page, 1998), which

implies that “many firms fail to realize the potential gains from partnering activity” (Gulati, Lavie, & Singh, 2009: 1213). Major reasons for these failures are found in the difficulties associated with the management of the R&D-related consortia (Hagedoorn et al., 2000). Essentially, it takes considerable entrepreneurial effort to design an R&D consortium that successfully synchronizes both the “R” and the “D” stages of the product development. In this paper, we attempted to clarify the underlying factors that negatively impact the operation and outcome of R&D consortia. Using a basic model, we described four types and its associated traps. We suggest that those tensions, when not well manage, could originate a dysfunctional form of organization.

Our model indicates that each cooperative alternative involves different risk/return tradeoffs for the parties, and that these tensions are amplified, in the setting of a collaborative R&D organization, by both internal and external dynamics. As such, consortium managers need to ensure that participating firms arrive at a shared cognitive model of the envisioned venture in order to ensure the inputs and disseminate the technology (Olk, 1998; Tiwana, 2008). In that sense, as long as the availability of resources and competencies depends upon the contributions of individual member firms, collaborative R&D entities will face equity or membership conflicts, unless managers are successful in building relational capital based on trust and close interaction between partners (Kale, Singh, & Perlmutter, 2000).

The practical implication of this model is that theory can be linked more closely to the design of R&D consortia. Far from providing definitive answers in this regard, our paper suggests questions that need to be addressed in the future.

In summary, the dilemma for an R&D consortium is either to specialize or to become a dual player. As such, managers are called not only to reconcile the multiple -and sometimes colliding- expectations of member companies (Hagedoorn et al., 2000; Olk, 1998); they are also looked to for creating organizational linkages to support multiple structures, strategies and processes (Jansen et al., 2009; O'Reilly & Tushman, 2007). When trying to compete with a dual business model (Markides & Charitou, 2004), a collaborative organization is not only contingent on its own resources, but also on its ability to rapidly learn and develop organizational skills and capabilities to effectively integrate and build upon both strategies (Benner & Tushman, 2003). Otherwise, we risk observing a plethora of organizations getting *stuck in the middle* of local peaks (Siggelkow & Levinthal, 2003).

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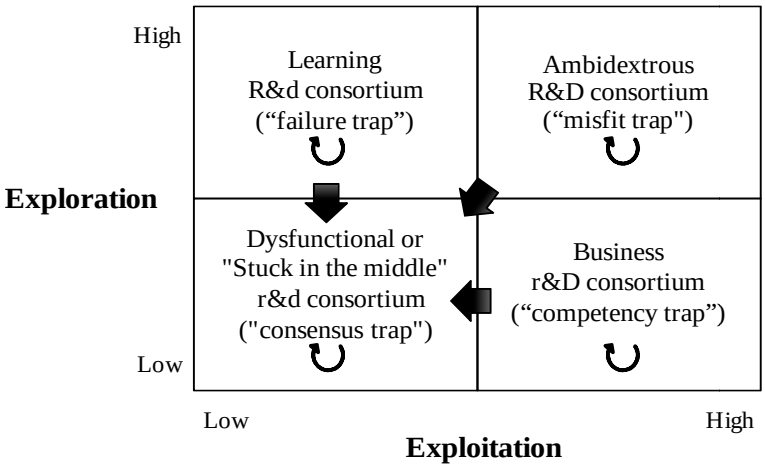
Table 1: Types of cooperative R&D organizations

Category	Learning collaborative R&D organizations (LCOs)	Business cooperative R&D organizations (BCOs)	Hybrid R&D cooperative organizations (HCOs)	Dysfunctional or "stuck in the middle" cooperative R&D organizations
Description	LCOs are established to explore territories where technologies are either immature or very expensive to develop (Rothaermel & Deeds, 2004). LCOs put a very marked emphasis on the research ("R") components of the innovation process, "enabling partners to share tacit knowledge and develop new knowledge" (Lavie & Rosenkopf, 2006: 799).	The primary intent for business cooperative research organizations (BCOs) is to help founding firms to establish a successful commercial position in a new market. BCOs are concentrated more in applied research (product development and prototype/pilot plants) and commercialization stages (Lavie & Rosenkopf, 2006).	Hybrid or ambidextrous cooperative organizations (HCOs) connect companies that seek to simultaneously maximize opportunities for both value creation and value capturing (Koza & Lewin, 2000: 149). HCOs combine properties from both learning and business collaborative organizations, and features of ambidextrous organizations.	Cooperative R&D organizations that suffer from an effort dispersion expressed in fragmentary activities and unfinished projects (Copani et al., 2006) due to the inability to pursue an ambidextrous position.
Focus	Pre-competitive R&D (Aldrich & Sasaki, 1995: 303)	Competitive, downstream R&D development (Alic, 1990)	Both pre-competitive and competitive, downstream R&D development (Alic, 1990; Hagedoorn et al., 2000).	Lack of focus.
Design type	Loosely coupled structures, decentralized units and informal relations intended to facilitate creativity, capability development and long-term growth (He & Wong, 2004; Jansen et al., 2006; Nielsen, 2010).	Hierarchical structure, centralized decision-making and formal controls and communication to decrease the risk of undesired spillovers and information leaks (He & Wong, 2004; Jansen et al., 2006; Nielsen, 2010).	Ambidexterity (Duncan, 1976; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996). Combination of Mechanic and organic structures (Burns & Stalker, 1961). Compensatory fit (Gulati & Puranam, 2009)	Implies tradeoffs between alternatives.
Design context	Singular, dominant or dominant set of functions (Gresov & Drazin, 1997). Engineered pattern (Doz et al., 2000)	Singular, dominant or dominant set of functions (Gresov & Drazin, 1997). Emergent pattern (Doz et al., 2000)	Multiple, conflicting set of functions (Gresov & Drazin, 1997). Both engineered and emergent patterns (Doz et al., 2000)	Multiple, conflicting set of functions (Gresov & Drazin, 1997). Both engineered and emergent patterns (Doz et al., 2000).
Traps	Failure trap (Levinthal & March, 1993)	Competency trap (Leonard-Barton, 1992); familiarity trap, maturity trap, and propinquity trap (Ahuja & Morris Lampert, 2001).	Misfit (Gilbert, 2006; Menguc & Auh, 2010; Porter, 1996; Siggelkow, 2001); Misfit trap (Tiwana et al., 2004); Mismatch (Nielsen, 2010).	Stuck in the middle (Porter, 1980); Consensus trap (Fiorino, 1997); Low local peaks (Siggelkow & Levinthal, 2003); Lack of slack resources (Floyd & Lane, 2000). Knowledge sharing versus knowledge expropriation (Heiman & Nickerson, 2004), cooperative versus non cooperative modes of behavior (Kumar & Nti, 1998).
Research examples	Aldrich and Sasaki (1995); Mowery, Oxley, and Silverman (1996); Doz, Olk, & Ring (2000); Mothe and Quelin (2001); Branstetter and Sakakibara (2002); Miotti and Sachwald (2003); Rothaermel & Deeds (2004); Lavie & Rosenkopf (2006).	Aldrich and Sasaki (1995); Doz, Olk, & Ring (2000); Mothe and Quelin (2000); Rothaermel (2001); Mathews (2002); Argyres and Silverman (2004); Rothaermel & Deeds (2004); Powell and Grodal (2005); Lavie & Rosenkopf (2006); Dodgson, Mathews, and Kastelle (2006).	Koza and Lewin (2000); Lavie & Rosenkopf (2006).	Miles and Snow (1992); Porter (1980, 1998); Lin, Yang, & Demirkan (2007).

The format of this table was adapted from Gresov and Drazin (1997)

Figure 1: Types of R&D consortia and associated traps



Adapted from Koza and Lewin (2000), Fiorino (1997) and Tiwana, Bharadwaj and Sambamurthy (2004).

(Note: ↻ refers to a vicious circle inside the quadrant; ➡ Movement from one quadrant to another).