UNIVERSITAT RAMON LLULL

**DOCTORAL THESIS**

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| Title | **Governance of Inter-Organizational Collaborations When Engaged in Open Innovation** |
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**ABSTRACT**

The use of external knowledge, through open and collaborative projects with external partners, enables firms to effectively and efficiently solve their innovation problems, thereby generating greater innovation performance. Yet many open and collaborative innovation projects have failed to complete their objectives as initially planned. Scholars have tried to examine this problem by studying the governance mechanism of collaboration process in both formation and execution phases of projects. While these studies have provided important insights, still little is understood about the nature of collaboration dynamics and the attributes of projects affecting governance mechanisms. In response, this dissertation seeks to establish a comprehensive and clarifying view of open and collaborative innovation governance through addressing the following overall question: How do firms govern the collaboration process with external partners to increase the likelihood that their open and collaborative innovation projects are successfully completed? Three specific research questions are framed to answer the overall question: 1) How do firms manage the dynamics of collaboration process with external sources to successfully complete their open and collaborative innovation projects? 2) Does the use of a formalized joint technology-development process help to increase the likelihood that an open innovation project with external sources is successfully completed? 3) Which open innovation modes do managers choose for projects characterized by different levels of complexity and 'hiddenness' of knowledge? We approach these questions with combining a cross-case systematic analysis of qualitative cases on open and collaborative projects and a survey study. The results of this study demonstrate that partnering firms need to regulate the knowledge sharing-protecting tension in collaboration processes to successfully complete joint projects. Moreover, I introduce an alternative form of formalization into the collaboration process, in addition to formal intellectual property (IP) control, to regulate the knowledge sharing-protecting tension. Finally, the results indicate that project attributes, specifically complexity and hiddenness of required knowledge, affects the selection of governance mechanisms in open and collaborative projects.

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# Chapter 1: General Introduction of Thesis

## 1.1 Relevance of the Topic and Overall research Objective

*"Open and collaborative innovation is growing into a mainstream phenomenon of increasing business relevance in large firms, but mastering and managing it is a challenge". Sabine Brunswicker, Former Head of Open Innovation at the Fraunhofer Society.*

The topic of open and collaborative innovation has received substantial research attention in the management literature consistently over the last 10 years. An extensive body of literature on inter-organizational collaboration (IOC) and open innovation (OI) has devoted considerable attention to show that firms can purposively transcend their organizational boundaries to improve their innovation activities through conscious use of inflows and outflows of knowledge in a cooperative relationship with external partners (Browning, Beyer, & Shetler, 1995; Brunswicker & Vanhaverbeke, 2015; Chesbrough, 2003; Faems, Janssens, Madhok, & Van Looy, 2008; Faems, Van Looy, & Debackere, 2005; Laursen & Salter, 2006; West & Bogers, 2014). A recently completed survey of large firms in the United States and Europe reports that OI is the pre-eminent mechanism adopted by large firms for improving internal innovation. 78% of firms in our sample have engaged in OI; the financial support for OI has also clearly increased for 61% of survey respondents over the last two years (Brunswicker, Chesbrough, & Bagherzadeh, 2016).

Open and collaborative innovation can be enacted in a variety of contexts with a range of external partners, such as customers, suppliers, universities, competitors, and start-ups (Chesbrough & Brunswicker, 2014; Faems et al., 2005; Foss, Laursen, & Pedersen, 2011; Laursen & Salter, 2006). To capitalize on the knowledge of these external partners, firms use a variety of mechanisms. Alliances (Faems et al., 2008; Franco & Haase, 2015), joint ventures (Ariño & De La Torre, 1998), consortia (Browning et al., 1995), networks (Jarvenpaa & Välikangas, 2014), licensing agreements (Li-Ying & Wang, 2015), user communities (Von Hippel, 2001), and innovation contests, or innovation crowdsourcing (Afuah & Tucci, 2012; Malhotra & Majchrzak, 2014) are examples of mechanisms that firms apply in order to access, generate, channel and organize external knowledge. Scholars have presented empirical evidence that tapping into external knowledge allows firms to improve their ability to solve their innovation problems in a more effective and efficient way, thereby leading to greater innovation performance (Browning et al., 1995; Doz, 1996; Foss et al., 2011; Laursen & Salter, 2006; Ness, 2009). For example, the partnership between DreamWorks, an animation technology leader, and Hewlett-Packard resulted in a groundbreaking new technology for rendering films (Brunswicker, Bagherzadeh, & Lamb, 2016). Also, recent case study on the Lilly Open Innovation Drug Discovery (OIDD) platform depicts they are tapping into the knowledge of a large number of scientists and researchers to successfully explore new molecule types with the specific biological activity in a more open manner. This OIDD platform gained for Lilly access to a significant amount of previously inaccessible chemical diversity. It also has allowed for the identification of many scientists and researchers doing great work that were previously unknown to Lilly, thereby supporting Lilly's internal research teams, which are focused on the development of new drugs and biopharmaceuticals (Brunswicker et al., 2016).

As much promise as openness and collaboration can bring to innovation potential, far too many collaborations have been documented as failure cases (Ariño & De La Torre, 1998; De Rond & Bouchikhi, 2004; Faems et al., 2008; Park & Ungson, 2001). For instance, research on international joint venture termination shows that approximately 90% of collaborations are unexpectedly terminated earlier than reaching the initially planned goals (Makino, Chan, Isobe, & Beamish, 2007). An equity joint venture (JV) between two companies active in the chemical and cleaning-products industries, intending to develop a new ecological cleaning liquid for the U.S. and Asian markets, was unsuccessful and unfruitful as "the partners announced in September their decision to dissolve the JV as of December 1993" (Ariño & De La Torre, 1998: 319). De Rond and Buchikhi (2004) report how the IOC partners' different and opposing views about compounds-developing technology, led to tensions between them, thereby stopping the collaboration before completing the partnership's initial goals. Similarly, recent OI case studies show that unexpected tensions arising from partner differences, such as conflicting interests, views, goals, etc., during the collaboration, if not understood and accommodated effectively, can delay the project in achieving its predefined objectives, and even stop the project prematurely (Brunswicker et al., 2016). Collaboration process can and should be better managed, resulting in fewer failures and greater levels of innovation. Consequently, managing the collaboration with external partners to successfully complete the collaboration, while vital to progress innovation, is currently quite challenging, even fraught with high risk for failure. I argue that the main question needing to be addressed to advance the cause of innovation on the literature of OI and IOC has shifted from 'open and collaborative' versus 'closed' innovation towards the appropriate governance mechanisms for guiding collaboration processes to successful innovation outcomes. 'Governance mechanism' is defined as a set of managerial and coordination activities adopted by partners to organize collaboration process including communication channels between the partners, decision making processes, roles and processes required for collaboration, incentive structures used to motivate involved partners, and property rights control (Grandori, 1997; Faems et al., 2008; Nickerson & Zenger, 2004).

The formation phase in collaboration refers to the point when initial agreements have been established and the partners are expected to start active work towards joint objectives. A number of authors have argued that the governance of collaboration processes after the formation phase is a critical mechanism to study why some open and collaborative projects (henceforth "collaborative project") succeed while others fail. (Das & Teng, 2000; De Rond & Bouchikhi, 2004; Doz, 1996; Greve, Baum, Mitsuhashi, & Rowley, 2010). These authors have concentrated upon the role of specific factors affecting the governance, such as partners' expectation about efficiency of collaboration (Doz, 1996) or performance approach. But such a narrow focus can result in a constrained understanding of the governance of collaboration process itself. Moreover, other scholars argue that selection of the governance mechanism for collaborative projects in the formation phase can play a crucial role in project successes. Most studies have targeted firm-level and industry-level characteristics as determinants of governance mechanism (van de Vrande, Vanhaverbeke, & Duysters, 2009). These studies provide us with limited understanding, ignoring particular attributes of the project itself (Felin & Zenger, 2014).

Thus, there is a need for a more comprehensive and holistic view to study the governance of collaboration process. The main objective of this dissertation is to create such a comprehensive view, in order to advance our understanding of open and collaborative innovation governance. This dissertation aims to address the following overall question: *How do firms govern the collaboration process with external partners to increase the likelihood that their open and collaborative innovation projects are successfully completed?*

## 1.2 Theoretical Background

To address the overall research objective driving my research in this dissertation, the current section provides an overview of the theoretical background. This overview analyzes the current literature on interorganizational collaboration dynamics, knowledge sharing-protecting tension in collaborative projects, and project attributes and their role in governance mechanism selection to frame specific research questions as the foundations for the following chapters.

### *1.2.1 Interorganizaitonal Collaboration Dynamics*

Despite the research interest in the governance of open and collaborative innovation, current studies have provided only a limited understanding of the nature of governance by focusing primarily on static initial factors affecting the governance mechanism, such as contractual interface structure and expectation of performance, rather than explicitly studying the dynamics that occur during collaboration and analyzing how these dynamics affect governance and outcomes.

Numerous studies in the IOC and OI literature have argued for a focus on collaboration dynamics as an important building block in understanding the governance of collaboration process and why some collaborative projects with the same initial conditions thrive and others underperform (Ariño & De La Torre, 1998; Das & Teng, 2000; Doz, 1996; Ring & Van de Ven, 1994). Ring and Van de Ven (1994) suggest that certain dynamics occur at different stages of a collaborative project that can affect the governance of collaboration. Similarly, evolutionary phases of collaborative projects are highlighted as a critical factor affecting governance (Doz, 1996). For example, Ariño and De la Torre (1998) and Doz (1996) suggest that collaborative projects require continuous learning about outcome discrepancies, referring to failures to achieve expected value from the collaboration. Then, the appropriate governance mechanism should be applied to respond to the outcome discrepancies; otherwise, performance failure can stop the collaboration. Ness (2009) shows when alliance performance and value disappear for the partners and they fail to reach their initially planned goals, they reduce their contributions and commitments to project. Another study indicates that since the collaboration requires discourse and the individuals may have little prior joint working experience, misunderstandings may arise, creating the need for unexpected modifications of governance to support effective communications (Hardy, Lawrence, & Grant, 2005). Faems et al., (2008) argue that firm attention to the dynamics of collaboration is needed to enable the partners to adopt an appropriate governance mechanism characterized by the formalization of levels of monitoring, task division, and information flows. They show that, over time, the partners in an R&D alliance gradually adapted the governance mechanism by increasing the number of technical meetings to involve more people from each partnered firm in joint problem definition and solution generation in order to effectively respond to increasing technical problems. Moreover, Das and Teng (2000) argue, tensions between competition and cooperation give rise to imbalances in behaviors of partners to operate the joint collaboration; thus, a proper governance mechanism is required to accommodate to changes in tensions.

In sum, these studies highlight the critical effect of dynamics occurring during the course of collaborative projects upon understanding the governance mechanism of collaborative projects. Also, they argue that the source of the dynamics, originally promoted by Das and Teng (2002), has a critical effect on how the governance mechanism can be framed. Although these studies have provided important insights, each of them only focuses on a single case related to specific form of collaborative project among various forms, including alliances, research and development projects, buyer-supplier agreements, networks, joint-ventures, and consortia. It seems there is a need to create a comprehensive understanding, based on multiple cases, of the nature of dynamics over time, the sources for these dynamics, and the effects of these dynamics on project performance among different forms of collaboration. This comprehensive view provides a strong foundation to understand relevant factors with crucial effect on the governance of collaborative projects.

### *1.2.2 Knowledge Sharing-Protecting Tension in Collaborative Projects*

Partners in collaborative projects tend to facilitate flexible dialogue and interaction among involved actors. This greater flexibility results in knowledge sharing between the partners, defined as making knowledge accessible for involved individuals and actors from each partner firm within the collaborative projects (Davenport & Prusak, 1998; Rezazadeh Mehrizi & Bontis, 2009). This knowledge sharing leads to expanded capacity for re-conceptualize problems and synthesize different knowledge areas relevant to the project, thereby increasing the probability of project successes (Browning et al., 1995; Faems et al., 2008). For example, Buchel (2000: 652) reports how flexible dialogue among interacting individuals from different partner firms was supported as they were allowed to "directly call up their counterpart and resolve any differences in understanding". Similarly, in the SEMATECH consortium, partnered firms encouraged flexible interaction between involved individuals by adopting "a structure and method emphasizing joint problem solving through meetings pervade the organization" (Browning et al., 1995: 117).

Although such flexible interactions support more collaboration between partners, it exposes the partner firms to opportunistic risk from unintended over-sharing of knowledge where a partner pursues its own goals at the expense of the partner's or joint goals and knowledge (Ariño & De La Torre, 1998; Faems, Janssens, & Van Looy, 2010; Heiman & Nickerson, 2004). This creates a fear of opportunistic risk as valuable knowledge is subject to potential expropriation by partners who may abuse unintended shared knowledge for their own benefits and interests (Faems et al., 2010; Heiman & Nickerson, 2004) which may harm the partner firms by losing their intellectual properties and competitive position (Jarvenpaa &

Majchrzak, 2016). Therefore, this fear of opportunistic risk gives rise to defensive behavior of partner firms and unwillingness to collaborate (De Rond & Bouchikhi, 2004; Jarvenpaa & Majchrzak, 2016; Jarvenpaa & Välikangas, 2014) for knowledge protection, defined as safeguard against the expropriation of knowledge and the hazard of opportunism (Heiman & Nickerson, 2004). For example, in collaboration between an imaging company (Graph) and a stock-quoted inkjet technology company (Jet), Jet management explicitly asked their engineers "not to share information on technological problems due to the fear of unintended knowledge spillovers and losing command over the project" (Faems et al., 2008: 1063).

According to the dialectical view, there is inherent tension between the need to share and the need to protect due to two opposing and contradictory needs that compete with each other in collaborative projects (Poole & Van de Ven, 1989; Van de Ven, 1992). This knowledge sharing-protecting tension is caused by the presence of contradiction between sharing and protecting of knowledge and the efforts to resolve such contradiction (Das & Teng, 2000). Das and Teng (2000) argue that tension between sharing and protecting results in imbalances in behaviors of partners for joint collaboration. The partners need to effectively respond to this tension. A recent cross-case systematic analysis of qualitative cases on IOCs show that, in successful collaborative projects, the partners are able to manage the simultaneous sharing and protecting of knowledge (Majchrzak, Jarvenpaa, & Bagherzadeh, 2015). Therefore, knowledge sharing-protecting tension should be regulated to support collaboration among partners to successfully complete the joint initially planned objectives (Bogers, 2011; Heiman & Nickerson, 2004; Jarvenpaa & Majchrzak, 2016).

One potential solution to regulate this tension is to introduce some form of formalization into the collaboration process (Majchrzak et al., 2015). The type of formalization receiving the most attention in the open and collaborative innovation literature is legal formalization, such as contracts around IP control (Cassiman & Veugelers, 2002; Laursen & Salter, 2014). However, these types of formalization may not address more specific activities of the partners, thus, the partners may share IP-related knowledge that they should not sharing while they are collaborating (Jarvenpaa & Majchrzak, 2016). As a result, in addition to formal legal IP control, an alternative conceptualization for formalizing of collaborative process is required. This alternative conceptualization can introduce formality into the joint collaboration process (also called "joint technology development process" in this dissertation) itself by specifying activities and evaluation criteria that should be followed by the parties for completing the collaborative project. Introducing formality into the joint technology development process decreases the uncertainty about required knowledge that should be shared for furthering project goals (Avadikyan, Llerena, Matt, Rozan, & Wolff, 2001; Vlaar, Van den Bosch, & Volberda, 2006). This formality can create a predictable guidelines about what should be shared and what should be protected (Jarvenpaa & Majchrzak, 2016). This predictability stimulates the partners for self-monitoring and regulation of knowledge sharing and protecting tension during the joint projects to avoid the opportunistic risk. As a result, flexible interaction between the parties without losing critical knowledge is supported, thus increasing the likelihood of success of open and collaborative innovation projects.

### *1.2.3 Governance Mechanism and Collaborative Project Attributes*

Partners can apply various governance mechanisms including partnerships, licensing agreements, communities, innovation contests, and innovation crowdsourcing for their collaborative projects (Felin & Zenger, 2014). In light of the wide variety of governance mechanisms, a key issue for firms is selecting of appropriate mechanism. Most existing advice on selection of governance mechanism takes a firm-level perspective. Some studies suggest that particular firm-level and industry-level characteristics, such as firm size or environmental uncertainty, are critical contingencies for the effectiveness of particular governance mechanism (van de Vrande et al., 2009). However, advice drawn from such studies can mislead our understanding of adoption appropriate governance mechanism as the attributes of project constitute the effectiveness of a particular mechanism (Afuah & Tucci, 2012; Bianchi, Cavaliere, Chiaroni, Frattini, & Chiesa, 2011; Chiaroni, Chiesa, & Frattini, 2009; Felin & Zenger, 2014; Salter, Criscuolo, & Ter Wal, 2014). For example, Bianchi et al. (2011) and Chiaroni et al. (2009) show that the governance mechanisms that firms select to manage their relationship with their external partners in open innovation projects vary along the two stages of bio-pharmaceutical R&D process (i.e., drug discovery and drug development), because each stage is characterized by different needs for exploration and exploitation of knowledge. Based on the problem solving perspective, complex problems, in which the solution depends upon a large number of highly interdependent tasks, elements, or knowledge sets that make complex problems less decomposable (Fernandes & Simon, 1999), need extensive dialogue and knowledge exchange to ensure sufficient understanding to progress to an appropriate solution (Nickerson & Zenger, 2004). For example, in a technological partnership to develop a new technology for rendering movies, the technological problem was complex. This technological problem was comprised of different elements and knowledge sets related to data storage, cloud computing, and animation technologies, and these elements are interdependent and should be considered at the same time to develop a successful technological solution (Brunswicker et al., 2016).

For such complex problems, governance mechanisms that support knowledge exchange and dialogue may lead to greater project outcomes. Thus, partnerships, in which trusted knowledge exchange is possible, can be the appropriate mechanism (Felin & Zenger, 2014). In contrast, simple problems usually require little knowledge sharing and integration (Nickerson & Zenger, 2004). Thus, licensing agreements or competitive innovation contests, as those create strong incentive effects, can be adopted as proper mechanism.

Although scholars have started to consider problem attributes as important factors affecting the selection of governance mechanism, there is still lack of understanding. Particularly, there is no strong empirical evidence regarding the role of problem attributes in the extant literature on open and collaborative innovation. Thus, a comparative cross-project analysis is needed to have a more integrated and nuanced advice on the relationship between micro-level project attributes and different governance mechanisms.

Based on the recent more theoretical and comparative discussion of governance mode for open innovation (Felin & Zenger, 2014), two main attributes of problem, including problem complexity and hiddenness of required knowledge, are considered in this dissertation. In addition of these two problem attributes, the tacitness or noncodifiability of problem (Heiman & Nickerson, 2004) and modularity of problem are also considered as problem attributes that can affect the selection of search approach in the literature (Afuah & Tucci, 2012).

Hiddenness of required knowledge is defined in terms of the degree to which the sources or locations of knowledge deemed relevant to develop a solution for the problem at hand are known to a firm and project team (Felin & Zenger, 2014; Fernandes & Simon, 1999). In other words, firms and project teams have no idea which external partners may have the relevant knowledge required for solving their innovation problem. For example, as an open innovation manager at Bosch described “we knew that there were technological [solutions] to fulfill our technical requirements” to develop a non- electrochemical energy storage technology but we had no idea about the optimal and best solutions and where we could find them (Brunswicker et al., 2016).

## 1.3 Specific Research Questions: Addressing the Overall Research Objective

The main objective of this dissertation is to advance our understanding of how firms govern the collaboration process with external partners in order to successfully complete the joint collaborative project. Three specific research objectives are framed to address this overall objective.

The first objective is understating the nature of dynamics in collaborative projects and how these dynamics affect governance mechanism to have successful outcomes. Thus, I seek to answer the following question (Research question 1) to address the first objective: *How do firms manage the dynamics of collaboration process with external sources to successfully complete their open and collaborative innovation projects?*

The second objective is to examine the role of introducing formality into the joint collaboration process (i.e., joint technology development process) with the aim of managing the knowledge sharing-protecting tension to have successful outcomes. This is addressed by research question 2: *Does the use of a formalized joint technology development process help to increase the likelihood that an open innovation project with external sources is successfully completed?*

The final objective is to explore how the governance mechanism of open and collaborative project (is called "open innovation mode" in this dissertation as well) is affected by two problem attributes namely, problem complexity and hiddenness of knowledge. Research question 3 addresses this final objective: *Which open innovation modes do managers choose for projects characterized by different levels of complexity and hiddenness of knowledge?*

## 1.4 Structure of Dissertation

This dissertation is a monograph based on a three-article format. Each of the three articles[1] aims to address one of the interconnected questions derived from the overall research objective. The first article (Chapter 2) is a systematic analysis of the research literature on qualitative cases describing dynamics of collaborative projects to understand the nature of dynamics and their effects on governance and project performance (Research question 1). The second article (Chapter 3), an empirical survey-based study, is built based on one of the main implications of the findings from this review to understand the role of collaboration process formalization in the regulation of knowledge sharing-protecting tension (Research question 2). Also, the question addressed by the third article (Chapter 4) is derived by a relevant implication of the findings of the second article to explore the role of project attributes (i.e., complexity and hiddenness of required knowledge) in governance selection. Finally, last chapter provides an integrated overview of findings, theoretical and managerial implications, limitations, and future

[1] Each article has its own abstract, introduction, research gap, question addressed, literature review, methodology, results, and discussion parts. References are reported at the end of respective chapters.

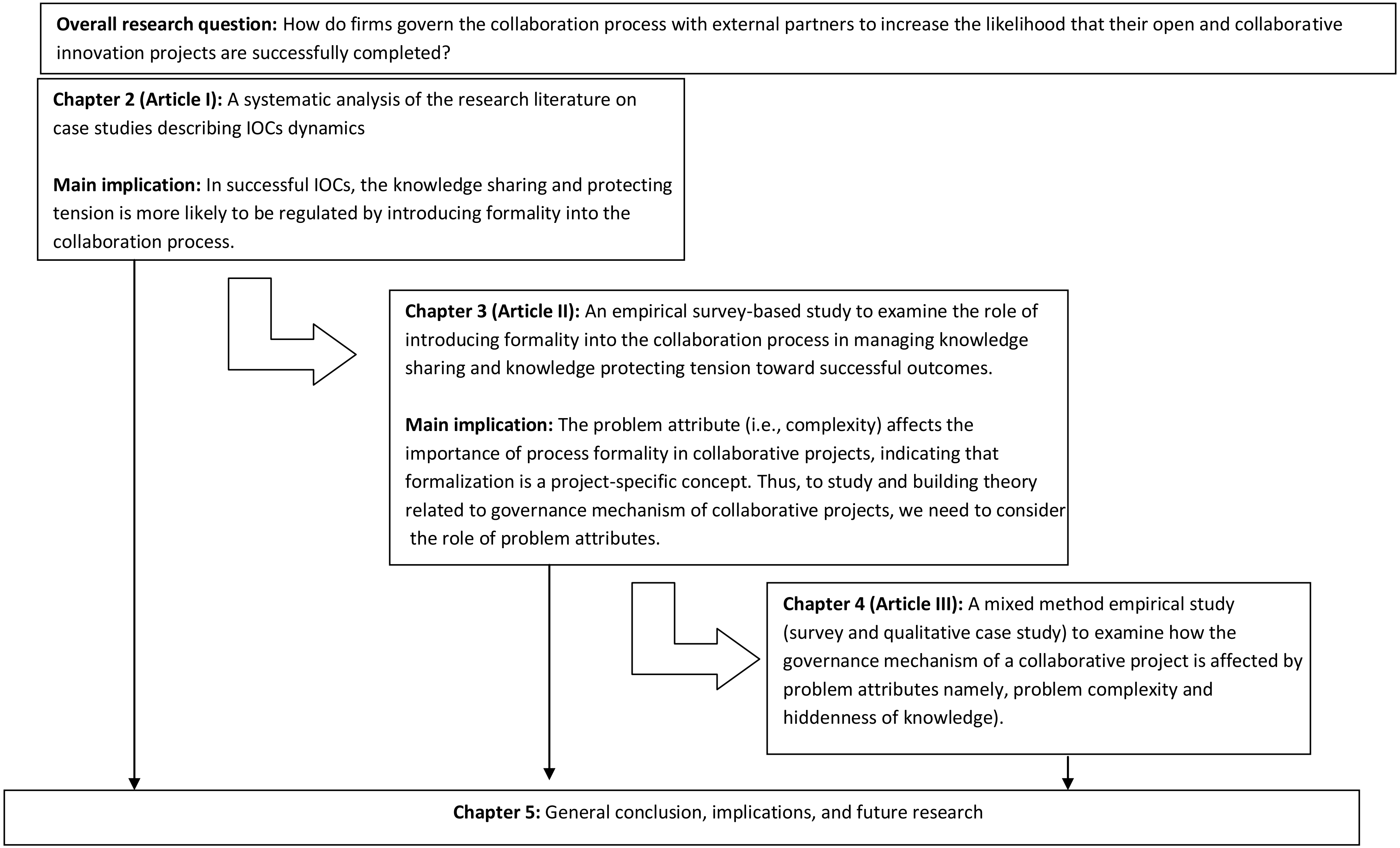
researches. A summary of the structure of dissertation and relationship between three articles is presented in Figure 1.1. In the following sections, I will briefly explain the content and main implications of each article as well as the relationship between all three articles.

### *1.4.1 Article I: A Review of Interorganizational Collaboration Dynamics*

In the first article (Chapter 2), in order to better understand the governance of the collaboration process and its effect on performance, a cross-case systematic analysis of dynamics is conducted across different forms of open and collaborative innovations such as alliances, joint ventures, consortia, and networks. Only longitudinal qualitative cases of collaborative projects are included in this article to capture the nature of the dynamics. There is now an accumulated wealth of longitudinal studies on collaborative projects that explore processes and dynamics of collaboration[2]. Conducting this systematic review serves a crucial purpose for this dissertation. It summarizes what is known about how collaborative project characteristics change over time (e.g., interaction style dynamics, decision making control dynamics, and organizational structure dynamics), the sources for dynamics of characteristic (e.g., between-partner differences), patterns of dynamics, and the effect of these patterns on project performance, thereby identifying relevant factors related to governance of collaborative process that can drive the other two articles (Chapter 3 and 4). Thus, this review provides a strong foundation for this dissertation to develop deeper insight into how firms govern the collaboration process to successfully complete their collaborative projects.

[2] 22 projects published in the top-tier journals, such as Academy of Management Journal, Journal of Management Studies, etc., are included in the study.

**Figure 1.1: Structure of the Dissertation**



One of the main implications of the findings from this review is the presence of simultaneous cooperative (refers to open knowledge exchange and sharing among the partners in the collaborative projects) and competitive (refers to limited and constrained exchange and sharing of knowledge) interaction style between the partners. Moreover, this review shows the presence of duality in changes in interaction style over time in collaborative projects, meaning both changes of increased competitive interaction over time, and changes in increased cooperative interaction over time. For example, over time in a research and development collaborative project, the two partners increasingly shared sensitive technological information (Faems et al., 2008). In contrast, Ness (2009) reports how changes in a goal led to highly contentious interaction style and less knowledge sharing over time in an alliance while initially the relationship was dominated by cooperative style and information sharing. This systematic review shows that the shift from competitive to cooperative (more knowledge sharing between partners over time) is primarily caused by allowing project technical teams to have control over the decision as the team-based decision making can increase flexible dialog and interaction among involved technical staff from all partners.

Comparing change in interaction style between successful and unsuccessful cases shows that successful collaborative projects are more likely to have an increased use of cooperative interaction style and knowledge sharing over time, coexisting with competitive style and hiding knowledge. Thus, the two interaction styles (i.e., simultaneous sharing and hiding of knowledge) appears to be required to ensure effective knowledge sharing to successfully complete the joint project and at the same time protecting knowledge from potential partner opportunistic behavior. In other words, in successful projects, the partners are able to manage the simultaneous knowledge sharing and protecting (i.e., regulating knowledge sharing and protecting tension). Based on this review, knowledge sharing and protecting tension seems to be regulated by the introduction of procedural formality to collaboration process (i.e., formalization and standardization of roles and processes of collaborative project) to have successful outcomes. Thus, increased knowledge sharing between the partners over time is attributable to team-based decision making and the introduction of process formalization. At first, the presence of both procedural formality and team decision making in collaborative projects seems to be a paradox between formality and informality (team-based decision making). However, instead of a paradox, I believe that involved teams of technical staff in decision making may particularly require such formality due to the syndrome that individuals working within collaborative projects must simultaneously both trust and distrust their partners to protect themselves from opportunism. The formal procedures make the team-based decision making more feasible by reducing the possibility of opportunism. This important finding highlights the need to examine the role of procedural formality in the regulation of knowledge sharing and protecting tension that arises from the simultaneous need to trust and distrust of partners in the collaborative projects. The second article aims to deepen our understanding of this main finding based on a survey-based empirical study.

### *1.4.2 Article II: How to Manage the Downside of Deep Engagement with External Sources in Open Innovation Projects*

The second article (Chapter 3) is focused on studying the role of introducing formality into the collaboration process for managing knowledge sharing and knowledge protecting tension toward successful outcomes. This article is an empirical study based on a sample of 82 open innovation projects collected from large firms in the United States and Europe through survey. The results clearly indicate that in order to manage the knowledge sharing-protecting tension, process formality seems to have a positive effect on projects outcomes.

Likewise, the results of this article show that the positive relation between the level of formalization and project performance is made even stronger when the problem being solved is more complex. This indicates that as collaborative projects undertake more complex problems, the importance of process formality in creating successful innovation outcomes increases. The findings of this article clearly show that the problem attribute (i.e., complexity) affects the importance of process formality in collaborative projects, indicating that formalization is a project-specific concept. The main implication of this finding is that only focusing on firm level characteristics (firm-level aggregated data) may lead to incomplete understanding (Du, Leten, & Vanhaverbeke, 2014). Thus, this implication suggests that for studying and building theory related to open and collaborative innovation particularly, adopting governance mechanism for collaborative projects, we have to consider not only industry- (van de Vrande et al., 2009) and firm-level characteristics, but also the role of problem attributes (Bianchi et al., 2011; Chiaroni et al., 2009; Felin & Zenger, 2014). The third article (Chapter 4) enhances our understanding of how the governance mechanism of open and collaborative project is affected by problem attributes.

### *1.4.3 Article III: What's Your 'Open Innovation Mode'? Problem Types and Open Innovation Governance Modes*

The main focus of the third article (Chapter 4) is on understanding the appropriate governance mechanism of collaboration with external partners (called open innovation mode in this article) based on problem attributes. In this article, a two-step approach is taken by combining a survey-based study (survey database of 104 open innovation projects in large firms in Europe and the United States) with multiple case study analysis (6 open innovation projects from large firms). The results clearly reveal that the problem type is associated with a particular open-innovation mode. Market and contractual modes (such as licensing) are associated with simple problems for which the required solution knowledge can also be easily identified by firms. The open innovation platform (such as contests, intermediaries, tournaments) is a proper mode in which to solve simple problems with unknown required knowledge. In such cases, firms may use the crowd to identify hidden knowledge sources. Partnerships (such as alliances and joint ventures) seem to be an appropriate mode for complex problems for which the required solution is known for firms. Moreover, the results of this study show that the selection of open innovation modes is affected by the interaction of the two attributes as well. For example, for simple problems (type 1 and 2) they can adopt either open innovation markets or open innovation platforms. But, open innovation market is preferred for problem type 1 as the location of knowledge for solving problem is known for project teams so that they can make a contract with external partners to solve their problem. By contrast, for problem type 2, project teams have no idea about the location of the required knowledge. As a result, they prefer to engage in open innovation platforms to access a wide range of potential external sources. Two different open innovation modes are adopted for the simple problem based on the level of hiddenness. Thus, the two attributes should be considered at the same time (the interaction between them) to select the appropriate open innovation mode.

## 1.5 Contribution of Dissertation

Taken together, the three articles of this dissertation aim to provide a comprehensive and holistic understanding of governance of open and collaborative innovation by studying the nature of collaboration dynamics and their role in governance mechanisms for project successes, the role of procedural formality in regulation of the knowledge sharing-protecting tension, and the role of problem attributes (i.e., complexity and hiddenness of required knowledge) in selection of governance mechanisms of collaborative projects. Findings of this dissertation have relevant theoretical contributions for extant literature on IOC and OI.

This dissertation has theoretical implication for research literature on IOCs dynamics with findings dualities in IOC characteristics (such as interaction style between partners and decision making control) as important descriptors of dynamics affecting governance of collaboration. The results presented in this study also have implications for coopetition literature (Bengtsson & Kock, 2000; Bengtsson, Wilson, Bengtsson, Eriksson, & Wincent, 2010; Ritala & Hurmelinna-Laukkanen, 2009) by suggesting how the tension between cooperation and competition can be regulated toward successful outcomes by introducing procedural formality and using teams of technical staff for decision making. This dissertation suggests that process formalization may support the legal formalization related to IP control (Cassiman & Veugelers, 2002; Laursen & Salter, 2014) to reduce the concern over knowledge sharing and opportunistic behavior of external partners. Moreover, my findings have contribution to self-regulatory theory (Jarvenpaa & Majchrzak, 2016), arguing the importance of flexible interaction among involved individuals from partners for regulating sharing and protecting tensions, with the suggestion of introducing formality to support this flexible interaction in which decisions about sharing and protecting are made by individuals. Similarly, the process formality presented makes critical contributions to research on relational mechanisms for governing collaborative projects (Ring & Van de Ven, 1992, 1994) with the suggestion that process formality can help building trust (i.e., relational governance) by reducing the opportunistic risk of knowledge sharing. Many studies have indicated that developing a dynamic capability is required for firms interested in collaborative innovation to succeed (Jarvenpaa & Majchrzak, 2016; Schepker, Oh, Martynov, & Poppo, 2014). The current research suggests what such a dynamic capability looks like. Finally, this dissertation shows that in studying and building theory on the governance of collaboration with partners to make use of external knowledge, we need to consider to micro-level variables such as project attributes as well (West, Salter, Vanhaverbeke, & Chesbrough, 2014).

## 1.6 Presentation and Scholarly Contribution

Three articles of this dissertation are in different stages of publication as summarized in Table 1.1. The first article, co-authored with Dr. Ann Majchrzak and Dr. Sirkka L. Jarvenpa, was published in the Journal of Management (with Impact Factor 2015: 6.071 and first Quartile) in July 2015. The second article, co-authored with Dr. Ann Majchrzak and Dr. Sabine Brunswicker, has been submitted to the Open and User Innovation Conference (OUI) 2016 - Harvard Business School (under review). The final article, written with Dr. Sabine Brunswicker, was revised and resubmitted (under the second round of review) to the California Management Review (CMR) in late February 2016.

**Table 1.1: Presentation and Scholarly Contribution**

| Title | Authorship | Journal | Status | Conference and Seminar Presentations |
|---|---|---|---|---|
| Article I: A Review of Interorganizational Collaboration Dynamics | Ann Majchrzak, Sirkka L. Jarvenpa, & Mehdi Bagherzadeh | Journal of Management (JOM) *(Impact Factor 2015: 6.071 Ranking: Business 3/115 and 4* in the ABS journal ranking)* | Published (July 2015,Vol, 41, 5: PP. 1338-1360) | - Presented at a research seminar at Universitat Autònoma de Barcelona (UAB), Barcelona, Spain<br>- Presented at a research seminar at NOVA School of Business and Economics, Lisbon, Portugal |
| Article II: How to Manage the Downside of Deep Engagement with External Sources in Open Innovation Projects | Mehdi Bagherzadeh, Ann Majchrzak & Sabine Brunswicker | Targeted for Organization Science | Submitted to the Open and User Innovation Conference (OUI) 2016, Harvard Business School, Boston (under review) | |
| Article III: What's Your 'Open Innovation Mode'? Problem Types and Open Innovation Governance Modes | Mehdi Bagherzadeh & Sabine Brunswicker | California Management Review (CMR) *(Impact Factor 2015: 1.667 And top 45 financial journals, and 3 in the ABS journal ranking)* | Revised and resubmitted in late February (under the second round of review) | - Initial version presented at the 2nd Annual World Open Innovation Conference (WOIC) 2015 (awarded a top four best student paper)<br>- A modified version presented at the DRUID Academy Conference 2016, France<br>- Latest version presented at the Barcelona Research Workshop, May 2016, IESE Business School |

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# Chapter 2: A Review of Interorganizational Collaboration Dynamics[3]

## 2.1 Abstract

A selected review of the research literature on qualitative case studies describing interorganizational collaborations (IOCs) yielded 22 longitudinal cases that address dynamics, or changes, that occur during IOCs. We systematically review the cases

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for the sources and effects of these IOC dynamics on outcomes. We find six distinct patterns of IOC dynamics varying in complexity from a simple binary loop to multiloop recursive flows. We also find that the more complex dynamic patterns are associated with successful outcomes. This review highlights directions for future research with the aim to advance the literature on IOC dynamics.

## 2.2 Introduction

*Interorganizational collaboration* (IOC) is defined as "a cooperative, inter-organizational relationship that is negotiated in an ongoing communicative process, and which relies on neither market nor hierarchical mechanisms of control" (Hardy, Phillips, & Lawrence, 2003: 323). There have been many calls in the IOC literature for a focus on dynamics of IOCs to explain why IOCs with the same characteristics thrive and others underperform (Das & Teng, 2000; De Rond & Bouchikhi, 2004; Greve, Baum, Mitsuhashi, & Rowley, 2010; Park & Ungson, 2001. Despite these calls, this is the first review we know of that provides a crosscase systematic analysis of the nature of these dynamics across different forms of IOCs, such as alliances, joint ventures, consortia, network, and buyer-supplier arrangements. The review focuses on dynamics that occur during IOCs, their sources, and how these dynamics affect outcomes. We define IOC dynamics generally here (with more details provided in the next section) as changes in the conditions (e.g., goals), processes (e.g., organizational structure), or mechanisms (e.g., interaction style) of an IOC. Our focus is beyond the initial conditions (sometimes referred to as the formation, initiation, or "start-up" phase) of IOCs as these aspects have already been reviewed (Schepker, Oh, Martynov, & Poppo, 2014). Instead, we examine dynamics as IOCs execute or function (Das & Teng, 2002; Ring & Van de Ven, 1994) after the initial contracts have been established. We are exclusively interested in dynamics pertaining to IOCs. This approach yields a focused and bounded review on IOC dynamics.

This review is intended to complement the many reviews that focus on specific forms of IOCs, such as alliance partnerships and joint ventures (e.g., Brouthers & Hennart, 2007; Shi,Sun, & Prescott, 2012; Spekman, Forbes, Isabella, & MacAvoy, 1998; Wassmer, 2010),buyer-supplier agreements (e.g., McCutcheon & Stuart, 2000), networks (e.g., Phelps, Heidl,& Wadhwa, 2012; Provan, Fish, & Sydow, 2007), and research-and-development consortia (e.g., Eisner, Rahman, & Korn, 2009). Additionally, this review is intended to complement reviews of prevailing theoretical perspectives, since the dynamic patterns identified in this paper can provide suggestions for providing dynamic elements for a range of extant theories. While the discussion of specific theoretical suggestions is beyond the scope of the current work, such theories as structuration (Sydow & Windeler, 1998, 2003), relational (Ring & Van de Ven, 1992), agency (Geringer & Woodcock, 1995), and transactional (Williamson, 1991) theories can benefit from increased attention to dynamics.

Our review indicates that IOCs are exceedingly unstable. We found instability to be present in a variety of situations. We found that instability may surface as IOCs start with certain goals and contracts that need to be renegotiated (e.g., Doz, 1996; Faems, Janssens, Madhok, & Van Looy, 2008). Instability may arise as people assigned to IOCs are replaced (e.g., Ariño & De la Torre, 1998; Browning, Beyer, & Shetler, 1995) or leave to join competitor partner firms (De Rond & Bouchikhi, 2004). Instability can also come about as partner firms withdraw from the IOC because of government regulations (White, 2005). When strategic needs of each firm begin to overlap, a discourse can change from collaborative to competitive (e.g., Ariño & De la Torre, 1998; Buchel, 2000; Doz, 1996). Or alternatively, the discourse can take a form of more cooperative interactions as mutual understanding and trust evolve in the collaboration (e.g., Ness, 2009; Ness & Haugland, 2005).

Importantly, the instability can produce successful IOC outcomes. The review suggests that instability, rather than being associated with improper design and planning or poor management (Franko, 1971; Parkhe, 1996), is an inherent characteristic of successful IOCs. Moreover, whereas extant literature has suggested that dynamics occur at the boundaries between evolutionary phases of IOCs (Ariño & De la Torre, 1998; Doz, 1996; Jay, 2013; Reuer & Ariño, 2002; Ring & Van de Ven, 1994), this review demonstrates that dynamics are found to occur continuously. Finally, the review discovers different patterns of dynamics as IOCs respond to different sources of change. Some of these patterns are associated with successful IOC outcomes, and others are associated with unsuccessful IOC outcomes.

This review comes at a critical point in the management literature. There is broad recognition in the literature that environments, organizations, and interorganizational relationships are dynamic. However, there has not been an in-depth review of the patterns of dynamics within IOCs. Moreover, there is much we can learn by examining such dynamics across different forms of IOCs. This review summarizes what is known about how IOCs change over time, thereby identifying directions for future theorizing.

## 2.3 Definition of Dynamics

We define *dynamics* broadly as any change in the form or state of the IOC over time (Van de Ven & Poole, 1995). Our broad definition allows us to examine a variety of more specific dynamics defined in the IOC literature, including: self-reinforcing processes and feedback cycles (Browning et al., 1995; Salk & Shenkar, 2001); relationships of social structures across multiple levels of analysis (Berends, van Burg, & van Raaij, 2011); generative mechanisms that cause observed events to happen (Buchel, 2000); changes in contractual interface structures (Faems et al., 2008), and tensions and dialectics with recursive interplay (De Rond & Bouchikhi, 2004; Jay, 2013; Vlaar, Van Den Bosch, & Volberda, 2007; White, 2005). To capture these variations in definitions of dynamics, we examined longitudinal case studies of IOCs for two forms of dynamics: a) dynamics as a change in an IOC characteristic, and b) dynamics as patterns of relationships between sources of change, and changes in the IOC characteristics.

***Dynamics as Changes in IOC Characteristics:*** As IOCs execute their plans, characteristics of the IOCs may change in some way. These shifts can be qualitative or quantitative. Qualitative shifts may be changes in form, function, or emphasis placed on a particular characteristic, such as a change in how decisions are made in the IOC. Quantitative shifts refer to increases or decreases in an existing characteristic of an IOC, where the shift could occur in linear or non-linear ways, such as sudden jumps versus gradual increments. For example, an increasing number of new job roles for an IOC indicate a quantitative shift in the number of roles.

***Dynamics as Patterns of Relationships between Sources and IOC Characteristics:*** Several models of IOCs proposed by scholars mention that IOCs involve feedback cycles between sources of change and effects of changes on the IOCs (De Rond & Bouchikhi, 2004; Jay 2013; Vlaar et al., 2007; White 2005). Such a dynamic is indicated by change in one IOC characteristic attributable to a particular source, with the possibility that the change in the IOC characteristic leads to subsequent changes to the source or other IOC characteristics.

## 2.4 Approach

This review of research on dynamics of IOCs included research-based case studies (as opposed to teaching cases) submitted to peer review for methodological rigor. Only case studies which had been published or pre-published as forthcoming articles in the following general management journals were included: *Academy of Management Journal*, *Administrative Science Quarterly*, *Journal of Management*, *Journal of Management Studies*, *Management Science*, *Organization Science*, *Organization Studies*, and *Strategic Management Journal*. These journals have a high five-year impact citation factor and are known for their rigorous peer review process (Podsakoff, Mackensize, Bachrach, & Podsakoff, 2005; Podsakoff, MacKenzie, Podsakoff, & Bachrach, 2008).

We first screened for articles describing case studies which had been published from January 1980 to January 2014 in these journals. We initially limited the search to the following keywords: alliances, joint ventures, buyer-supplier, licensing, trade association, consortia, interorganizational, co-creation, co-branding, product development, outsourcing, collaboration, merger, network, interfirm, partnership, joint project, and constellation. These keywords are derived from a list of inter-organizational relationship forms in Barringer & Harrison (2000) and Parmigiani & Rivera-Santos (2011). We also added several search terms, including partnership, virtual collaboration, and co-creation. This search yielded more than 100 qualitative articles. This compilation excluded quantitative articles that statistically examined a single or narrow set of IOC characteristics.

We then reviewed the 100 qualitative studies to identify those with a longitudinal perspective, defined as "research emphasiz[ing] the study of change and contain[ing] at minimum three repeated observations on at least one of the substantive constructs of interest" (Ployhart & Vandenberg, 2010: 97). We included only cases in which the IOC had progressed beyond the initiation or formation stage. In addition, only organizationally motivated IOCs were included, excluding IOCs motivated purely for interpersonal advice and friendship. This step reduced our sample to a total of 24 articles that contained qualitative case studies describing the longitudinal events of an IOC, for periods ranging from 2 years to 30 years. Several articles contained multiple case studies, yielding 36 longitudinal case studies. However, of the 36 cases, only 22 had sufficient detail about the dynamics of the case to allow analysis. Therefore, our final sample consisted of 22 longitudinal cases of dynamics in IOCs.

For each of the 22 cases, we then examined the cases for the two forms of dynamics: changes to IOC characteristics, and patterns of relationships between sources and IOC characteristics. We did not predefine categories for characteristics that had changed, the form of the changes (such as qualitative or quantitative), sources of the changes, or the patterns of relationships between sources and changes. Instead, we inductively developed axial codes that we introduce as our findings. Our determination of what was changed, sources, and patterns were based exclusively on how each case researcher presented the case and findings of the case. In addition, we coded for whether the case researcher indicated that the case had succeeded or failed, allowing us to explore if dynamics were related to IOC outcomes. Of the 22 cases, in 21 cases, the case researchers indicated the case was a success or failure. Success was indicated in one of two ways: the IOC continued as of the completion of the research, or the IOC had achieved its intended outcomes. Failure was indicated as the IOC ending prematurely.

The coding for the 22 cases is listed in Table 2.1. From Table 2.1, three findings emerged. Finding 1 focused on the nature of the changes to IOC characteristics, Finding 2 focused on the nature of the sources of those changes, and Finding 3 focused on the patterns of relationships between sources and IOC characteristics. To explore patterns of relationships between sources and IOC characteristics, we engaged in additional analysis, which will be explained as part of Finding 3.

## 2.5 Finding 1: Multifaceted Dynamics in Each of Six IOC Characteristics

The review identified six characteristics of IOCs that change during the course of an IOC, after the initiation or formation stage: (a) IOC goal; (b) IOC contract frame (transactional and/or relational); (c) interaction style between the IOC partners (competitive and/or cooperative), (d) decision-making control (i.e., how decisions about the IOC were made); (e) IOC organizational structure, such as roles and procedures; and (f) composition of the actors (organizations and/or individuals) involved in the IOC. Changes in more than one IOC characteristic were often observed in the cases. Below we define each change as well as provide an example for the change, referring to the author and case number in Table 2.1.

### *2.5.1 Goal Dynamics*

IOC goal dynamics are changes to the explicit mission or goals established for the collaboration. Dynamics were qualitative shifts and adjustments in goals for the IOC among partners. Changes in goals were coded according to the case researchers’ use of words, such as ”[the IOC partners] widened their cooperation over time to include the complete range of civilian products” (Doz, 1996: 69, Case

2) and “[the IOC partners decided to] stop the other part of [the] project” (Ness, 2009: 465, Case 20).

Changes in goal dynamics include adding a new goal (e.g., Browning et al., 1995, Case 1; Boddy, Macbeth, & Wagner, 2000, Case 3; Doz, 1996, Case 2; White, 2005, Case 18) or dropping or replacing the original goal (e.g., Ariño & De la Torre, 1998, Case 16; De Rond & Bouchikhi, 2004, Case 17; Ness, 2009, Case 20). Adding a new goal is exemplified in the SEMATECH consortium case in which the initial goal of developing new manufacturing technologies was augmented with a new goal of improving the quality of suppliers’ products and services (Browning et al., 1995, Case 1). Goal replacement was exemplified in an IOC between a small biotech firm and a large pharmaceutical company that initially focused on the discovery of novel chemical compounds but was later changed to technology transfer (De Rond & Bouchikhi, 2004, Case 17).

### *2.5.2 Contract Frame Dynamics*

An IOC contract frame refers to the formal (i.e., transactional) and informal (i.e., relational) elements in the interorganizational agreements that establish the nature of the collaboration among the partners, including knowledge-transfer methods, intellectual property provisions, shared risks, and mutual benefits. The transactional elements mitigate threats from opportunistic behavior when a partner pursues its own goals; relational elements focus on maximizing joint benefits from a close trusted and interdependent relationship (Poppo & Zenger, 2002). Both transactional and relational elements exist simultaneously in IOCs but at varying degrees of emphasis. We define dynamics for this characteristic as changes in this emphasis. Changes in emphasis are based on the case researchers’ own words, such as ”loss of trust” (Ariño & De la Torre, 1998: 322, Case 16) and “increased interpartner trust” (Inkpen & Pien, 2006: 801, Case 7).

## Table 2.1: Changes to IOC Characteristics, Sources for Dynamics, Patterns of Dynamics and Outcomes

| | | | IOC Characteristics Dynamics | | | | | | Sources | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Case # | IOCs | Outcomes | Goal | Contract Frame | Interaction Style | Decision Making Control | Organizational Structure | Actor Composition | Between-Partner Differences | External Sources | Within-IOC Sources | Patterns of Dynamics |
| 1 | (Browning et al., 1995) | S | Add new goal | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | Add new actor / Exclude existing actor | −Different views between top managers→ Δ Actor Composition [Chief operating officer, companies]<br>− Different processes and cultures →Δ Organizational Structure [Standard technical terms and processes]<br>−Unclear and different processes →Δ Decision Making Control[Team control] | −Δ Industry competitiveness → ΔGoal [New] | −Δ Decision Making Control, Δ Organizational Structure, and Δ Actor Composition → ΔInteraction Style [Cooperative]<br>−Δ Interaction Style → Δ Contract Frame [Relational]<br>−ΔContract Frame →Δ Decision Making Control [Team control]<br>−Δ Contract Frame →Δ Organizational Structure [More structured] | C, D, F |

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| 2 | (Doz, 1996, C3) | S | Add new goal | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | Add new actor | −Different routines and roles →Δ Organizational Structure [new processes and roles]<br>−Different cultures and structures →Δ Decision Making Control [Team control] | −Δ Market competitiveness → Δ Goal [New product] | −Δ Goal→Δ Actor Composition [experts]<br>−Δ Decision Making Control and Δ Organizational Structure → Δ Interaction Style [Cooperative]<br>−Δ Interaction Style →ΔContract Frame [Relational]<br>−Δ Contract Frame→Δ Decision Making Control [Team control]<br>−Δ Contract Frame→Δ Organizational Structure [More structured] | C, D, F |
| 3 | (Boddy et al., 2000) | S | Add new goal | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | | −Different organizational backgrounds →Δ Organizational Structure [new routines and roles]<br>−Different cultures and structures →Δ Decision Making Control [Team control] | −Δ Market competitiveness and Technological uncertainty → ΔGoal [New products, new geographical areas] | −Δ Decision Making Control and Δ Organizational Structure → ΔInteraction Style [Cooperative]<br>−Δ Interaction Style →ΔContract Frame [Relational]<br>−ΔContract Frame →Δ Decision Making Control [Team control] | C, D |
| 4 | (Salk & Shenkar, 2001) | S | | | Increasing reliance on cooperative style | Increasing IOC team control | | Add new actor / Exclude existing actor | −Different views between top managers→ Δ Actor Composition [Senior manger]<br>−Cultural differences → Δ Decision Making Control [Team control] | | −Δ Decision Making Control and Δ Actor Composition → Δ Interaction Style [Cooperative] | C |

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| 5 | (Mayer & Argyres, 2004) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | Add new actor | –Different design process →Δ Organizational Structure [new roles and processes]<br>–Different design process →Δ Decision Making Control [Team control] | –Technological uncertainty → ΔOrganizational Structure [new roles]<br>–Technological uncertainty → ΔInteraction Style [Cooperative]<br>–Δ Partner firms→Δ Actor Composition [Manger] | –Δ Decision Making Control and Δ Organizational Structure → Δ Interaction Style [Cooperative]<br>–ΔInteraction Style →ΔContract Frame [Relational]<br>–Δ Contract Frame→Δ Decision Making Control [Team control]<br>–Δ Contract Frame→Δ Organizational Structure [More structured] | C, D, F |
| 6 | (Ness & Haugland, 2005) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | | –Different interests between partners→Δ Organizational Structure [new processes]<br>–Different opposing views between partners →Δ Decision Making Control [Team control] | Δ Regulation→ ΔInteraction Style [Cooperative] | –Δ Decision Making Control and Δ Organizational Structure → Δ Interaction Style [Cooperative]<br>–ΔInteraction Style →ΔContract Frame [Relational]<br>–Δ Contract Frame→Δ Decision Making Control [Team control] | C, D |
| 7 | (Inkpen & Pien, 2006) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | More structured | Add new actor / Exclude existing actor | –Cultural differences and managerial methods →ΔOrganizational Structure [new roles and processes]<br>–Cultural differences and managerial methods →Δ Decision Making Control [Team control] | | –Performance failure →Δ Actor Composition [Senior manger]<br>–Δ Decision Making Control → ΔInteraction Style [Cooperative]<br>–ΔInteraction Style →Δ Contract Frame [Relational]<br>–Δ Contract Frame →Δ Decision Making Control [Team control] | D |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | (Vlaar et al., 2007) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | | −Cultural differences →Δ Organizational Structure [new routines]<br>−Different views between partners→Δ Decision Making Control [Team control] | | −Δ Decision Making Control and Δ Organizational Structure → Δ Interaction Style [Cooperative]<br>−Δ Interaction Style →ΔContract Frame [Relational]<br>−Δ Contract Frame →ΔDecision Making Control [Team control] | C, D |
| 9 | (Faems et al., 2008, C2) | S | Add new goal | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | | Add new actor | −Different views regarding technological problems→Δ Decision Making Control [Team control] | −Δ Market competitiveness and Technological uncertainty → ΔGoal [New stages of technology development]<br>−Δ Partner firms→Δ Actor Composition [Experts] | −Δ Decision Making Control →Δ Interaction Style [Cooperative]<br>−Δ Interaction Style →ΔContract Frame [Relational]<br>−Δ Contract Frame→Δ Decision Making Control [Team control] | D |
| 10 | (Ness, 2009, C1) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | Add new actor / Exclude existing actor | −Different opposing interests →Δ Decision Making Control [Team control]<br>−Different opposing interests →Δ Actor Composition [Senior manager]<br>−Lack of standard operating procedures between partners →Δ Organizational Structure [Standard procedures] | | −Δ Decision Making Control, ΔOrganizational Structure, and Δ Actor Composition → Δ Interaction Style [Cooperative]<br>−ΔInteraction Style →ΔContract Frame [Relational]<br>−ΔContract Frame→Δ Decision Making Control [Team control]<br>−Δ Contract Frame→Δ Organizational Structure [More structured] | C, D, F |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | (Berends et al., 2011 and van Burg et al., 2013) | S | | Moving between relational and transaction al | Moving between cooperative and competitive | | Add new structure | Add new actor / Exclude existing actor | −Different interests and technologies →ΔInteraction Style [Cooperative, competitive] | −Δ Partner firms→Δ Actor Composition [Firm partners] | −Performance failure→Δ Organizational Structure [New roles]<br>−Performance failure→Δ Actor Composition [Firm partners]<br>→Δ Organizational Structure and Δ Actor Composition→ ΔInteraction Style [Cooperative, competitive]<br>−Δ Interaction Style →ΔContract Frame [Relational, transactional] | C |
| 12 | (Jay, 2013) | S | Add new goal | | | | Add new structure | Add new actor | | | −Performance failure→Δ Goal [New business strategy]<br>−Δ Goal →Δ Actor Composition [Executive director, expert]<br>−Δ Goal →Δ Organizational Structure[New groups] | A |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | (Beck & Plowman, 2014) | S | | Increasing reliance on relational | Increasing reliance on cooperative style | Increasin g IOC team control | Add new structure | | −Different operating ways →Δ Decision Making Control [Team control]<br>− Different operating ways →Δ Organizational Structure [New structures, routines and roles] | | −Δ Decision Making Control and Δ Organizational Structure → Δ Interaction Style [Cooperative]<br>−Δ Interaction Style →ΔContract Frame [Relational]<br>−Δ Interaction Style →ΔContract Frame [Relational, transactional] | C, D |
| 14 | (Doz, 1996, C1) | U | Add new goal | Increasing reliance on transaction al | Increasing reliance on competitive style | | Add new structure | | −Different interests →ΔInteraction Style [Competitive]<br>−Different interests →ΔContract Frame [Transactional]<br>−Different cultures, structures, and procedures →ΔOrganizational Structure[New procedures and structures] | −Technological uncertainty → ΔGoal [Manufacturing] | −Performance failure→Δ Goal [Manufacturing]<br>−Δ Contract Frame→Δ Interaction Style [competitive]<br>−Δ Interaction Style →ΔContract Frame [Transactional] | B |
| 15 | (Doz, 1996, C2) | U | | Increasing reliance on transaction al | Increasing reliance on competitive style | | | | −Different interests →ΔInteraction Style [Competitive] | | −Δ Interaction Style →ΔContract Frame [Transactional]<br>−Δ Contract Frame→Δ Interaction Style [competitive] | B |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | (Ariño & De la Torre, 1998) | U | Replace the original goal | Increasing reliance on transactional | Moving between cooperative and competitive | | | Add new actor / Exclude existing actor | –Different interests →ΔInteraction Style [Competitive, cooperative] | – Market uncertainty →Δ Goal [Replaced with new products]<br>–Δ Partner firms→Δ Actor Composition [Members of executive board] | –Performance failure →Δ Goal [Replaced with new products]<br>–Δ Interaction Style →ΔContract Frame [Transactional] | A, B |
| 17 | (De Rond & Bouchikhi, 2004) | U | Replace the original goal | Increasing reliance on transactional | Increasing reliance on competitive style | | | Add new actor / Exclude existing actor | –Different views between partners about each other capabilities →Δ Interaction Style [Competitive]<br>– Different views between partners about each other capabilities →Δ Contract Frame [Transactional] | –Δ Industry competitiveness → Δ Goal [Replaced with new goal]<br>–ΔPartner firms →Δ Actor Composition [Principal negotiator, senior executive] | –Δ Actor Composition →Δ Interaction Style [Competitive]<br>–ΔInteraction Style →Δ Contract Frame [Transactional]<br>–Δ Contract Frame→Δ Interaction Style [competitive] | B |
| 18 | (White, 2005) | U | Add new goal | Increasing reliance on relational | Increasing reliance on cooperative style | Increasing IOC team control | Add new structure / More structured | Exclude existing actor | –Different standards and design processes→Δ Organizational Structure [new processes]<br>– Different standards and design processes →Δ Decision Making Control [Team control] | –Δ Market competitiveness → ΔGoal [New product]<br>ΔRegulation→Δ Actor Composition [Partner firm]<br>–ΔPartner firms→Δ Actor Composition [Partner firm] | –Δ Decision Making Control and Δ Organizational Structure → ΔInteraction Style [Cooperative]<br>–Δ Interaction Style→Δ Contract Frame [Relational]<br>–Δ Contract Frame→Δ Decision Making Control [Team control] | A, C, D |
| 19 | (Faems et al., 2008, C1) | U | | Increasing reliance on transactional | Increasing reliance on competitive style | | | | –Different views between partners about technologies →ΔInteraction Style [Competitive] | | –Δ Interaction Style →ΔContract Frame [Transactional]<br>–Δ Contract Frame→Δ Interaction Style [competitive] | B |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | (Ness, 2009, C2) | U | Drop one part of original goal | Increasing reliance on transactional | Increasing reliance on competitive style | Increasing top management control | | Add new actor / Exclude existing actor | –Different views about the value of IOC →ΔInteraction Style [Competitive]<br>–Different views about the value of IOC →ΔDecision Making Control [Top management] | –Δ Market competitiveness → ΔGoal [Stop one part of project] | –Performance failure→Δ Goal [Stop one part of project]<br>–Performance failure→ΔInteraction Style [Competitive]<br>–Performance failure →Δ Actor Composition[Project manager, key experts]<br>→Δ Contract Frame [Transactional]<br>–ΔContract Frame →ΔDecision Making Control [Top management] | A, E |
| 21 | (Ness, 2009, C3) | U | Add new goal | Increasing reliance on transactional | Increasing reliance on competitive style | | | | –Different views about the value of IOC →ΔInteraction Style [Competitive] | –Δ Market competitiveness →ΔGoal[Marketing] | →ΔContract Frame [Transactional] | A |
| 22 | (Buchel, 2000) | A | Add new goal | Increasing reliance on transactional | -Increasing reliance on competitive style but some groups became more cooperative | | Add new structure / More structured | | –Different structures, cultures and unclear roles and responsibilities →Δ Organizational Structure [new processes, roles]<br>–Different interests and different views about sharing knowledge →ΔInteraction Style [Competitive] | –Δ Industry competitiveness and technological uncertainty →Δ Goal[New technologies] | –Δ Interaction Style →ΔContract Frame [Transactional]<br>–Δ Contract Frame→Δ Interaction Style [competitive] | A, B, |

Note: Outcome: S = Successful, U = Unsuccessful, A= Ambivalent; Patterns of Dynamics: A = Single Change, B = Binary Loop, C = Parallel Multisource, D = Positive Multicharacteristic Loop, E = Negative Multicharacteristic Loop, F = Multiloop Flow; Δ = Change; C = Number of Case in the original paper

We found changes in emphasis on both relational and transactional frames. Increased emphasis on relational elements was exemplified in a number of cases (Boddy et al., 2000, Case 3; Browning et al., 1995, Case 1; Inkpen & Pien, 2006, Case 7; Ness & Haugland, 2005, Case 6; Vlaar et al., 2007, Case 8; White, 2005, Case 18). One such example is the Esthetique- L'Oreal IOC, where initially, "the relationship between the two firms was transaction based and relied extensively on a formal contract" (Ness, 2009: 460, Case 10), "but over time, governance became increasingly relational," coexisting with the transactional elements (Ness, 2009: 458, Case 10). Increased emphasis on transactional elements of the contract framing over time is exemplified in the COOP-Lilleborg supplier retailer relationship, in which both partners had initially begun the IOC based on trust and value creation for both parties (relational emphasis), but as the relationship evolved, the transactional aspects of the contract became increasingly important, since COOP emphasized its interests at the expense of Lilleborg, with additional transactional elements (price/incentive items) added to the relational contract (Ness, 2009, Case 20).

### *2.5.3 Interaction Style Dynamics*

Interaction style refers to the emphasis placed in how interactions were conducted between the technical staff from each of the partner firms tasked with fulfilling the goal. The interactions were described by case researchers in terms of behaviors involved in sharing information and engaging in dialogue. The behaviors were determined by the case researchers' use of such words as "open sharing of information without hidden agendas" (Ness, 2009: 463, Case 20) and "[the] kind of information would not be shared" (White, 2005: 1402, Case 18).

Two different behavioral forms were identified from the cases: competitive behaviors, in which the partners had limited and constrained information sharing, and cooperative behaviors, in which the partners had open information sharing. While both forms are likely to be in place within any particular IOC, we focused only on a form that the case researchers indicated had changed during the IOC. We found evidence of cooperative behaviors being increasingly emphasized over time, competitive behaviors being increasingly emphasized over time, and emphasis on both cooperative and competitive behaviors changing over time. An increased use of cooperative behaviors is exemplified in a research-and-development alliance; the two partners increasingly shared "sensitive technological information" related to their joint goal (Faems et al., 2008: 1071, Case 9). An increased use of competitive behaviors over time is exemplified in the COOP-Lilleborg IOC, where the partners initially interacted in a cooperative style but then, as the IOC evolved, engaged in less cooperative interaction and information sharing (Ness, 2009, Case 20). A case in which changes to both behaviors occurred is the EHPT joint venture between HP and Ericsson: Some technical teams became more open and direct in their actions over time, and other teams became increasingly competitive (Buchel, 2000, Case 22).

### *2.5.4 Decision-Making Control Dynamics*

Decision-making control refers to whether most of the decisions about how work is organized within the IOC are made by top-level managers in the IOC and/or by lower-level IOC teams of technical staff. Dynamics refers to whether decision-making control changes in the IOC over time. Changes in decision-making control could involve top managers of the IOC initially making the decisions and then increasingly allowing IOC technical teams to gain control over the decisions, or IOC top managers increasingly exerting control over the decisions formerly made by IOC technical teams. Changes in decision-making control were determined by the case researchers' use of such statements as "more personnel from each firm became involved in reviewing and approving the projects" (Mayer & Argyres, 2004: 401, Case 5).

An example of increased decision-making control provided to the IOC technical team over time is the case study of SEMATECH (Browning et al., 1995, Case 1). Initially, a strong hierarchical structure persisted in which the consortium executives made most decisions. Over time, however, SEMATECH partner firms increasingly relied on the technical teams' group-based understandings and decisions, which were then reported to the upper management. An example of the opposite change is in the IOC between COOP and Lilleborg, in which decision-making control was initially delegated to technical-level working groups, but over time, executive level project managers from each partner firm made the decisions about the projects (Ness, 2009, Case 20).

### *2.5.5 Organizational Structure Dynamics*

IOC organizational structure dynamics refers to the degree of formalization and standardization of roles and processes of IOCs. Dynamics in structure can refer to shifts toward and away from increased structure. Shifts in IOC organizational structure were coded based on such statements used by case researchers as development of "new organizational processes" for the IOC (Doz, 1996: 69, Case 2) and the partners "created new roles" that increasingly structured interactions (Boddy et al., 2000: 1011, Case 3).

We identified from the cases no mention of reduced structure over time, only increased structure over time. Increased structure included the creation of a new role or procedure to be used by the IOC. For example, in Doz (1996: 69, Case 2), the GE-SNECMA alliance developed a "set of new organizational processes" to facilitate involvement of both partner firms in IOC. Additionally, some IOCs gradually became more structured over time by increasing the number of structured processes and roles. For example, Boddy et al. (2000, Case 3) describe how a supply chain partnership between an electronics company and a supplier of plastic moldings (plastic enclosure) became more structured over time by adding and implementing more and more new roles, processes, and procedures not previously existing in the IOC, including logistics processes and procedures, a tooling engineer, a sales coordinator, a supplier engineer, and a buyer planner to facilitate information flow and work flow between the partner firms.

### *2.5.6 Actor Composition Dynamics*

Actor composition refers to membership in the IOC partner organizations and key individuals in the IOC collaboration. Dynamics refers to adding new actors or excluding existing actors. Changes in managers (e.g., Salk & Shenkar, 2001, Case 4) and partner firms (Berends et al., 2011, Case 11; White, 2005, Case 18) were described. Examples of cases of adding new actors include the SEMATECH consortium, where new senior managers were brought in to replace existing ones (Browning et al., 1995, Case 1), and the IOC for development of a new aircraft material in which some partner firms, such as Akzo, Alcoa, and 3M, were added to the IOC (Berends et al., 2011, Case 11). Examples of actors leaving include the NedCar joint venture, in which the "Dutch government had to give up [by pulling out from the IOC] as a result of [an] EU ruling" (White, 2005: 1403, Case 18) and the case in Ariño and De la Torre (1998: 317, Case 16) where three members of the [joint venture] executive board retired from their respective companies [and left the partnership]."

### *2.5.7 Changes in IOC Characteristics and Relationship to Outcomes*

In sum, based on the data in Table 2.1, six characteristics of IOCs were found to change at some point after the formation stage. The changes were clustered neither at the beginning nor at the end of the collaboration. Changes in multiple directions were observed, with IOC goals being added or deleted, changes observed in emphasis in both relational and transactional contract frames, decision-making control delegated to technical teams as well as pulled back up to the executive IOC level, interactions being increasingly competitive and cooperative, and actors being added and replaced. Only with the IOC characteristic of structure was there a single direction reported, of increasing structure. Thus, we conclude from this review of changes in IOC characteristics that in an IOC, changes in any of the six characteristics, in different directions, may happen. This suggests that not only is there considerable instability in the IOC characteristics over time, but the instability is multifaceted in nature.

Table 2.1 also indicates which cases were considered successful and which failed. Comparing changes for those succeeding versus failing indicate that cases with successful outcomes were more likely to experience change in more characteristics. Moreover, for these successful cases, the direction of these changes tended to include (a) increased use of technical teambased control over decision making; (b) increasingly structuring the IOC with new roles, processes, and routines; (c) increasingly emphasizing cooperative interaction styles; and (d) an increased emphasis on a relational-based contract frame. Thus, there appears to be a pattern of changes associated with successfully enacted IOCs. We turn next to sources of these changes in IOC characteristics.

## 2.6 Finding 2: Multiple Sources for Dynamics of IOC Characteristics

Case researchers provided causes when changes in IOC characteristics occurred. We iteratively searched for similarities and differences in these causes. Three categories of causes emerged, (a) between-partner differences, (b) external sources, and (c) within-IOC sources, where changes that occur within IOCs have subsequent effects on the IOC.

### *2.6.1 Between-Partner Differences*

Each partner to an IOC has its own interests, goals, cultures, and practices, with these differences often in opposition of each other (Das & Teng, 2002). For example, in one case, one partner had a strong culture of openness, while another partner had a strong culture of protectionism (Browning et al., 1995, Case 1). Partners had different practices in how problems were solved, how data were formatted, which criteria were used to evaluate potential solutions, which knowledge bases were considered credible, which product development process was followed, how decisions were documented, and how the others in home organizations were involved in the IOC (e.g., Boddy et al., 2000, Case 3; Ness, 2009, Case 10). While partners may be unlikely to intentionally harm other partners within an IOC, partner interests may not coincide; in one case, a partner preferred to develop new technology, and the other partner preferred to minimize development and move quickly to commercialization (Buchel, 2000, Case 22). These differences between partners were repeatedly mentioned as the reason why an IOC characteristic changed. The differences were rarely depicted as conflict; rather, the differences were depicted instead as potential precursors to conflict: If the differences were not managed well, conflict might erupt.

To manage between-partner differences, several changes in IOC characteristics were mentioned. In several cases, partner differences were managed by increasing IOC structures so that new roles and procedures superseded existing roles and procedures. For example, in a supply chain partnering, "the two firms had radically different histories" and backgrounds (Boddy et al., 2000: 1010, Case 3): One firm was a research-based firm in a dynamic industry, and the other one was an established engineering firm. The differences between the partners required changes in the IOC structure, including adding new roles, processes, and routines specific to the IOC in order to facilitate work flow between partners. In other cases, partner differences were managed by giving technical IOC teams more decision-making control to resolve interpartner differences (e.g., Boddy et al., 2000, Case 3; Doz, 1996, Case 2; Mayer & Argyres, 2004, Case 5). In one case, partner differences were managed with an increasing reliance on top management executive councils to resolve the differences (Ness, 2009, Case 20). In some cases, partner differences led to conflict between the partners, which resulted in greater emphasis on competitive interaction style or transactional elements (e.g., De Rond & Bouchikhi, 2004, Case 17; Doz, 1996, Case 14; Faems et al., 2008, Case 19; Ness, 2009, Case 20, Case 21).

## 2.6.2 External Sources

Case researchers mentioned a variety of sources external to their IOCs that contributed to changes in IOC characteristics. These included changes in regulations (Ness & Haugland, 2005, Case 6; White, 2005, Case 18), changes in market and industry competitiveness (e.g., Boddy et al., 2000, Case 3; Browning et al., 1995, Case 1; Doz, 1996, Case 2), technological uncertainty (e.g., Faems et al., 2008, Case 9; Mayer & Argyres, 2004, Case 5), and events experienced by one of the partner firms' own organization that ended up having ramifications for the IOC (e.g., Ariño & De la Torre, 1998, Case 16; Berends et al., 2011, Case 11; De Rond & Bouchikhi, 2004, Case 17; White, 2005, Case 18). An example of the impact of increased market technological uncertainty on an IOC was in the alliance between a small biotech firm and a large pharmaceutical company, in which the two partners found it necessary to include functions not initially anticipated (e.g., manufacturing) because of the uncertain and unpredictable development process (Doz, 1996, Case 14). Examples of events occurring within one firm' s own organization that had subsequent implications for changes in the IOC included strategic reorientations of a partner during the IOC (Berends et al., 2011, Case 11), a partner firm changing senior executives (Ariño & De la Torre, 1998, Case 16; De Rond & Bouchikhi, 2004, Case, 17), key actors leaving the firm (De Rond & Bouchikhi, 2004, Case 17), and a change in ownership of a partner firm (White, 2005, Case 18).

## 2.6.3 Within-IOC Sources

A final category includes sources that arose within the IOC that produced changes to IOC characteristics. Two within-IOC sources surfaced. The first was changes in

IOC characteristics themselves that produced changes in other IOC characteristics. The SEMATECH consortium provides one example. The dominant contract frame initially was transactional; over time, the interaction style became more cooperative as the technical teams became acquainted and also standard technical terms and process were added. This led to a greater emphasis on the relational elements in the framing of the IOC (Browning et al., 1995, Case 1). The second within-IOC source was referred to by case researchers as performance failures. Example performance failures included the failure to reach initially planned goals or provide expected value to partner firms (Berends et al., 2011, Case 11; Doz, 1996, Case 14; Jay, 2013, Case 12; Ness, 2009, Case 20), the failure to move the project forward as expected (Inkpen & Pien, 2006, Case 7), and achieving less success than the initial expectation (Ariño & De la Torre, 1998, Case 16).

### *2.6.4 Sources Affecting Changes in IOC Characteristics and Relationship to Outcomes*

In sum, sources affecting IOC changes included between-partner differences, external sources, and within-IOC sources. Together, the sources create the possibility of a multitude of sources contributing to changes in IOC characteristics. Some of these sources are continuously experienced throughout the duration of the IOC, such as partner differences, while other sources are more event driven, such as changes in a partner firm's senior executive causing a change in who directs the IOC. Moreover, the same source in different cases had vastly different effects on IOC characteristics. For example, in different cases, partner differences were found to both increase and decrease technical team-based decision making.

As another example, a new role was created or a new goal was added to IOCs due to performance failures. Thus, a variety of relationships emerge between sources of change and the changes to IOC characteristics. IOCs appear to be so dynamic that changes can occur from a variety of directions, having a variety of effects.

We compared the successful and unsuccessful cases for the different sources of changes in IOC characteristics. For some sources, there were differences. Cases with unsuccessful outcomes were more likely to have changes in the external environment, suggesting that it is difficult for IOCs to survive environmental shifts. In successful cases, differences between partner firms were more likely to be the source of changes in IOC characteristics, presumably to manage the differences so that they would not evolve into conflict. Finally, of note is that performance failures within the IOC did not differentiate between successful and unsuccessful cases, suggesting that the presence of a performance failure is not an early indicator of a later IOC failure.

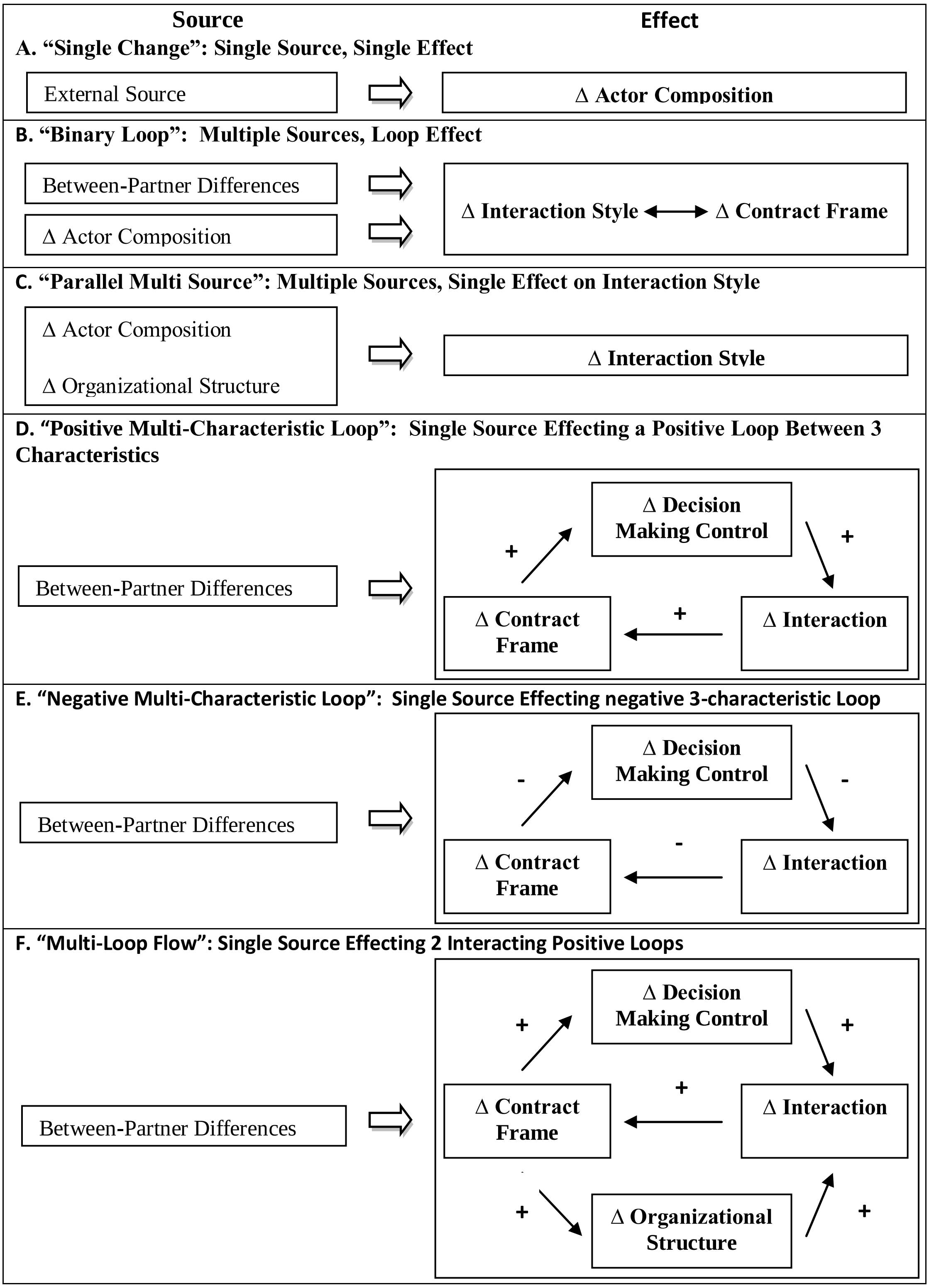
## 2.7 Finding 3: Six Patterns of Dynamics

Having identified six changes to IOC characteristics, and three different categories of sources contributing to these changes of IOC characteristics, in this section of our review, we examine the patterns of relationships in more dynamic detail, looking at the feedback loops that occur. For each of the cases, we diagrammed the logic of the case researchers in depicting what initial source appeared to initiate a change in an IOC characteristic, whether subsequent effects were involved, and whether additional sources of further changes emerged over time. From this examination, we were able to identify six distinct patterns of dynamics. The six dynamics are (a) a *single change in IOC characteristic*, in which there is a single cause and effect that is isolated from the remainder of any other changes to the IOC; (b) a *binary loop*, in which there is a recursive feedback loop between changes in two IOC characteristics, (c) *parallel multisource effect*, in which multiple sources cause a change in the one specific characteristic of interaction style; (d) *positive multicharacteristic loop*, in which a source initiates a positive three-characteristic loop; (e) *negative multicharacteristic loop*, in which a source initiates a negative three-characteristic loop; and (f) *multiloop flow*, wherein more than one multicharacteristic loop interact. The dynamics differ in whether a recursive loop exists between IOC characteristics once a change has been initiated by a source, whether one or more sources start the recursive loops, whether the self-reinforcing loops are in a positive or negative direction, the number of sources that initiate the effect, the number of IOC characteristics involved in the loop, and the number of loops occurring in the IOC. As such, we identify dimensions of dynamics that have not heretofore been identified, such as the breadth of the dynamics (i.e., number of IOC characteristics involved), the direction (i.e., positive or negative), whether recursion is involved, multiplicity of initiating sources, and the extent of recursion (number of loops). Figure 2.1 presents a depiction of the six dynamic patterns. More than one pattern was seen for some cases since different patterns captured different dynamics in different parts of the IOC.

### *2.7.1 Single Change in an IOC Characteristic*

In some cases (Cases 12, 16, 18, 20, 21, and 22), external sources produced single changes in an IOC characteristic. Importantly, these changes were not propagated to changes in other IOC characteristics. For example, in Ariño and De la Torre (1998, Case 16), participants' retirement from their respective companies (as an external event unrelated to the IOC) led to changes in the actor composition of the joint venture, without having any other effects to other IOC characteristics reported by the case researchers.

**Figure 2.1: Patterns of Dynamics** ( ∆ = change; + = positive effect; - = negative effect.)



### *2.7.2 Binary Loop*

In several cases (Cases 14, 15, 16, 17, 19, and 22), the cause-effect dynamic was initiated by multiple sources. The effect was limited to a single loop between two IOC characteristics with no outflows affecting other IOC characteristics. This two-characteristic loop flow was initiated either as a result of partner differences (e.g., Doz, 1996, Case 14, Case 15; Faems et al., 2008, Case 19) or as changes in the IOC actor composition (De Rond & Bouchikhi, 2004, Case 17). These sources resulted in changes to the IOC characteristic of interaction style (moving from more emphasis on cooperative to more emphasis on competitive). These changes in emphasis in interaction style then affected changes in the IOC contract frame (moving from more emphasis on a relational frame to more emphasis on a transactional frame), which then further affected changes in the IOC interaction style, continuing this loop. For example, in an alliance, partner differences in culture, expectations, and skills led to little trusting of each other, changing an initial emphasis on a cooperative interaction style to a competitive emphasis (Doz, 1996, Case 14). This increased competitive emphasis caused changes in the contract frame from relational to transactional, which in turn led to a further decreased emphasis on a cooperative interaction style.

### *2.7.3 Parallel Multisource Effect on Single IOC Characteristic*

Several cases (e.g., Cases 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, and 18) focused on changes in one IOC characteristic of interaction style. The dynamic between the source and effect indicated that while the effect was a singular change in interaction style, the sources were many, simultaneous, and often operating in parallel. Changes in interaction style were primarily attributable to simultaneous changes in at least two of the following three IOC characteristics: decision-making control, IOC organizational structure, and actor composition.

For example, in the alliance between Esthetique and L'Oreal (described by Ness, 2009: 461, Case 10), the two partners tried to "reduce conflict and improve interactions by relying on standard operating procedures." Adding new standard procedures and thus reducing the conflict level allowed the interactions between them to become less competitive and more cooperative than they previously had been. However, they still had conflicts because the behavior of the director for distribution in L'Oreal (as one of the key actors in the IOC) had negative influences on the level of cooperation. Consequently, the director for selective distribution was replaced, and cooperation increased between the two partners. Thus, the positive effect of introducing new standard procedures on cooperative interaction was strengthened by replacing the director. In addition, several joint product meetings and joint activities for decision making took place in the alliance, thereby increasing cooperation between the two partners.

### *2.7.4 Positive Multicharacteristic Loop*

In several cases, a loop of three IOC characteristics that continuously evolved and positively reinforced each other was identified (Cases 1, 2, 3, 5, 6, 7, 8, 9, 10, 13, and 18). This loop involved one of two sets of characteristics: (a) changes in the three characteristics of decision-making control, interaction style, and contract frame or (b) changes in the three characteristics of IOC organizational structure, interaction style, and contract frame. In some cases, only one of these loops was present, and we only found four cases in which both of these loops were present. Both loops were generally triggered by recognition of betweenpartner differences.

In the first type of positive multicharacteristic loops, team-based control over decision making increased, which led to greater use of cooperative interactions, which in turn gave rise to greater reliance on a relational-based contract frame and, consequently, greater use of team-based control, thus continuing the loop. For example, in an alliance between an imaging company and a stock-quoted inkjet printer technology, partner firms increasingly relied on team-based decision making for technical problems by organizing technical meetings to involve more people from each partnered firm in joint problem definition and joint problem solving (increased IOC team decision making control; Faems et al., 2008, Case 9). This allowed the partner firms to have more intensive information sharing and more cooperation, which led to greater reliance on more relational elements (i.e., mutual trust) over time since they had a mutual understanding of technology problems and each other's competencies. This increased trust led partners to engage in even more team-based decision making such that a positive self-reinforcing loop of more team-based control over decision making, a more cooperative interaction style, and increased reliance on relational-based contract frame emerged.

In the second type of positive self-reinforcing feedback loop, a more structured IOC (by adding new roles, processes, and routines) reduced tensions between the partner firms, leading to increased cooperation between them. As a result of extensive cooperation, greater emphasis was placed on a relational-based contract frame, which allowed the partners to be able to negotiate adding new roles, processes, and routines to the IOC, thus increasing the structure and continuing the positive loop. This positive self-reinforcing loop then was between more structure, more cooperative interaction, and increased emphasis on a relational-based contract frame. For example, in the SEMATECH consortium, new formal processes and roles (more structured collaboration) were implemented to facilitate interaction between partners. Increased interaction promoted a more cooperative interaction style among the partners, which in turn was an input to increased reliance on a relational-based contract frame. Moreover, this relational based contract frame had an effect on adding new roles and processes to pave the way for more information exchange and cooperation. A positive selfreinforcing loop between more structured, greater cooperative interaction style, and increased reliance on a relational-based contract frame took place for the SEMATECH consortium (Browning et al., 1995, Case 1).

### *2.7.5 Negative Multicharacteristic Loop*

In one case, the COOP-Lilleborg alliance (Ness, 2009, Case 20), a loop of three IOC characteristics that continuously evolved but negatively influenced each other was identified. Here the changes in the three characteristics were the same as above: decision-making control, interaction style, and contract frame. Also, as above, the changes to characteristics were initiated by between-partner differences. In this pattern, however, the between-partner differences had devolved into conflict between the partners, which led to increasing emphasis on top management control (instead of teams) over decision making, which, because each partner's value was now being questioned, led to increased emphasis on interaction styles that were more competitive than cooperative. Increased reliance on competitive interactions in turn decreased reliance on the relational contract frame, as "trust and norms were weakened" (Ness, 2009: 465). Decreased reliance on the relational contract frame led to even more decisions being made by top management control over decision making, thus continuing the negative loop.

### 2.7.6 Multiloop Flows

In some cases (Cases 1, 2, 5, and 10), more than one recursive loop occurred between sources and effects during the IOC. These loops interacted, creating a more complex pattern of dynamics. In the GE-SNECMA alliance, for example, there were two recursive loops: one between increased team-based control over decision making, more cooperative interactions, and greater reliance on a relational contract frame; and the other recursive loop between more structured IOC, more cooperative interaction, and increased reliance on the relational elements of contract frame. These two loops were triggered by differences between partners in cultures and practices. In this alliance, the partners had sufficient overlapping experience and skill in working together at the outset, and they also developed new organizational structures for mitigating conflicts in the IOC: "They were fortunate enough to start the alliance with the definition of new organizational roles" (Doz, 1996: 78, Case 2). Also, partner firms increasingly relied on team-based decision making. These new structures and increased IOC team decision making control contributed to increased information sharing and cooperation in the IOC, which results in increased emphasis on a relational-based contract frame. In addition, the relational-based collaboration between the partners allowed the partners to become more adaptive and flexible for adding new more formal processes.

### 2.7.7 Dynamic Patterns and Relationship to Outcomes

In sum, we found evidence of several different dynamic patterns, including binary loops, positive multicharacteristic loops, negative multicharacteristic loops, and multiloop flows, as well as evidence of single changes that were disconnected from the other IOC characteristics and hence not integrated into the system of dynamics in the IOC. More than one pattern is seen for some cases in which three-characteristic loops and multiple loops are triggered by between-partner differences and parallel effects of changes in other parts of the IOC (parallel simultaneous effects). Finally, the dimensions on which these patterns varied indicate specific ways in which dynamics in IOCs take place and can be further studied. That is, a deeper understanding of dynamics can result from an examination of the breadth of the dynamics (i.e., number of IOC characteristics involved), the direction (i.e., positive or negative), whether recursion is involved, multiplicity of initiating sources, and the extent of recursion (number of loops).

Were the patterns of dynamics related to outcomes? We juxtaposed the different dynamic patterns on whether the outcome of the IOC was judged by case researchers to be successful or unsuccessful. We found that IOCs considered unsuccessful by the case researchers had single changes that were disconnected from the other IOC characteristics, binary loops, and negative three-characteristic loops. In contrast, successful cases had positive multicharacteristic loops, parallel multisource changes, and multiple loops. This suggests that more successful cases are those with more recursions, signifying IOCs that have developed more ways to accommodate change iteratively. Iterations are particularly helpful as any single passage through the loop may accommodate only very small or modest amounts of positive change.

## 2.8 Implications and Future Research Directions

A first implication of the findings from this review is that despite the extensive variability in how IOC characteristics changed over time, and the sources and patterns of these changes, we found a clear distinction in the dynamics associated with the cases in which successful outcomes were documented compared to the cases in which unsuccessful outcomes were documented. We discovered three distinctions. First, cases with successful outcomes were more likely to experience change in more characteristics. Second, in successful cases, these changes were often proactively initiated because of differences between partners in interests, organizational cultures, and practices. Finally, more successful cases experienced dynamic patterns with more complex feedback loops having subsequent effects on other IOC characteristics throughout the collaboration.

Examining the six patterns of dynamics leads to five elements of a dynamic that warrants description because they differentiate between successful and unsuccessful IOCs. These five descriptors of the patterns include (a) breadth of dynamics, (b) direction, (c) whether recursion is involved, (d) multiplicity of initiating sources, and (e) the extent of recursion. As more longitudinal research cases accumulate with future research, the relative contribution of each of these five on the outcomes can be assessed. These five descriptors provide direction on how to study dynamics. Rather than treating dynamics as an indivisible complex system, the descriptors can provide parameters for studying the multifaceted nature of dynamics. Consequently, the five descriptors provide a means to study IOCs over time as integrated complex systems (e.g., Brown & Eisenhardt, 1997; Page, 2009) rather than being studied from the perspective of a single function or a characteristic (such as contractual frames or organizational structures). These five descriptors provide research questions deserving attention in future studies. Does the regularity of the feedback loops and time between changes affect IOC outcomes, as has been found for changes over time within a firm (Klarner & Raisch, 2013)? Are successful IOCs more likely to keep or intentionally allow changes in one characteristic to affect changes in other characteristics? How does the recursion stop, since continuous recursion would be counterproductive? Is there a synergistic effect that is required among the sources so that changes caused by the sources are in concert, or is conflict between the downstream effects of sources of change likely to foster innovative dynamic patterns?

A third implication is the presence of dualities in changes in IOC characteristics. In some IOCs, for example, both increased differentiation (as an increased number of new roles) and decreased differentiation (as increased use of teams to make decisions) occurred. In other IOCs, interaction style between the IOC partners became increasingly cooperative over time, coexisting with competitive behaviors. The two interaction styles seemed to be needed to ensure effective knowledge sharing while maintaining alertness and visibility to potential partner opportunistic behaviors. Similarly, in some cases, the relational elements of the IOC contract frame became increasingly important as IOC evolves, coexisting with the transactional elements. These three dualities suggest dualism as another descriptor of dynamics, echoing perspectives of others in non-IOC contexts (Farjoun, 2010; Gebert, Boerner, & Kearney, 2010; Smith & Lewis, 2011). To leverage such duality, both sides of the duality need to be examined so that subtleties of how IOCs manage dynamics are not lost.

The coopetition literature has examined firms that simultaneously cooperate and compete with each other (Ang, 2008; Bengtsson, Eriksson, & Wincent, 2010; Bengtsson & Kock, 2000; Hau & Evangelista, 2007; Ritala & Hurmelinna-Laukkanen, 2009; Zineldin, 2004). The IOC dynamics depicted here can be used to examine how coopetition unfolds over time, a needed research focus (Gnyawali & Park, 2011). From this review, coopetition appears to be managed with changes in decision-making control, changes in organizational structure, changes in interaction style, and changes in the contract frame as the coopetiting partners execute their plans. The alternative patterns of dynamics found in this review further suggest that the duality between competition and cooperation becomes expressed in a dynamic pattern. Which of the six dynamic patterns describes successfully coopetitive partners requires further research. For example, Bengtsson and Kock (2000) found that firms in a coopetitive relationship shared knowledge in the joint product development activities but hid knowledge from each other about activities closer to the customer. The review reported here suggests that this hiding and sharing of knowledge may have evolved over time as changes occurred in decision-making control and the contract frame. These changes, along with the introduction of new routines, processes, and roles may have helped to manage the balance of competitive and cooperative interaction styles. Through examination of the dynamic pattern of the coopetitive arrangement over time, how this complex arrangement evolves over time can be more richly understood.

Progress in understanding IOC dynamics requires methodological advancements. The relationship of dynamics to IOC outcomes suggests the need for rigorous research specifically focused on identifying key descriptive elements of the dynamics and the different conditions under which these dynamic descriptive elements are likely to occur. We inferred the dynamic patterns from what case researchers reported, recording no dynamics if the authors did not mention the change (e.g., goal change). Findings based on omission of data are always circumspect (Yin, 1994). Hence, future qualitative IOC researchers are encouraged to reveal more clearly not just the content of changes but the patterns that those changes take.

An understanding of dynamics cannot be achieved solely with further qualitative analyses. Computational experiments and simulations (Burton, Obel, & De Sanctis, 2011) are needed to allow examination of the feedback loops. Simulations allow examining the temporal cause-effect relationships of intertwined learning processes not just in the short term but in the long term, over a large number of time periods, and across levels (Anderson & Lewis, 2014). Simulations can be particularly valuable in teasing out the “core rigidity” disruptions caused by the different sources and characteristics found in this review as well as in identifying which changes in IOCs are adaptive in positively or negatively impacting performance and at what rate over time. Simulations can help predict which form of change is more likely to occur under different conditions as well as responses to extreme events.

Sequence analysis methods are another way to develop fine-grained models of temporal or spatially related cause-effect relationships in process flows (Abbott, 1990; Abbott & Tsay, 2000). Sequence analysis strives to find if preferred outcomes are associated with particular sequences of activities or events. It can also measure the elapsed times in terms of events of activities. This technique can also help explain events such as why one pattern changed to another one. Sequence analysis techniques with applicability to IOCs have been used recently to describe firm performance over time (Klarner & Raisch, 2013).

In conclusion, even with a relative dearth of articles in the review, we were able to develop an understanding of dynamics that occur and effect outcomes in IOCs. The review identified several patterns of dynamics, ranging from qualitative shifts to quantitative effects, from recursive loops to multiple interacting loops, relating these to outcomes. Future studies should test and discover alternative patterns of dynamics in IOCs.

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# Chapter 3: How to Manage the Downside of Deep Engagement with External Sources in Open Innovation Projects[4]

## 3.1 Abstract

There is a conundrum when a firm engages deeply with external sources in its open innovation projects. This conundrum is related to the simultaneous activities

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of knowledge sharing and knowledge protecting. Many studies about open innovation have focused on the role of legal formalization in the context of intellectual property (IP) control. But legal formalization around IP may not address more specific activities of the parties such as tacit knowledge of involved individuals that may lead to revealing too much knowledge. In this study, we introduce formality into the joint technology development process itself, an alternative form of formalization, to manage this conundrum. Moreover, we argue that as the firm attempts to solve more complex problems, the importance of the formal joint process increases. We test our argument based on a sample of 82 open innovation projects collected from large firms in the United States and Europe. Our results clearly indicate that to manage the conundrum of simultaneously engaging in knowledge sharing and knowledge protecting, formalizing the joint technology development process seems to have a positive effect on projects outcomes that gets stronger as the problem becomes complex. We contribute to external sourcing literature by suggesting that the process formalization may support the legal formalization of IP control to manage the knowledge sharing and protecting tension. Moreover, we make important theoretical contributions to literature regarding relational mechanisms in interorganizational collaborations through our assertion that the combination of formality and informality between the partners seems to be required to increase the likelihood of success of open innovation projects without the loss of critical intellectual property.

## 3.2 Introduction

*If you want to have a fast success in developing a new technological solution with external partners, you need to support dialogue, discussion and actual collaborative development of a solution in which deep-level of knowledge exchange and integration among the partners happen especially, it is more crucial when you want to tackle a complex problem area. But it creates a risk of knowledge leakage to external partners. (A Chief Innovation Officer)*

There is a conundrum in the firm's use of external sources in its open innovation projects. Many studies about open innovation have argued that firms should deeply engage in external sources to solve their innovation problems (Chesbrough, 2003; Faems, Janssens, Madhok, & Van Looy, 2008; Laursen & Salter, 2006). As problems become more complex, there may be an even greater need to deeply engage in external sources (Felin & Zenger, 2014). Deep engagement refers to flexible interactive dialogue among the parties to be able to reconceptualize problems and solutions in order to increase the possibility of innovation (Faems et al., 2008). But, the conundrum is that such flexible interactions with external sources expose the firm to opportunistic risk from unintentional knowledge sharing or sharing too much knowledge (Heiman & Nickerson, 2004; Jarvenpaa & Majchrzak, 2016). This fear of potential opportunistic risk can result in the firm taking a defensive behavior by the parties and becoming unwilling to collaborate, which in turn can slow down a project in achieving its intended goals and even stop a project prematurely (Jarvenpaa & Välikangas, 2014; Majchrzak, Jarvenpaa, & Bagherzadeh, 2015). This paper aims to address this knowledge sharing and knowledge protecting conundrum.

One potential solution to this conundrum is to introduce some form of formalization into the engagement (Majchrzak et al., 2015). The type of formalization receiving the most attention in the open innovation literature is legal formalization, such as contracts around IP control (Cassiman & Veugelers, 2002; Laursen & Salter, 2014). However, these types of formalization may not address more specific activities of the parties, which may lead to revealing too much knowledge (Berends, Van Burg, & Van Raaij, 2011; Jarvenpaa & Majchrzak, 2016). As a result, the parties may share IP-related knowledge that they should not sharing while they are deeply interacting.

An alternative conceptualization for formalizing the engagement is to introduce formality into the engaged joint technology development process itself. Formality of the joint technology development process is defined as specifying and enforcing technological activities that are supposed to be followed by the parties to jointly develop a technology in the form of procedures, manuals, and roles (Vlaar, Van Den Bosch, & Volberda, 2007). Such specified processes could include, for example, how often the technology development is reviewed by senior management for its progress in achieving a predefined goal (Faems et al., 2008; Majchrzak et al., 2015).

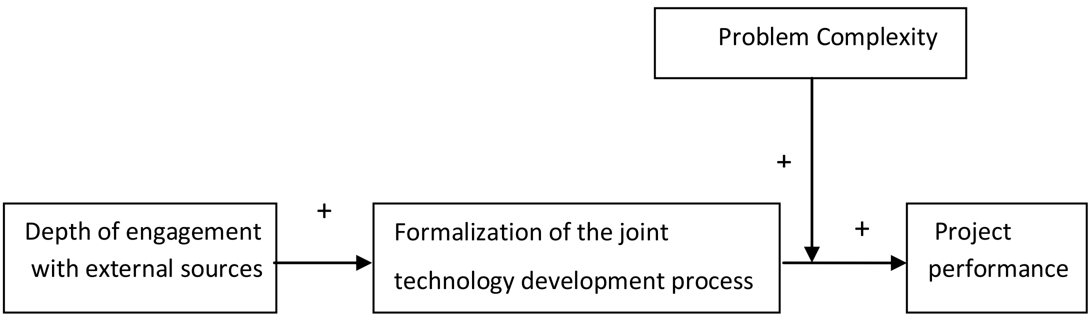
For example, Jarvenpaa and Majchrzak (2008) found that a primary mechanism used by security guards to protect knowledge in security-related interorganizational collaborations is to break down knowledge into smaller pieces and allow different partners to have only some of the knowledge. Others have similarly theorized and conducted research on the value of knowledge segmentation during interorganizational collaborations (Faems, Janssens, & Van Looy, 2010; Jarvenpaa & Majchrzak, 2016; Lewicki, McAllister, & Bies, 1998). Therefore, formalizing the joint technology development process may keep the parties from sharing too much knowledge with one particular external source during the technology development process (Avadikyan, Llerena, Matt, Rozan, & Wolff, 2001; Faems et al., 2008; Vlaar, Van den Bosch, & Volberda, 2006). With built-in and frequent senior management reviews, it may be possible to ascertain as soon as possible when highly sensitive knowledge has been shared with external parties in order to take appropriate action (Jarvenpaa & Majchrzak, 2016). Moreover, as the formal technology development process is applied to a new open innovation partnership with a new partnership, knowledge needing to be shared and knowledge needing to be protected can be clarified, thereby alerting the parties to the need for self-monitoring and regulation of knowledge sharing during the joint technology development process. As the innovation problem becomes more complex, greater flexible interaction and knowledge sharing among the parties is required (Felin & Zenger, 2014). This increases the possibility of sharing too much knowledge unintentionally compared to the interactions required to solve a less complex problem. Thus, as projects undertake more complex problems, the importance of formal joint technology development practices for managing the deep interaction increases. The concern over knowledge sharing and opportunistic risk can slow down an open innovation project and even end it prematurely. Therefore, when an open innovation project successfully reaches its initially planned goals, this risk is more likely to be managed before creating problem for the project. Therefore, we ask the following research questions: *Does the use of a formalized joint technology development process help to increase the likelihood that an open innovation project with external sources is successfully completed? And if so, what role does problem complexity play in this process?*

We approach these questions with a sample of 82 open innovation projects collected from large firms in the United States and Europe. With project-level data, we are able to assess the degree of process formalization used within the project in more detail compared to the more traditional level of firm-aggregated data often used in open innovation research (Felin & Zenger, 2014; Laursen & Salter, 2006; Laursen & Salter, 2014). We find that to manage the conundrum of deep engagement with external sources, formalizing the joint technology development has a monotonically positive effect on project outcomes, and that this positive effect of formalization becomes more pronounced as the technology problem serving as the impetus for the open innovation becomes more complex.

## 3.3 Theoretical Model and Hypothesis Development

In this section, we develop two hypotheses related to a firm's deep interaction with external sources in their open innovation project and the role of joint technology development process and problem complexity in project performance. The theoretical model of this study and related hypotheses are presented in Figure 3.1.

**Figure 3.1: The Theoretical Model**




***Deep engagement and project performance: The mediating role of the process formalization***

Deep engagement is defined in terms of the extent to which firms interact intensively with different external sources to jointly complete an innovation project through purposive use of inflows and outflows of knowledge (Chesbrough & Brunswicker, 2014; Laursen & Salter, 2006). For example, in a collaborative research and development project, Evonik deeply engaged in a diverse set of external sources, including potential customers in the electronics industry, universities and research centers, and equipment suppliers by spending a lot of time with them for making use of their knowledge to develop a new technology (Brunswicker, Bagherzadeh, & Lamb, 2016). Many scholars present empirical evidence that deep engagement in external sources allows firms to solve their innovation problems in a more effective and efficient way, thereby leading to a greater innovation performance (Faems et al., 2008; Foss, Laursen, & Pedersen, 2011; Laursen & Salter, 2006; Ness, 2009).

To support deep engagement, partners facilitate flexible interactive dialogue to reconceptualize problems and synthesize different knowledge areas relevant to novel solutions to increase the probability of project successes (Browning, Beyer, & Shetler, 1995; Jarvenpaa & Majchrzak, 2016). For example, in a research and development collaboration project, partner firms organized technical meetings among involved individuals from each partner firm in order to have more intensive and interactive dialogue to build a mutual understanding of technology problems (Faems et al., 2008).

Such flexible interaction increases the potential risk of opportunistic behavior as valuable knowledge is subject to potential expropriation by partners who may abuse unintended shared knowledge for their own benefits and interests (Faems et al., 2010; Heiman & Nickerson, 2004) which may harm the partner firms by losing their intellectual properties and competitive position (Jarvenpaa & Majchrzak, 2016). Thus this leads to taking a defensive behavior by the parties and an unwillingness to cooperate (Majchrzak et al., 2015). For example, in an R&D collaboration project, one of partnering firms explicitly asked their engineers "not to share information on technological problems with Graph due to the fear of unintended knowledge spillovers and losing command over the project" (Faems et al., 2008: 1063). Therefore, partners need to regulate the tension between sharing and protecting in deep engagement, thereby allowing flexible interaction for successful innovation outcome without the loss of critical knowledge (Bogers, 2011; Heiman & Nickerson, 2004; Majchrzak et al., 2015).

Jarvenpaa and Majchrzak (2008) found, in a national security interorganizational collaboration, breaking down knowledge into segmented pieces and sharing only some of the knowledge with the partners is used by security professionals to manage the knowledge sharing-protecting tension (Jarvenpaa & Majchrzak, 2008). Likewise, other researchers focusing on sharing-protecting tension have studied the value of knowledge segmentation (Faems et al., 2010; Jarvenpaa & Välikangas, 2014; Lewicki et al., 1998) and selective sharing, "sharing part of the firm's knowledge", (Jarvenpaa & Välikangas, 2014: 68) for regulating this tension in collaborative projects. Recent theorizing about the sharing and protecting tension argue that knowledge segmentation, defined as "breaking down knowledge into segmented pieces, with each different piece of knowledge shared in a different way", is required to regulate this tension in interorganizational collaborations (Jarvenpaa & Majchrzak, 2016: 11). An example of knowledge segmentation for managing sharing and protecting is related to the joint venture between Boeing and the Japanese in building Boeing 777. Boeing performed knowledge segmentation by which significant amounts of technical information was shared, but simultaneously Boeing protected some of its technical knowledge by "limiting the access of Japanese engineers to secure areas within Boeing" (Lewicki et al., 1998: 447). As another example, in an alliance, the partners segmented knowledge by defining partner-specific task domains for the collaboration through which "the need to share sensitive information was reduced and the risk of unintended knowledge spillovers was mitigated" (Faems et al., 2010: 13). Through knowledge segmentation, the parties are likely to effectively respond to the sharing and protecting tension, thereby having their flexible interaction to ensure project successes without losing sensitive knowledge.

For the involved actors to effectively segment the knowledge in the interactive engagement, awareness of which knowledge that is required to be shared in order to ensure project success is needed. The uncertainty about what knowledge should be shared and what knowledge should be protected complicates the knowledge segmentation for individuals who "need to make in-the-moment decisions" about which knowledge to share with the parties without losing the critical knowledge (Jarvenpaa & Majchrzak, 2016: 23). This uncertainty that involved actors have can result either in a fear of knowledge sharing, even sharing knowledge that needs to be shared, or enacting too much and unintended sharing, complicating the regulation of knowledge sharing and protecting. For example, in the SEMATECH consortium, individuals should "confer with their companies about what they would share at SEMATECH, sometimes by calling home [organizations] at breaks during meetings to inquire about sharing a particular piece of information" due to lack of standard operating process and different views among partners about knowledge needing to be shared (Browning et al., 1995: 135). In this example, this uncertainty made their collaboration unproductive, which in turn slowed down the consortium in reaching its initially planned goals.

One recommendation for supporting knowledge segmentation is to specify a formal process, including a set of required technological activities and evaluation criteria such as technological specifications, that the parties can follow (Lewicki et al., 1998). We argue that introducing formality into the joint technology development process decreases the uncertainty about required knowledge that should be shared for furthering project goals (Avadikyan et al., 2001; Vlaar et al., 2006). Formalization of the joint technology development process is defined as specifying and enforcing technological activities that are supposed to be followed by the parties to jointly develop a technology in the form of procedures, manuals, and roles (Vlaar et al., 2007). Formalizing the joint technology development process forces the parties to explicitly articulate technological specifications and knowledge sets required for developing and completing the technology (Faems et al., 2008; Vlaar et al., 2006). Process formalization ensures that the required knowledge is well-defined in the project, thereby reducing the uncertainty about what knowledge should be shared with the parties in the interaction, which in turn decreases conflicts among the parties. This articulation makes the interaction more predictable in terms of knowledge sharing. For example, in a collaborative project for designing a new small car, the partners developed a set of operating documents, roles, and manuals, including technological activities and specification that should be followed by each partner during the project (White, 2005). What knowledge was needed during the design process was clear. Thus, the partners were able to define "what kind of information would not be shared as part of collaboration" (White, 2005: 1402). They divided the knowledge related to technological specifications for car components and only shared for components that were common to the partners' car models, and they protected for the remaining components. This clarity about the technological specification allowed the partners to have effective knowledge segmentation and to successfully reach the predefined objective without unintentional knowledge sharing. Moreover, such formalization enables individuals to focus their attention on the required technological specifications and knowledge sets that are needed to complete the project (Vlaar et al., 2006). This focus on required knowledge reduces the complexity of making in-the-moment decisions on what knowledge to share and what to protect, thus enabling them to complete effective knowledge segmentation. Ness (2009) illustrates how a set of formal technological guidelines, as a project handbook for use by the technical workers during the interaction in a collaborative joint project paved the way for information exchange between the partners without sharing unintended knowledge. This formal project handbook focused individuals' attention on the required knowledge to be shared in the interaction, therefore easing decision making on information exchange without losing critical knowledge.

In summary, partners must cope with the knowledge sharing-protecting tension during deep engagement; otherwise this tension can slow down the collaborative project in successfully reaching its initially defined goals and even stopping it prematurely. The process formalization can create a predictable situation about what should be shared and what should be protected. This predictability stimulates the partners for self-monitoring and regulation of knowledge sharing and protecting tension during the joint projects to avoid the opportunistic risk. We suggest that process formalization creates a foundation for effective knowledge segmentation, thus supporting flexible interaction between the parties without losing critical knowledge. This flexible interaction allows the parties to more effectively reframe and reconceptualize problems and solutions, enhancing the probability of project success in reaching their predefined objectives. A recent review on interorganizational collaboration dynamics shows that successful collaborative projects do not appear to be accompanied by the knowledge sharing and protecting tension that is not regulated by the parties during the project (Majchrzak et al., 2015). Thus, when a joint collaborative project successfully achieves its goals, this tension is more likely to be effectively regulated before creating problems for the projects (Das & Teng, 2000; Jarvenpaa & Majchrzak, 2016). Therefore, the following hypothesis can be developed:

*Hypothesis 1: Level of formalization of the joint technology development process mediates the relationship between depth of engagement with external sources and project performance.*

***Process formalization and project performance: The moderating role of problem complexity***

Problem complexity is defined in terms of the number of involved tasks, components, or knowledge sets and the degree of interdependency among them (Fernandes & Simon, 1999). Complex problems are comprised of a large number of highly interdependent tasks, elements, or knowledge sets that make complex problems less decomposable. For example, in a technological partnership to develop a new technology for rendering movies, the technological problem was complex. This technological problem was comprised of different elements and knowledge sets related to data storage, cloud computing, and animation technologies, and these elements are interdependent and should be considered at the same time to develop a successful technological solution (Brunswicker et al., 2016).

The problem solving perspective argues that depending on the problem complexity, different solution search approaches are needed (Nickerson & Zenger, 2004). Nickerson and Zenger (2004: 621) differentiate between two different search approaches, directional[5] and theory-driven, and state that "[theory driven] search is necessary when problems are complex" whereas "directional search is warranted when problems are decomposable [not complex]". Theory-driven (also called cognitive search) is a search approach in which "an actor or a group of actors cognitively evaluate the probable consequences of design choices rather than relying solely on feedback after design choices are made" (Nickerson & Zenger, 2004: 621). Such a theory-driven search implies that the partners need to understand the interaction between involved tasks, find and synthesize different knowledge sets relevant to problem to shape a search theory and a cognitive map

[5] This search approach is only "guided by feedback or experiences from prior trials" (Nickerson & Zenger, 2004: 620).

as a basis for the cognitive evaluation of the likely consequences of solution selections for guiding solutions search (Gavetti & Levinthal, 2000; Nickerson & Zenger, 2004). One way suggested for supporting an effective theory-driven search is to facilitate deep interaction and extensive knowledge sharing among the parties to ensure sufficient understanding of the problem (i.e., tasks and interaction among them) and make sure that all relevant knowledge sets are exchanged by the parties (Felin & Zenger, 2014).

As a result, when the problem being solved is more complex, partners need greater flexible interaction and knowledge sharing during the project. For example, in a collaborative project for developing a complex new technology for rending films the partners engaged in mutual extensive knowledge exchange. As stated by an involved manager in this project, "without sharing knowledge and open communication between partners, I do not think we could have [a successful technological solution] from this collaboration" (Brunswicker et al., 2016). This greater flexible interaction and knowledge sharing for complex project increases the possibility of opportunistic risk of unintended knowledge sharing compared to projects having less complex problems. This greater possibility of opportunistic risk makes the knowledge segmentation more important in regulating knowledge sharing and protecting to ensure project successes. As a result, the importance of process formalization to enable successful completion of the project without losing critical knowledge increases when the problem is more complex. In sum, the positive relation between the level of process formalization and project performance is made even stronger when the problem becomes more complex, indicating that as projects take on more complex problems, the importance of formal process in creating successful innovations outcome increases. Thus, the following hypothesis can be developed:

*Hypothesis* 2: *Problem complexity moderates the relationship between level of formalized joint technology development process and project performance such that the relation is stronger with more complex problems.*

## 3.4 Empirical Study

### *3.4.1 Sample and Data Collection*

Most empirical quantitative studies on open innovation have been conducted at the firm level aggregated data (regularly using the Eurostat Community Innovation Survey-CIS-) with innovation performance measured at the firm level (Campbell & Cooper, 1999; Chesbrough & Brunswicker, 2014; Foss et al., 2011; Foss, Lyngsie, & Zahra, 2013; Laursen & Salter, 2006; Lhuillery & Pfister, 2009; Un, Cuervo-Cazurra, & Asakawa, 2010). However, firms typically run innovation related activities through different projects (e.g., R&D projects) (Du, Leten, & Vanhaverbeke, 2014; Hobday, 2000; Sydow, Lindkvist, & DeFillippi, 2004). Innovation projects conducted in the same company can be either successful or less successful. Using firm level aggregated data makes the measurement of innovation performance, coming from heterogeneous projects, difficult (West, Salter, Vanhaverbeke, & Chesbrough, 2014). As a result, innovation performance should really be measured at the project level. Moreover, innovation projects have different attributes, even those managed in the same firm, that may differently affect the degree of joint process formalization. Faems et al. (2008) show the formalization level of behavioral monitoring is different in two joint projects conducted by the same partners. Others also reveal that degree of formalization is a project-specific variable (Kirsch, 1996; Kirsch, Ko, & Haney, 2010). In the current study, we argue that formalization is a project-specific variable. But, in many quantitative studies on open and collaborative innovation, formalization is almost always measured as an organizational level factor (Foss et al., 2011; Foss et al., 2013). The results of the paired-samples t-test show that there is significant difference in degree of formalization between projects in the same firm in our sample, indicating that the formalization is unique to each project.

In this study, we collected data on open innovation activities at the project level. Our sample includes large firms listed on the stock market with annual revenues of more than $250 million, total assets of more than $250 million, and more than 1,000 employees in Europe and the United States (2445 large firms). Only large firms were selected to make sure that we could collect data at the project level. Small firms may not conduct project based innovation activities. Data collection was done via a global open innovation survey (using a questionnaire) between December 2014 and August 2015. Before sending the questionnaire out, we conducted a pilot test with one CEO, two CIOs, and two researchers working on open and collaborative innovation. The results of this pilot study gave rise to a few minor revisions of the initial questionnaire.

We first collected the information of a minimum of two senior executives (e.g., CEOs, CIOs, CTOs, R&D Directors, Open Innovation Managers, etc.) from each firm as primary contacts including the name, email address, and phone number. Then, we sent them an email including the link of the survey. They were asked to select two open innovation projects[6] (successful and less successful[7]) that they have completed within the last two years (we asked them to select recent projects to make sure that respondents are able to remember project activities to complete the survey). To minimize key-informant bias, we asked the primary contacts to

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[6] To make sure the respondents selected an open innovation project, we provided them with a definition of open innovation at the beginning of the survey. Open innovation implies that your organization makes purposive use of external know-how and capabilities and/or external paths to market, as your organization looks to accelerate internal innovation, and expand the markets for external use of internal innovation, respectively (Chesbrough, 2006)

[7] We provided the respondents with a definition about project success as follows: A successful open innovation project is a project that has successfully supported the firm's innovation strategy and targets, while a less successful project did not.

assign the most suitable respondent (e.g., project manager) to complete the survey based on the selected open innovation projects (Kumar, Stern, & Anderson, 1993). To increase the response rate, we sent four reminder emails to those firms that did not complete the survey by the first email invitation. We also followed up by calling the contact persons.

Finally, 121 large firms participated in our survey (response rate = 4.9 %.) Out of 121 firms, 94 firms have engaged in open innovation. Only 59 firms (out of 94) completed the survey for one or two open innovation projects. We collected data on general firm characteristics from secondary data sources. The two-sample t-test and the chi-square test were conducted to assess non-response bias. The results showed that our sample was not significantly different from the nonrespondent firms in terms of R&D expenditure, total revenue, total assets, number of employees, and industry group.

In total, 59 firms completed the survey for 104 open innovation projects. 45 firms completed the survey for two open innovation projects (successful and less successful) and 14 firms only completed the survey for one project[8]. Having a pair of successful and less successful projects from the same firm enabled us to control for the organizational level factors such as organizational structure and culture that affect innovation. We had some missing values on the variables of interest. We performed the two-sample t-test and the chi-square to test whether there were systematic differences in terms of other observed variables in the study between projects with missing and without missing observations. No significant differences were found. Moreover, a missing value did not depend on

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[8] We also compared early and late respondents based on key variables of this study by applying the ANOVA test. The results showed that there were no significant differences in terms of engagement with external sources, degree of formalization, and problem complexity, confirming there is no late-response bias.

the nature of variables and unobserved values of the data set. As a result, variables are missing completely at random so that we could exclude projects with missing values from the sample (Schafer & Graham, 2002). Also, we checked for univariate (case-wise diagnostics) and bivariate (examining scatter plots) outliers (Hair, Anderson, Tatham, & Black, 1998). 22 projects (out of 104) were excluded from analysis because of a missing value (18 projects) for at least one of the variables of the study or for being outliers (four projects). Finally, our sample includes date from 82 open innovation projects from 59 different large firms.

### *3.4.2 Measures*

To operationalize the constructs of our theoretical model, we applied measures from the existing literature based on the definitions adopted in this study. In this section, we briefly explain each measure.

***Depth of engagement with external sources:*** This construct refers to the extent to which firms interact intensively with different external sources to jointly complete an innovation project. Respondents were asked to indicate "how much of their time did the team members in the open innovation project spend to interact with external sources on average per week?" We followed previous studies on open and collaborative innovation for including customers, suppliers, competitors, universities, and start-ups as five different external sources (Brunswicker & Vanhaverbeke, 2015; Chesbrough & Brunswicker, 2014; Faems, Van Looy, & Debackere, 2005; Laursen & Salter, 2006). We asked respondents to provide a rough estimation about the time spent in the interaction with external sources based on a five-point scale: 1) No time at all, 2) Less than 25%, 3) Between 25% and 50%, 4) Between 50% and 75%, and 5) More than 75%. To measure the depth of engagement, we developed an aggregate measure as the sum of the allocated time with the five different external sources.

***Formalization of the joint technology development process:*** This construct was operationalized based on three items adapted from Kirsch (1996) to measure the extent to which firms specify and enforce technological activities to be followed by partners to jointly develop a technology in the form of procedures, manuals, and roles. We asked respondents to assess the following three items for the project: 1) We had an understandable, written sequence of activities supposed to be followed by internal and external actors; 2) We had a set of established documents such as procedures, manuals, etc., that could guide involved external and internal actors; and 3) External actors were required to know a set of existing documents to achieve the project goal. All items were assessed on a seven point Likert scale (1, Strongly Disagree; 7, Strongly Agree). To measure level of formalization, we calculated the average of three items.

***Problem complexity:*** It refers to the number of involved tasks, components, or knowledge sets to complete the project and the degree of interdependency among them (Fernandes & Simon, 1999). Consistent with our definition, respondents were asked to describe the problem being solved in the project based on two items: 1) It involved a large number of highly interdependent tasks (they could not be completed independently); and 2) New tasks and interdependencies between them emerged unexpectedly. Both items were assessed on a seven point Likert scale (1, Strongly Disagree; 7, Strongly Agree). The average of two items was calculated to measure the problem complexity.

***Project performance:*** We operationalized performance based on three items related to technical, managerial, and financial dimensions of projects (Akgün, Lynn, & Byrne, 2006; Foss et al., 2011; van de Vrande, Vanhaverbeke, & Duysters, 2009). The survey asked respondents to answer “to what extent did you achieve the following performance measures relative to your stated objective?". Three measures are: 1) Number of new technological opportunities successfully introduced; 2) Market reputation from results of the project; and 3) Revenue from results of the project. The measures were assessed based on a four-point scale including[9]: 1) Less than 25%, 2) Between 25% and 50%, 3) Between 50% and 75%, and 4) More than 75%. We averaged the values of the three measures to create project performance. To find empirical proof of the validity of the performance measure, we applied the two-sample t-test to check whether the performance is significantly different between successful and less successful projects. Significant differences were found between them, indicating the validity of our performance measures.

### *3.4.3 Construct Analysis (Reliability, Validity, and Common Method Variance)*

We built content validity using measures from the extant literature and contributions of three senior managers and two researchers in the pilot test of questionnaire, for improving the questions (MacKenzie, Podsakoff, & Podsakoff, 2011). We applied an exploratory factor analysis (EFA) to test the dimensionality of the multiple items, as well as convergent and discriminant validity. We used maximum likelihood extraction and varimax rotation methods[10]. The results supported our proposed four-factor structure of items (total explained

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[9] We provided respondents with an answer option "Not used at all" as well. So, they were not forced to answer if they did not use any of these items for measuring performance.

[10] We performed the EFA with using different extraction and rotation methods (such as unweighted least squares and promax rotation) to make sure that the results are reliable. We found the same results from all methods, indicating the reliability of results.

variance=58.98%). Also, all items had standardized factor loadings exceeding the suggested cut-off value of 0.5 with the exception of the first item of problem complexity, however, this item was also very close to the suggested threshold (Fornell & Larcker, 1981; Hair et al., 1998). Moreover, all items loaded on the intended factor and no item was found with cross-loading. All these results support convergent and discriminant validity of the constructs (Fornell & Larcker, 1981).

Reliability of the constructs was tested based on corrected item-total correlation and Cronbach's alpha. The corrected item-total correlation was higher than the cut-off value of 0.25 for all items (Ranging from 0.47 to 0.6) (Nunnally & Bernstein, 1994). Also, Cronbach's alpha coefficients (0.7 and 0.75 for the formalization and performance respectively) exceeded the accepted threshold value of 0.7 (Nunnally & Bernstein, 1994). Overall, these results indicate an adequate reliability of the measures in this study.

**Table 3.1: Factor Analysis Results**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Problem complexity item 1 | 0.145 | 0.263 | **0.476** | -0.070 |
| Problem complexity item 2 | -0.054 | 0.009 | **0.990** | 0.128 |
| Formalization item 1 | 0.131 | **0.677** | -0.035 | -0.085 |
| Formalization item 2 | 0.220 | **0.699** | 0.133 | 0.174 |
| Formalization item 3 | 0.117 | **0.542** | -0.190 | 0.073 |
| Performance item 1 | **0.591** | 0.202 | -0.070 | 0.107 |
| Performance item 2 | **0.682** | 0.070 | 0.149 | 0.034 |
| Performance item 3 | **0.766** | 0.219 | -0.141 | 0.127 |
| Depth of engagement | 0.204 | 0.078 | 0.440 | **0.974** |
| Eigenvalue | 2.853 | 1.505 | 1.251 | 0.960 |
| Percentage of variance explained | 17.18 | 15.67 | 14.56 | 11.58 |

Our data were gathered from a single informant for each project through self-report survey. Therefore, our data is vulnerable to CMV (Podsakoff & Organ, 1986). To reduce the problem of CMV, we separated the dependent and independent variables proximally and also by using various scales (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). We put the performance measures after our independent variables in the questionnaire when we designed the survey following Foss et al., (2011). To test the potential for the results of this study to be explained by CMV, we conducted the Harman's single-factor test as the most widely used and rigorous statistical test for assessing CMV (Podsakoff et al., 2003; Podsakoff & Organ, 1986). We conducted this test based on EFA (e.g., Flores, Zheng, Rau, & Thomas, 2012; Foss et al., 2011; Jarvenpaa & Majchrzak, 2008). We entered all of the variables (performance, depth of engagement, problem complexity, and formalization) into EFA analysis (applying a principle component method for extraction). Then, we assessed the results of the unrotated factor solution to see how many factors should be extracted to explain variance of all variables. The logic of this approach is that if we have a serious amount of CMV, EFA should provide us with a single-factor structure or the first factor accounting for a majority of variance of the variables (Podsakoff et al., 2003; Podsakoff & Organ, 1986). Our EFA analysis did not result in a single-factor structure, rather, it proposed the four-factor structure. Moreover, the first factor extracted only 33.52% of variance of all the variables. Therefore, the results of this test provide evidence that although there is likely some CMV (i.e., method-related effects), the effect is not large enough to bias the results of our study.

### *3.4.4 Statistical Methods*

Descriptive statistics and correlations are shown in Table 3.2. We do not have high collinearity among the main constructs, indicating that multicollinearity is not an issue in our subsequent analysis. We also checked the distribution of our variables based on the skewness and kurtosis. The skewness and kurtosis of all variables are within -1.2 and +0.5, indicating that the variables are normally distributed (CDATA-West, Finch, & Curran, 1995). As can be seen in Table 3.2, there is a significant positive relationship between depth of engagement and level of formalization (r=0.18 and p<0.1).

**Table 3.2: Means, Standard Deviations, and Correlations**

| | Mean | Standard deviation | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| 1- Problem complexity (1-7) | 5.20 | 1.39 | - | | | |
| 2 - Formalization (1-7) | 4.83 | 1.34 | **0.24**** | - | | |
| 3 - Depth of engagement (1-20) | 4.76 | 2.16 | 0.10 | **0.18*** | - | |
| 4 - Performance (1-4) | 2.42 | 1.05 | 0.07 | **0.27**** | **0.25*** | - |

* = p<0.1, **= p<0.05

We followed regression based mediation analysis outlined by Baron and Kenny (1986) to test the first hypothesis. According to this approach, process formalization level (M) can be considered as a mediator for the relationship between depth of engagement (X) and project performance (Y) when the following four conditions are satisfied: 1) There is a significant relationship between X and M; 2) There is a significant relationship between X and Y; 3) There is a significant relationship between M and Y; and 4) The relationship between X and Y should become non significant or significantly smaller when we control for the effect of M. As shown in the correlation matrix (Table 3.2), there is a significant positive relationship between depth of engagement and level of formalization (r=0.18 and p<0.1), thereby supporting the first mediation condition. We performed a three-step OLS regression analysis to test the other three conditions of mediation effect. We first included control variables to control possible confounding effects[11] (Model I), and then we added the main effect, depth of engagement (Model II). The last model included our mediation effect, formalization. To check whether multicollinearity is an issue in our regression analysis, we calculated the Variance Inflation factor (VIF) for the variables. The VIF for variables in the first model ranged between 1.07 and 1.18, indicating that multicollinearity does not create a problem for our model.

A hierarchical approach was used for entering the independent and control variables in the OLS regression analyses to test the moderating effect of problem complexity on the relationship between formalization level and project performance. In the first step, we included the control variables, then we entered level of formalization and problem complexity. Finally, the interaction term between formalization and problem complexity were added. Adding an interaction term creates multicollinearity problems due to correlation with main independent variables. To avoid this problem, we centered the values of complexity and formalization on their means prior to multiplying them (Jaccard, Wan, & Turrisi, 1990). The VIF for variables in this model ranged between 1.06 and 1.21, indicating that multicollinearity is not a serious problem for our model.

We also checked the homoscedasticity assumption for both regression analyses by plotting the residuals against the predicted values of project performance (dependent variable) and independent variables (i.e., depth of engagement, formalization, problem complexity, and the interaction term). No

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[11] We included the number of internal employees (full time equivalent) formally assigned to work on the project. Larger projects (more internal employees) have more resources to invest in collaboration with external partners that may affect the project outcomes. Moreover, we included a dummy variable to see whether a project is directly controlled by the CEO or not. Projects that are controlled by top-level managers such as CEOs have a certain importance and may be more likely to be supported.

pattern was found in the plots supporting the homoscedasticity assumption (Hair et al., 1998).

### 3.4.5 Results

The results of the three-step Ordinary Least Squares (OLS) regression analysis testing the first hypothesis are shown in Table 3.3. Based on model I, CEO control over a project has a significant effect on project performance, indicating the importance of controlling for it in the model. Including depth of engagement (model II) added significant variance (5% - $\Delta F=3.882$, $p<0.1$). Depth of engagement with external sources is significantly and positively associated with project performance ($\beta=0.215$ and $p<0.1$) as predicted by the previous literature (Foss et al., 2011; Laursen & Salter, 2006). This result also supports the second condition for the mediation effect analysis. Also, entering formalization level led to a significant increase in variance (5% - $\Delta F=4.506$, $p<0.05$). We found a positive significant relationship between formalization level and project performance ($\beta=0.227$ and $p<0.05$), supporting the third condition of the mediation effect. Finally, model III shows that after including formalization level, the relationship between depth of engagement and project performance became nonsignificant ($\beta=0.215$ and $p<0.1$ to $\beta=0.176$ and $p=0.11$), supporting the last mediation condition.

**Table 3.3: Results of OLS Regression Analysis for Project Performance (Mediation Analysis)**

| Variables | Model I | Model II | Model III |
|---|---|---|---|
| Number of internal employees (Ln) | 0.061 (0.118) | 0.035 (0.116) | 0.022 (0.114) |
| CEO control over project | 0.216*(0.281) | 0.191 (0.278) | 0.192* (0.272) |
| Depth of engagement | | **0.215*** (0.053) | 0.176 (2.033) |
| Formalization | | | **0.227**** (0.084) |
| Adjusted $R^2$ | 0.04 | 0.07 | 0.11 |
| F-statistic | 2.522* | | |
| ΔR2 | | 0.05 | 0.05 |
| F change | | 3.882* | 4.506** |

Standardized coefficients are reported and standard errors in parentheses. * = p<0.1 ** = p<0.05

Taken together, these results indicate that the relationship between depth of engagement and project performance is fully mediated by the level of process formalization, thereby supporting the first hypothesis. Our finding suggests introducing formality into joint technology development process is the prerequisite for deep engagement with external sources in order to successfully complete the open innovation project.

The results of hierarchical regression analysis to test the moderating effects of problem complexity are revealed in Table 3.4. According to the change in F between the steps, entering variables from one step to the next (for all steps) added significant variance, indicating a better model fit. Adding the interaction term between complexity and formalization in the third step led to a significant improvement in R-squared ($\Delta R^2$=0.04, F change=3.671, p<0.1). The results show that there is a positive and significant association between the interaction term and project performance (β=0.21 and p<0.1), supporting the second hypothesis.

To show the moderating effects of problem complexity on the relationship between formalization and project performance with more details, we plotted the level of formalization against project performance for low and high levels of problem complexity (± 1 standard deviation around the mean). Figure 3.2 clearly shows, consistent with the second hypothesis, the strength of the relationship between formalization and project performance is significantly dependent on the complexity of the problem being solved in the open innovation project. That is, introducing formality into the joint technology development process has a positive effect on project performance and this positive effect gets stronger when the problem becomes more complex.

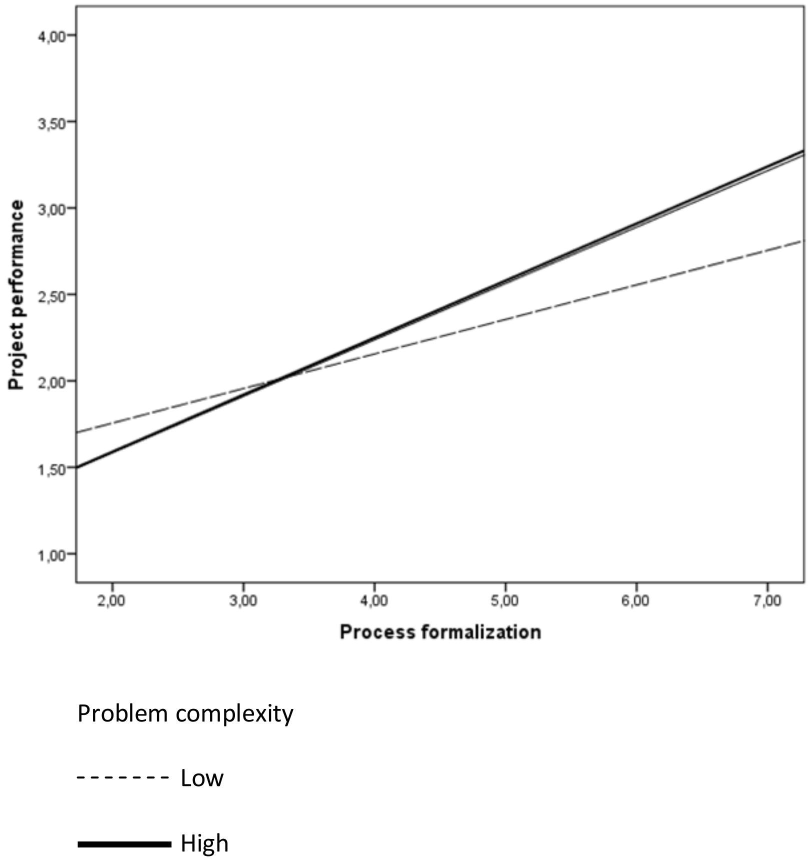
**Table 3.4: Results of Hierarchical OLS Regression Analysis for Project Performance (Moderation Analysis)**

| Variables | Step I | Step II | Step III |
|---|---|---|---|
| Number of internal employees (Ln) | 0.061 (0.118) | 0.048 (0.117) | 0.51 (0.115) |
| CEO control over project | 0.216*(0.281) | 0.218* (0.277) | 0.253**(0.031) |
| Problem complexity | | -0.05 (0.086) | -0.053 (0.084) |
| Formalization | | **0.267**** (0.086) | **0.213*** (0.087) |
| Problem complexity × Formalization | | | **0.210*** (0.073) |
| Adjusted $R^2$ | 0.04 | 0.08 | 0.11 |
| F-statistic | 2.522* | | |
| ΔR2 | | 0.07 | 0.04 |
| F change | | 2.970* | 3.671* |

Standardized coefficients are reported and standard errors in parentheses. * = $p<0.1$ ** = $p<0.05$

To show the moderating effects of problem complexity on the relationship between formalization and project performance with more details, we plotted the level of formalization against project performance for low and high levels of problem complexity (± 1 standard deviation around the mean). Figure 3.2 clearly shows, consistent with the second hypothesis, the strength of the relationship between formalization and project performance is significantly dependent on the complexity of the problem being solved in the open innovation project. That is, introducing formality into the joint technology development process has a positive effect on project performance and this positive effect gets stronger when the problem becomes more complex.

**Figure 3.2: Moderating Effects of Problem Complexity on the Relationship between Formalization and Project Performance**




## *3.4.6 Robustness Analyses*

To check the robustness of the results, we tested our moderated mediation model based on Edwards and Lambert (2007) analytical framework that improved the causal steps process of mediation analysis (Baron & Kenny, 1986) applied in this study. We performed two regression models. By the first model (Edwards & Lambert, 2007: Equation 3), we tested the effect of depth of engagement on formalization level. In the second model (Edwards & Lambert, 2007: Equation 10), we included depth of engagement, formalization, problem complexity, and the interaction term between problem complexity and formalization[12]. The result of first regression model showed that there is a positive and significant relationship between depth of engagement and level of formalization (β=0.18 and $p<0.1$). Based on the second model, we found that the direct relationship between depth of engagement and project performance was fully mediated by process formalization. Also, the interaction term between problem complexity and formalization significantly affected project performance (β=0.19 and $p<0.1$). Also, the additional part of variance of project performance explained by the interaction term was significant ($\Delta R^2=0.03$, F change=2.963, $p<0.1$). Overall, we found results which were the same as those found based on Baron and Kenny' (1986) approach (coefficients of the interaction and mediator changed slightly but remained significant), indicating the robustness of our results.

Given the significant positive effect of CEO control on project performance (β=0.216 and $p<0.1$), we tested the two hypotheses with controlling for board of director control over project. No substantial change was found for the mediating effect of formalization (β=0.225 and $p<0.05$) and the moderator effects (β=0.211 and $p<0.1$). Likewise, we examined our hypotheses by including equity control of partners[13] in project as another control variable. We found support for both hypotheses again. The results did not change dramatically and the mediating effect (β=0.211 and $p<0.1$) and the interaction between problem complexity and formalization (β=0.169 and $p<0.1$) were significant.

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[12] We also had two control variables in the regression including number of employees and CEO control over project.

[13] We used a dummy variable indicating whether firms had equity control via a joint board and committee in interaction with their external partners.

Moreover, we checked whether problem complexity had moderating effects on the relationship between depth of engagement and level of formalization and no significant effect was found. This suggests that problem complexity only moderates the relationship between the mediating variable (i.e., formalization) and project performance.

## 3.5 Discussion and Implications

While the use of deep external sources is related to successful innovation outcomes as expected by the literature (Foss et al., 2011; Laursen & Salter, 2006), this relationship of deep sources to outcomes is affected by the use of formalized joint technology development process. Our findings clearly show that, in order to manage the knowledge sharing and protecting conundrum in deep external collaborations, introducing formality into joint technology development process has a positive effect on open innovation project performance. The theoretical implication of our findings is that process formalization (in addition to formal legal IP control) needs to have a role in developing theories of using external sources particularly, a role which has been virtually ignored in previous studies of engaging in external sources (Cassiman & Veugelers, 2002; Laursen & Salter, 2014). As a result, future research should pay additional attention to the process formalization that firms require in order to ensure that open innovation is likely to result in successful technology development without the loss of critical intellectual property.

The establishment of formal IP protection may not address specific activities of individuals from the partners, which may lead to sharing IP-related knowledge that should not be shared in the interaction (Berends et al., 2011). External partners particularly, competitors may innovate around existing IP relatively fast, even if formal IP control is applicable during the interaction (Laursen & Salter, 2014). Relationships between individuals in the deep interaction play a key role in managing sharing and protecting as they involve in daily sharing of knowledge (Berends et al., 2011; Jarvenpaa & Majchrzak, 2016). Managing sharing and protecting of knowledge becomes complicated when exactly what knowledge should be shared is not clear for individuals. Our findings have important theoretical implications for research on using external sources by suggesting that process formalization may support the legal formalization around IP control to manage the concern over knowledge sharing and opportunistic risk in open innovation projects (Cassiman & Veugelers, 2002; Laursen & Salter, 2014) by reducing the ambiguity that individuals have in terms of what IP-related knowledge needs to be shared and what needs to be protected.

Our findings have also important theoretical implications for individuals´ autonomy in the deep interaction with external partners. Berends et al. (2011) indicate that the more individuals have the autonomy to have interactions with external partners, the more the collaboration will have the risk of sharing knowledge that needs to be protected. Similarly, Laursen and Salter (2014) argue, protecting IP is not only related to applying formal control but also related to forcing individuals to receive permission from the legal team before engaging with external sources (i.e., less autonomy). The lack of autonomy of individuals in deep interaction can create crucial barriers for successful collaboration with external partners as deep interaction happens through individuals from the parties. Our findings suggest that providing individuals with sufficient autonomy in open innovation projects is possible by clarifying what IP-related knowledge is permissible to be shared and what should be protected by the process formalization, thereby effectively guiding and enabling individuals to self-monitor and regulation of knowledge sharing during the open innovation project.

Our findings have important implications for interactive self-regulatory theory for sharing and protecting knowledge in interorganizational collaborations, arguing the crucial role that flexible collaboration process plays, between interacting individuals who engage in daily sharing and protecting knowledge, in regulation of the sharing-protecting tension (Jarvenpaa & Majchrzak, 2016). Our findings suggest that flexible interaction between individuals in open innovation projects is primarily possible not because it implies informal self-organized decision making about knowledge sharing and protecting in an ad-hoc fashion but instead that decisions that are made based on formalized joint processes. Open innovation projects may particularly require such process formality because of the syndrome that individuals functioning within projects must simultaneously both trust and distrust their parties to protect themselves from opportunistic risk (Doz, 1996; Lewicki et al., 1998). The formal joint technology development process reduces the possibility of opportunism due to clarity not only about what knowledge should be shared but also about what knowledge should be protected, making flexible interaction with the parties in open innovation projects more feasible (Salter, Criscuolo, & Ter Wal, 2014).

Our findings also introduce process formalization as a critical dynamic capability that needs to be in place for open innovation projects to succeed, explaining how successfully an individual on the project is able to manage the tension between knowledge sharing and protecting in the flexible interactive collaboration. This capability may help the parties improve their sensing capabilities through involved individuals within the interaction with external sources for better interpreting and identification of required knowledge for sharing (Jarvenpaa & Majchrzak, 2016). Also, formalized process improves the seizing capability (i.e., “the process of acting on sensed emotions by dynamically using knowledge segmentation actions”) of the parties through facilitating knowledge-segmentation actions (Jarvenpaa & Majchrzak, 2016: 16).

The process formalization presented in this study has also important implications for the literature on relational mechanisms in interorganizational collaborations, putting great emphasis on the importance of informal elements in creating trust between partner organizations to ensure collaboration success (Ring & Van de Ven, 1992, 1994). At first, it seems that there is a paradox between our findings, introducing formality into the joint technology development process, and the importance of informality and trust based relationship between organizations. In any informal and trusted relationship, there is some degree of distrust between the partners due to the concern over knowledge sharing and opportunistic risk (Lewicki et al., 1998). Particularly trust and distrust coexist between individuals in the collaboration when they want to make a decision about what knowledge can be shared that will not create problems for the home organization (Jarvenpaa & Majchrzak, 2016; Majchrzak et al., 2015). We believe that, instead of becoming a paradox, process formalization can help the parties manage distrust, particularly between individuals in deep interaction, by reducing opportunistic risk. Process formalization can reduce opportunistic risk by avoiding the ambiguity that individuals face in terms of what knowledge can be shared and what should be protected. As a result, the combination of formality and informality between the partners seems to be required to ensure open-innovation project successes without the loss of critical knowledge.

The effect of formalization on innovation activities and routines has been demonstrated in past research about innovation performance, but typically it has been examined in the context of internal innovation (Brunswicker & Vanhaverbeke, 2015; Du et al., 2014; Foss et al., 2011). Our study also contributes to this literature by arguing for the importance of the joint process formalization in adapting and even shaping formal process and routines internal to firms. Much of the literature on external search has focused on the critical role of formalization in the context of internal innovation to improve internal capabilities for managing innovation (Brunswicker & Vanhaverbeke, 2015), integration of knowledge (Foss et al., 2011), etc. However, the possible influence of joint process between the parties on internal formalization has not been specifically studied in the literature. In other words, the role of joint process has been ignored as a determining factor in formalization of activities and routines internal to parties. Internal formalization can prevent the development and implementation of the joint process formalization particularly, when the internal processes are inconsistent with the joint process (Doz, 1996; Ness, 2009). For example, when home organizations' formalized process have limited communication channels between individuals in open innovation projects to talk to each other to understand the technological specifications that should be followed, the implementation of joint process formalization as a critical dynamic capability is limited (Faems et al., 2008). Our study suggests that the internal innovation activities are better when formalized based on the joint process to support the implementation of the formalized joint process.

Our findings clearly show that the problem attribute (i.e., complexity) affects the formalization of the joint development process, therefore we assert that formalization is a project-specific concept. Thus, only focusing on firm level characteristics (and aggregated data) may lead to incomplete understanding (Du et al., 2014; Felin & Zenger, 2014). Our study suggests that for studying and building theory using external sources particularly, formalization of joint technology development in open innovation projects, we have to consider not only industry (van de Vrande et al., 2009; Veugelers & Cassiman, 1999) and firm level characteristics, but also the role of projects attributes.

Finally, our findings may help to explain why some open innovation projects fail, as documented in previous studies (Majchrzak et al., 2015). One implication is to examine the dialogue of the parties to determine how they are self-regulating. Another implication is studying how inconsistency between internal practices of the parties can limit the implementation of joint development process formalization, thereby limiting the sensing and seizing capability of the collaboration (Jarvenpaa & Majchrzak, 2016).

## 3.6 Limitations and Future Research Directions

This study has several limitations. Our findings are based on cross-sectional data and causal relation is problematic to establish based on cross-sectional dataset. For example, capability to establish process formalization may affect firm's decision to intensively interact with external sources in their open innovation projects (i.e., it is possible to have opposite direction between depth of engagement and process formalization). Future research applying longitudinal and/or experimental designs can be helpful in making causality between variables of this study clear. But, accessing senior managers to collect longitudinal data or run experiment is very difficult as they are very busy. Also firm policies prevent senior managers from participation in research studies because of confidentiality of information. Thus, running such a study for clarifying causality is very difficult. Moreover, we collected data from a single source (i.e., one respondent from each project completed the survey). Thus, this study is vulnerable to common method variance. Although we applied some strategies to reduce this problem when developing the questionnaire and tested CMV based on a statistical test, but to decrease potential common method variance a multi-source approach should be applied in the future studies. Another limitation of this study is that we did not directly measure whether firms completed their open innovation project without losing critical knowledge. We only relied on theoretical argument to explicate the role of process formalization in knowledge protecting, which in turn leads to project successes (Jarvenpaa & Majchrzak, 2016). As a result, we encourage future studies to directly measure the level of losing critical knowledge in open and collaborative projects.

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# Chapter 4: What's Your 'Open Innovation Mode'? Problem Types and Open Innovation Governance Modes[14]

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## 4.1 Abstract

Firms use a variety of governance modes to manage their open innovation projects, ranging from bilateral partnerships to open innovation communities. This paper examines how the choice of a particular mode is influenced by two project attributes: Problem complexity and hiddenness of knowledge. Using a dataset of 104 open innovation projects, we compare different problem types and the preferred modes for them: markets, partnerships, platforms, or communities. The choice of market and platforms seems to be straightforward. However, using partnerships and communities is challenging. Our results guide managers in choosing the mode that 'fits' best with a particular problem type.

## 4.2 Introduction

Open innovation is becoming pervasive among large firms; they are increasing investments in both financial and managerial resources devoted to open innovation (Brunswicker, Chesbrough, & Bagherzadeh, 2016; Chesbrough & Brunswicker, 2014). There is quantitative and qualitative evidence that greater openness may increase a firm's innovation capacity, that is, its ability to solve a firm's central innovation problems effectively and efficiently (Felin & Zenger, 2014; Jarvenpaa & Välikangas, 2014; Laursen & Salter, 2006; Majchrzak, Jarvenpaa, & Bagherzadeh, 2015). While this evidence may convince managers to shift from closed towards open innovation, it does not provide an answer to the question of which governance mode of open innovation is the best choice for a particular project or innovation problem. Indeed, open innovation comes in various governance modes (henceforth 'modes'): Bilateral partnerships, licensing agreements, innovation contests, and innovation crowdsourcing are examples of the various modes from which a manager may choose (Felin & Zenger, 2014; Malhotra & Majchrzak, 2014).

When exploring existing cases studies on open innovation, we learned that in some cases managers prefer to use more traditional modes such as bilateral partnerships (Keil, Maula, Schildt, & Zahra, 2008), while in other cases they use more ‘novel’ modes such as open innovation contests or challenges (Malhotra & Majchrzak, 2014) that involve a large number of problem solvers, including ‘strangers (Bahemia & Squire, 2010; Chesbrough, 2012). In light of this variety, a manager’s key decision shifts from the choice between open versus closed innovation to a choice among multiple modes with varying degrees of ‘openness’. For example, the open innovation modes that biotechnology and pharmaceutical companies select to use the knowledge of external partners in their open innovation projects vary along the two stages of bio-pharmaceutical R&D process, namely drug discovery and drug development (Bianchi, Cavaliere, Chiaroni, Frattini, & Chiesa, 2011; Chiaroni, Chiesa, & Frattini, 2009). Most of the existing advice on selecting the right open innovation modes takes a firm-level perspective. For example, some studies suggest that factors specific to a particular firm or industry, such as firm size or environmental uncertainty, are critical contingencies for the effectiveness of a particular open innovation mode (van de Vrande, Vanhaverbeke, & Duysters, 2009; Veugelers & Cassiman, 1999). However, advice drawn from such studies may mislead managers as it neglects the particularities of the problem that the firm wants to solve in a specific project.

Indeed, the recent, more theoretically-driven discussion on open innovation suggests problem attributes determine the effectiveness of a particular mode (Felin & Zenger, 2014). One of these attributes is the complexity of the problem to be solved in a particular project. For complex technological problems many technical and market related factors interact in an unpredictable manner. To understand these complex interdependencies, a transactional towards open innovation may be insufficient, as only with adequate dialogue and knowledge exchange can people grasp these complex interdependencies (Felin & Zenger, 2014; Gavetti & Levinthal, 2000; Nickerson & Zenger, 2004). This might explain why managers often opt for traditional partnerships in which trusted knowledge exchange is possible (Felin & Zenger, 2014).

However, there is another project attribute, namely 'hiddenness of knowledge', that might explain why managers choose more novel modes such as open innovation contests and open innovation intermediaries, which have become more popular in recent years in the discussion of open innovation (Afuah & Tucci, 2012; Jeppesen & Lakhani, 2010; Malhotra & Majchrzak, 2014). If a firm has little understanding about which technological area to explore for a solution or where the optimal solution is located, they might opt for modes that involve a large number of problem solvers. Open innovation challenges and contests bring more 'eyeballs' to the problem by broadcasting the problem widely to a large pool of potential problem solvers (Malhotra & Majchrzak, 2014). This diverse crowd may provide access to hidden and unexpected ideas that the internal project team had not been aware of at the beginning of the project (Malhotra & Majchrzak, 2014). However, open innovation contests also require firms to communicate widely and raise additional management challenges, including how to design appropriate incentive structures and mechanisms for preventing loss of control over innovation-related know-how. So does the hiddenness of knowledge trigger managers to choose a contest over a partnership?

In sum, the existing work on open innovation on the interplay between problem types and open innovation modes is fragmented and comparative cross-project analysis is needed to make an empirical claim about which is the right open innovation mode for a particular project. We need more integrated and nuanced advice on the archetypes of open innovation modes and their fit with a particular innovation problem. To create such a nuanced view, this study asks the following questions: *Which open innovation modes do managers choose for projects characterized by different levels of complexity and hiddenness of knowledge?* We take a two-stage approach to answering this question by combining a survey study with a case study analysis. First, we explore data of 104 open innovation projects in large firms in the US and Europe collected in a global open innovation survey in 2014 and 2015. We looked specifically at the contingent role of the project attributes, namely complexity and hiddenness of knowledge, in the choice of a particular open innovation mode. We complement this quantitative analysis with a case study analysis of six successful open innovation projects to gain deeper insight into the interplay between problem types and open innovation modes.

Our findings show that firms use open innovation for four different problem archetypes. Our study reveals a clear link between a particular problem type and a manager's choice among four open innovation modes: (1) Markets, (2) open innovation partnerships, (3) open innovation platforms, and (4) open innovation communities. These modes differ with respect to three governance dimensions: (1) the communication channels used to interact with external partners to support knowledge sharing, (2) the incentive structures used to motivate the external partners to engage in the problem solving process, and (3) and the control over IP to appropriate value from the problem solving process (Felin & Zenger, 2014). Thus, the four open innovation modes differ in terms of the degree of support for solution search. If the project is only challenging in one dimension, such as hiddenness of know-how, the choice to be made is clear: Projects with high hiddenness of know-how trigger the use of open innovation platforms that make use of diversity of sources for solution search. However, grand challenges, highly complex projects in which know-how is truly hidden, are puzzling. Our results have immediate managerial implications. They provide managers with a decision framework to guide theoretically grounded and empirically supported decisions on how to choose the right open innovation mode for the problem at hand.

## 4.3 Attributes of Open Innovation Project: A Problem Solving Perspective

There are a variety of firm-level and industry-level attributes that are important when managing open innovation (van de Vrande et al., 2009; Veugelers & Cassiman, 1999). However, the recent work on open innovation calls for a project-level and problem-centric view (Du, Leten, & Vanhaverbeke, 2014; Felin & Zenger, 2014; Macher, 2006; Nickerson & Zenger, 2004). In essence, open innovation serve the firm's interest in solving innovation problems in an effective and efficient way. Such open innovation projects may relate to different kinds of innovation problems. Felin and Zenger (2014), in their recent theoretical discussion on open innovation, suggest that depending on the nature of the problem, firms have to engage in different solution search approaches. They differentiate between two different search approaches: 1) directional search (also called trial and error search), which describes a search processes guided by feedback or experience through trial-and-error testing a various kinds of solutions; and 2) theory-driven search (also called cognitive search), referring to a processes in which the problem solvers evaluate the results of potential solutions by analyzing the underlying mechanisms of why the solution would be potentially successful or not before the solution is actually implemented. Felin and Zenger (2014) state "[theory driven/cognitive] search is necessary when problems are complex" whereas "directional search is warranted when problems are decomposable [not complex]" (Nickerson & Zenger, 2004). Others argue that “problems also differ in the degree to which the sources or location of knowledge deemed relevant are known to the manager” which require different search approaches (broad search and local search) (Felin & Zenger, 2014; Fernandes & Simon, 1999). It is argued that a broad search is needed when the location of knowledge is unknown to the project team. These theoretical contributions suggest that problem complexity and hiddenness of knowledge are two important problem attributes that make one of the search approaches more appropriate than the other. This theoretical discussion resonates with the broader literature on open innovation, which suggests these two project attributes are important when choosing a particular mode for a project. In addition of these two problem attributes, the tacitness or noncodifiability of problem (i.e., knowledge and information related to problem) is considered as another problem attribute that can affect the selection of search approach (Afuah & Tucci, 2012). Modularity of problem is also studied as another attribute that can play an important role in solution search (Afuah & Tucci, 2012). However modularity of problem is treated as a separate attribute, but it is highly related to complexity of problem. Most simple problems are easy to decompose and more modular. In the current study, we focus on the following two important problem attributes based on the recent more theoretical and comparative discussion of governance mode for open innovation (Felin & Zenger, 2014).

### *4.3.1 Problem Complexity*

Problem complexity is defined based on the number of involved tasks, elements, or knowledge sets and the degree of interdependency among them (Fernandes & Simon, 1999). In an abstract way, complex innovation problems imply that the final technological solution is influenced by multiple factors. Complex problems are comprised of a large number of highly interdependent tasks, elements, and knowledge sets. Therefore, complex problem are difficult to decompose as one part of the solution, such as technology, might influence another part of the solution, and also the overall value of the solution (Fernandes & Simon, 1999). An example of a complex problem that one of the companies in our case studies was attempting to solve is related to developing a new process technology for the elimination of vacuum-based processes in the production of electronic devices including many technical and market related factors interact in an unpredictable manner. Another complex problem from our case studies is related to developing a new technology for rendering movies, which requires different interdependent knowledge sets such as cloud computing and animation technologies.

### *4.3.2 Hiddenness of knowledge*

The hiddenness of knowledge is defined in terms of the degree to which the sources or locations of knowledge deemed relevant to develop a solution for the problem at hand are known to a firm and project team (Felin & Zenger, 2014; Fernandes & Simon, 1999). Sometimes, firms and project teams do not know which external parties have the relevant knowledge and ability to solve a firm’s innovation problem. This hiddenness of knowledge creates many difficulties in solving innovation problems as firms are not able to start a collaboration or contract until they have identified the individual or company with whom the relevant solution knowledge lies. An example of hidden knowledge from our case studies is related to Pfizer project related to design a tech-enabled locker for distributing prefilled syringes. This project required really novel solution concepts. However, the novel and optimal solutions were unknown for Pfizer.

## 4.4 Open Innovation Modes for Solving Innovation Problems

As mentioned earlier, firms can choose from a variety of modes to govern the problem solving process (Chesbrough & Brunswicker, 2014). While some firms still opt for more traditional modes such as alliance partnerships, joint ventures (Keil et al., 2008), and licensing contracts (Arora & Fosfuri, 2003; Li-Ying & Wang, 2015), others make use of the crowd (Afuah & Tucci, 2012; Kathan, Hutter, Füller, & Hautz, 2015; Malhotra & Majchrzak, 2014) to solve an innovation problem. For example, General Electric (GE) launched the Ecoimagination challenge and invited creative entrepreneurs, small businesses, and creative thinkers via an open call to submit their ideas and solutions for a particular clean-tech problem (Chesbrough, 2012).

In this study, we build upon Felin and Zenger (2014) and differentiate four archetypes of open innovation modes: (1) Markets, (2) open innovation partnerships, (3) open innovation platforms, and (4) open innovation communities. These archetypes differ in terms of three governance dimensions: (1) the communication channels used to interact with external partners to support knowledge sharing, (2) the incentive structures used to motivate the external partners to engage in the problem solving process, and (3) and the control over IP to appropriate value from the problem solving process (Felin & Zenger, 2014; (Brunswicker, Bagherzadeh, & Lamb, 2016). Table 4.1 provides an overview of four different modes in terms these three governance dimensions, which we will discuss in more detail below.

**Table 4.1: Comparative Analysis of Open Innovation Modes based on Three Governance Dimensions**

| | | Markets | Partnerships | Open Innovation Platforms | Firm's Open Innovation Communities |
|---|---|---|---|---|---|
| **Three governance dimensions** | **Communication channels** | Limited | Strong | Limited but wide | Strong and wide |
| | **Incentives** | Medium to highpowered incentives | High-powered, cooperative | Moderate incentives | Low to moderate incentives |
| | **Control rights over technology and knowledge (IP)** | Usually high (and externally owned) | Negotiable between firm and external partners | Varied | Varied |

## *4.4.1 Markets*

When engaging in markets and contracts, firms engage in transactional arrangements, usually with a single partner who owns a particular technology (Dahlander & Gann, 2010). Due to the contractual relationships, the external partner appropriates immediate value from their solution, and the control over intellectual property (IP) is usually quite transparent (Aghion & Tirole, 1994). Thus, the incentives to engage in the open innovation project are high. Also, compared to open innovation partnerships and communities (which will be discussed later), this mode implies little communication between the project team and the external partner. As a result, the exchange of knowledge is usually relatively low in a contractual relationship. Further, the diversity of sources involved is low.

### *4.4.2 Open Innovation Partnerships*

As a more collaborative category of mode, firms engage in a more open and interactive process of solving an innovation problem when opting for a partnership mode (Felin & Zenger, 2014). In partnerships, the allocation of control rights over existing and emerging technologies and knowledge is negotiable (Leiponen, 2008), ensuring effective value appropriation coming from joint collaboration. Therefore, external partners are motivated to intensively engage in the open innovation project. Relative to markets, we can think of partnerships as a set of governance modes with a more multidimensional and collaborative type of problem solving, providing richer communication channels between firms and their external partners (Ness, 2009). Thus, extensive knowledge sharing is supported by open innovation partnerships but at the same time the diversity of sources is limited.

### *4.4.3 Open Innovation Platforms*

Open innovation platforms imply that firms tap into a large number of problem solvers who potentially have relevant know-how to solve the problem of the firm, usually via a call via the internet (Malhotra & Majchrzak, 2014). Open innovation platforms subsume governance modes labeled as innovation tournaments, contests, or competition. Some firms launch such platforms on their own. In some cases, however, they opt for open innovation service providers such as Ninesigma, which have access to a large pool of problem solvers. These service providers offer firms the ability to access the long-tail of possible solutions without having to manage the overall problem solving process[15]. In open innovation platforms the control over IP is negotiable, and very often firms establish strong IP control over new solutions. Open innovation platforms imply a competitive situation among the problem solvers, who can range from creative individuals to specialists to start-up companies. Compared to markets and partnerships, the incentives to engage in the open innovation project are moderate. When using platforms, firms typically use incentive mechanisms such as prize money to compensate the participants who develop valuable solutions. Firms have a broad communication channel with a wide range of external partners in open innovation platforms but this communication channel does not provide for deep interactions. As a result, this mode supports access to a wide variety of external sources, but knowledge sharing is limited.

### *4.4.4 Firm's Own Open Innovation Community*

Firms set-up their own community to solve innovation problems in a collaborative manner with a group of individuals and organizations who share a common innovation vision (Dahlander & Piezunka, 2014). There are multiple motives for firms or individuals to participate in a firm's sponsored open innovation community such as learning about new technologies or market trends, building reputation, or gaining efficiency benefits due to the sharing of innovation risks and costs (Füller, 2010). Control over IP is usually negotiated before the launch of the community and implemented with the help of legal terms and social norms and rules (Fauchart & Von Hippel, 2008). Overall, the incentives to engage in the open

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[15] http://www.ninesigma.com/(February, 2016)

innovation communities are high. Open innovation communities create a strong communication channel between the involved actors, making the process of problem solving highly interactive. Open innovation communities have the advantage of a high diversity of actors and communities support knowledge sharing among the diverse members.

Also, the four open innovation modes differ in relation to the degree of support for solution search needs namely, (1) knowledge sharing, and (2) the diversity and number of actors involve (see Table 4.2) (Brunswicker at al., 2016).

**Table 4.2: Comparative Analysis of Open Innovation Modes with respect to Their Effect on Solution Search Needs**

| Solution search needs | **Markets** | **Partnerships** | **Open Innovation Platforms** | **Firm's Open Innovation Communities** |
|---|---|---|---|---|
| **Knowledge Sharing** | Limited | Strong | Limited (Problem) | Strong and multidimensional |
| **Diversity of sources involved** | Low | Low | High | High |

## 4.5 About the Research: Design, Data, and Methods

To furnish complete understanding of the interplay between problem attributes (i.e., complexity and hiddenness of knowledge) and open innovation modes, and to ensure well-founded conclusions, we combined a survey study with a case study analysis. In essence, our research method is both explorative and explanatory.

### 4.5.1 Survey Study

First, we drew upon a survey database of 104 open innovation projects in large firms in Europe and the United States collected as a global open innovation executive survey between December 2014 and August 2015. Our sample includes large stock market listed firms with annual revenues of more than $250 million and more than 1,000 employees. First, the survey was sent to senior executives (e.g., Chief Executive Officers, Chief Technology Officers, R&D Director, Open Innovation Manager, etc.) as primary contacts at the firms' headquarters. They were asked to select an open innovation projects that they have completed within the last two years. To make sure they selected an open innovation project, we provided them with a definition of open innovation[16] at the beginning of the survey. To minimize key-informant bias, we asked our primary contacts to assign the most suitable respondent based on the selected open innovation project (e.g., project manager). This survey includes a set of measures at the project level for different problem attributes and different types of open innovation modes that improves previous survey-based researches on open innovation. Therefore, our empirical study significantly advances existing survey-based empirical examinations of open innovation modes, which are mostly concerned with the more traditional level of firm aggregated data (Faems, Van Looy, & Debackere, 2005; Laursen & Salter, 2006). A number of statistical tests were conducted to assess non-response bias. The results showed that our sample was not significantly different from the sample frame in terms of revenue, number of employees, and firm age. We also compared early and late respondents on key

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[16] Open innovation implies that your organization makes purposive use of external know-how and capabilities and/or external paths to market, as your organization looks to accelerate internal innovation, and expand the markets for external use of internal innovation, respectively (Chesbrough, 2006).

variables of this study to test late-response bias. We found no significant differences, confirming there is no late-response bias. Perceptual measures were applied to operationalize the constructs based on their definition in this study, explicate in Table 4.4.

We followed a three-step exploratory statistical analysis for the survey study to explore optimal fit between problem type and open innovation mode. First, we classified open innovation projects that have similar problem attributes (i.e., complexity and hiddenness of knowledge) into homogeneous clusters. Second, open innovation projects were clustered based on open innovation modes utilized on a specific project to develop homogenous groups of projects in terms of open innovation modes. Third, we examined how problem attributes relate to open innovation modes.

### *4.5.2 Complementary Case Studies*

Secondly, to complement the quantitative analysis, we performed a case study analysis of six successful open innovation projects from our large survey sample. We conducted interviews with one or several project members via a semi-structured interview protocol (lasting between 30 to 45 minutes) between June and October 2015[17]. We also collected secondary data from company websites and other publically available information (such as documents provided by interviewees, press reports, company websites, etc.) to complement the primary data. All of interviews were recorded. We used a narrative interview technique to

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[17] Just for one case, we only relied on secondary data.

develop a deeper understanding about the nature of the problem attributes, the particularities of the open innovation mode in terms of the three governance dimensions (IP, communication channels, and incentives). We also probed the interviewees on the rationale behind choosing a particular mode for their project.

**Table 4.3: Case Information**

| | Firm | Name and Context of Project | Data collection |
|---|---|---|---|
| 1 | Clariant | **Chemical catalyst design:** The project aimed to enrich Clariant's portfolio of ActiSorb series of catalysts and adsorbents to help their customers achieve greater efficiency for the purification of hydrocarbon feedstock. | • More than 100 pages of secondary information |
| 2 | Bosch | **Non-electrochemical energy storage technology:** The project had the objective to develop a new non-electrochemical energy storage solution. | • 1 Interview<br>• More than 50 pages of secondary information |
| 3 | Pfizer | **Prefilled syringes:** The project was related to the design of a tech-enabled locker for prefilled syringes. | • 1 interview<br>• Secondary information |
| 4 | Eli Lilly | **Drug design:** The project was related to discovering new chemical structures (compounds and molecules) with particular biological activity for developing new drugs. | • 1 interview<br>• Secondary data |
| 5 | Evonik | **Non-vacuum process:** for The objective was to develop a new technological solution for elimination of vacuum-based processes in the production of electronic devices. | • 2 interviews<br>• Secondary data |
| 6 | HP Labs | **Rendering movies technology:** The project was related to developing a new technology for rendering movies. | • 2 Interviews<br>• More than 100 pages of secondary information |

**Table 4.4: Constructs, definition, and measures**

| Construct | Definition | Measures | Description |
|---|---|---|---|
| Problem complexity | It refers to the number of involved tasks, elements, or knowledge sets and the degree of interdependency among them. | It involved a large number of highly interdependent tasks (they could not be completed independently) | The respondents were asked to describe the problem being solved in the project based on these two measures on a seven point Likert scale (1, Strongly Disagree; 7, Strongly Agree). Pearson correlation (0.55 with P-value < 0.001) between these two items shows an adequate internal consistency which is higher than the cut-off value of 0.25 usually accepted. Thus, we calculated the mean score for these two items to have an overall score for the problem complexity. |
| | | New tasks and interdependencies between them emerged unexpectedly | |
| Hiddenness of required knowledge | It refers to the degree to which the sources or locations of knowledge deemed relevant are known for firms and project teams. | We were able to identify the know-how required to solve the problem before we started interacting with external sources[18]. | The respondents were asked to assess the project on a seven point Likert scale where 1 refers to "strongly disagree" and 7 refers to "strongly agree". |
| Open innovation modes | It refers to mechanisms used to coordinate or govern the problem solving process with external partners. | Contract/market | Respondents were also asked to select the open innovation modes applied by the project team during problem solving (binary variable). |
| | | Partnership | |
| | | Open innovation platforms (contests or open innovation intermediaries) | |
| | | Firm's own open innovation communities | |

[18] This item was used as a reverse item for measuring the hiddenness of required knowledge.

## 4.6 Findings

First, we explain empirical evidence on problem types by introducing a typology of four problem types followed by evidence on open innovation modes applied by the project team. After that, we answer the question "how do problem types and open innovation modes interact?"

### *4.6.1 A Typology of Project-Level Problem Types*

Our aim was to classify the problems addressed in the 104 open innovation projects. Thus, our first step was to identify distinct clusters of open innovation projects based on their problem attributes. On average, the 104 open innovation projects showed a relatively high complexity and moderate hiddenness of knowledge. The mean values for complexity and hiddenness of knowledge, both measured on a scale from 1-7, are 5.04 (standard deviation=1.47) and 3.49 (standard deviation=1.82) respectively. These two variables (Pearson correlation coefficient = -0.038, P-value = 0.7) are not correlated, suggesting that complexity and hiddenness of knowledge are distinct problem attributes (Multicollinearity, which is a notable difficulty in cluster analysis and may overweight one of variables, is not an issue) (Punj & Stewart, 1983).

Following Hair et al. (1998), we performed a two step procedure to cluster our projects using these two attributes. First, we conducted a hierarchical cluster analysis using the most commonly used Ward's method, because this method provides the most homogenous results within a cluster and heterogonous results across clusters, and the squared Euclidian distance measure. In addition to the Ward's method, we also applied other methods for hierarchical clustering such as between-group and within-group linkage to check the degree of consistency between solutions (i.e., reliability). To decide upon the number of clusters, we relied on the agglomeration coefficients. We also inspected the dendogram. Based on the results, we took the seeds of the three-cluster, four-cluster, and five cluster solution to define a starting solution for the K-means clustering (Punj & Stewart, 1983). After conducting the K-means clustering, we investigated the interrater reliability of three solutions between the hierarchical and the K-means clustering, using a Kappa test. We found a high degree of consistency for the four-cluster solution (with the highest Kappa coefficient of 0.86). The four-cluster solution was also interpretable and comparable in size. Thus, the four-cluster solution seemed to be the most appropriate number. To identify which clusters were significantly different based on involved variables to check the validity of the four-cluster solution, we applied the Analysis of variance (ANOVA) test and multiple two-sample T-tests. Based on Analysis of variance (ANOVA), the two attributes showed significant differences at P-value $< 0.001$ between four clusters. Projects in cluster 3 and 4 are significantly more complex than those in cluster 1 and 2. The required knowledge is more hidden (more unknown) for projects in cluster 2 and 4 compared to those in cluster 1 and 3. We also checked the validity of the four-cluster solution based on two external variables: (1) breadth of engaging with external sources in terms of the number of external sources, and (2) depth of engaging with external sources in terms of spending time to access or share know-how which were not used for clustering (Ketchen & Shook, 1996). ANOVA test showed significant differences with respect to both breadth (P-value= 0.075) and depth (P-value= 0.049) across four clusters. In essence, we identified four distinct project types. Table 4.5 describes the four clusters with respect to the two problem attributes.

**Table 4.5: Four Clusters of Open Innovation Projects based on Problem Attributes**

| Problem Attributes (mean) | C1: Simple Problem/ Known Knowledge (n=25) | C2: Simple Problem/ Unknown Knowledge (n=13) | C3: Complex Problem/ Known Knowledge (n=36) | C4: Complex Problem/ Unknown Knowledge (n=30) | ANOVA F-value (df=3) | T-test t-value |
|---|---|---|---|---|---|---|
| Complexity (5.04) | 3.46 | 3.27 | 6.03 | 5.93 | 88.973$^{*}$ | 3, 4 > 1, 2$^{**}$ |
| Hiddenness (3.49) | 2.20 | 5.85 | 2.08 | 5.23 | 139.890$^{*}$ | 2,4 > 1,3$^{**}$ <br> 2 > 4$^{*}$ |

Note: C = Cluster; n = Number of projects in each cluster; * = P < 0.05; ** = P < 0.001

***Problem Type 1: Well-structured problems***

Cluster 1 (24% of the open innovation projects in our sample) describe projects that address a problem that is well-structured. The problem to be solved can be delineated from other problems and tasks. The problem can be well described, and translated into requirements, as the set of factors that influence the problem seem to be manageable. In type 1 problems, the project team has a clear understanding of the location of relevant knowledge for solving these problems. In essence, the solution know-how is not hidden but accessible. To illustrate this problem type, we turn to the Clariant chemical catalyst design project, one of six of our case study projects that we explored more deeply. In this project, Clariant, a world leader in specialty chemical manufacturing, wanted to complement its other ActiSorb adsorbent products to provide integrated solutions to meet the requirements of its clients for greater efficiency for the purification of hydrocarbon feedstocks [19]. Developing a new technology for purification of

[19] <http://www.catalysts.clariant.com/bu/Catalysis/internet.nsf/023cfbb98594ad5bc12564e400555162/1f2fbe0521d9fc23c1257b1e0032460f?OpenDocument>. (February, 2016)

hydrocarbon feedstocks describes a well-structured problem as it did not relate to highly interdependent knowledge sets. Clariant understood the interdependencies among different parts of the technology very well. Moreover, they were aware of a fast and safe technology for removing mercury from natural gas that would provide a technical solution for the problem. This technology was developed by a team at Queen's University in collaboration with Petronas, and is called "HycaPure Hg" technology[20]. The Petronas Vice President of the Technology and Engineering Division stated the technology was "already used at Petronas's gas processing plants a few years and it demonstrated high adsorbent capacity and stable performance"[21].

***Problem Type 2: 'Holy grail' problems***

Problems that fall in our cluster 2 (12.5% of the open innovation projects in our sample) are also relatively simple in a sense that the factors that describe the problem are not particularly interdependent. However, the location of relevant knowledge for solving them is not known and accessible for the internal stakeholders. Colloquially, companies refer to such problems as 'holy grail' problems, as they cannot identify the right solution knowledge even though they are able to describe the problem. One of our case projects that we explored deeper illustrates the nature of a 'holy grail' or a simple but obscure problem. In the non-electrochemical energy storage technology project, Bosch had a plan to develop a new non-electrochemical energy storage solution. Such a solution

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[20]<http://www.rsc.org/chemistryworld/2015/03/mercury-removal-ionic-liquid-natural-gas>. (February, 2016)

[21] <http://www.chemanager-online.com/en/news-opinions/headlines/clariant-and-petronas-sign-licensing-collaboration>. (February, 2016)

should maximize the use of renewable energy while ensuring lower cost and a more reliable electricity supply[22]. Before the launch of the open innovation project, Bosch was still relying on traditional electrochemical energy storage technology. With the emphasis of greater sustainability, their innovation goal was to identify an alternative technology that could substitute the existing electro-chemical storage solution. Non-electrochemical technology was comprised of a limited number of technological areas and knowledge sets. Also, the interdependencies between different parts of technology that affect the success of the project were well-structured and understood. Moreover, at that time, new non-electrochemical technologies were already available and tested. As an open innovation manager at Bosch described it “we knew that there were technological [solutions] to fulfill our technical requirements” but we had no idea about the optimal and best solutions. Another project in our cases also falls into this category. In the Pfizer prefilled syringes project, Pfizer was focused on the design of a tech-enabled locker for prefilled syringes. “Essentially, this was a way that we could better understand when people are taking medication that's in a syringe - that they were actually adhering to [prescribed protocol doses],” mentioned the Open Innovation Manager at Pfizer. The design was relatively simple as it was relatively well defined and independent from other technical or market-related factors and challenges. However, this project required novel solution concepts and the optimal solution was unknown for Pfizer. Even though they have developed several designs before, they have not been successful in finding an effective solution.

[22] <https://boschenergystoragesolutions.com/>. (February, 2016)

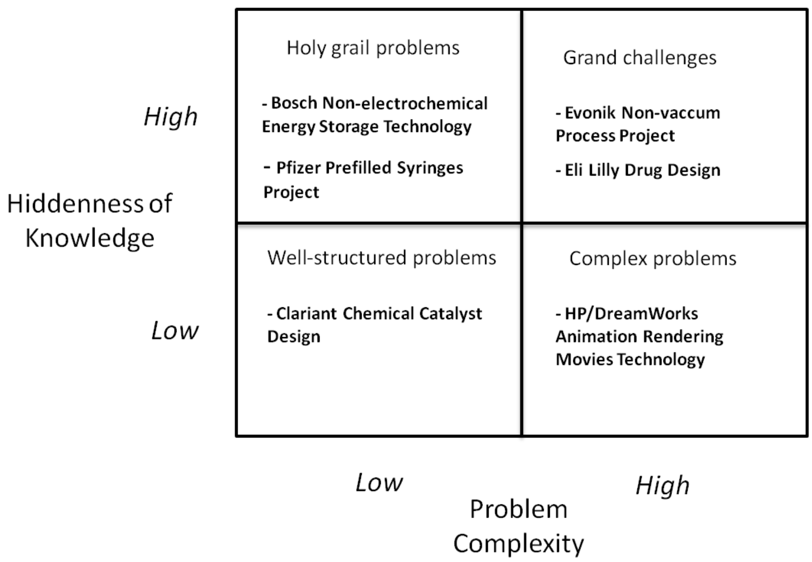
***Problem Type 3: Complex Problems***

They (34.7% of the open innovation projects in our sample) are very complex problem as there are so many different factors that influence the overall problem, and these factors interact in a complex way. Despite this complexity, the internal open innovation team is aware of the location of relevant knowledge for solving this type of problem. The challenge lies in tackling the complexity of the problem space. The HP/DreamWorks rendering movies technology project, falls into this category. This complex open innovation project at HP labs was focused on the development of rendering technologies. Since 2003, HP was focused on developing a new technology for rendering movies. At that point in time, the technology was completely new to the market. The project was technologically complex because it required different parts and knowledge sets such as data storage computing, animation technologies, and animation and these technologies are particularly interdependent. However, HP had developed a significant level of understanding of the broader technological problem and was able to identify the technological area and also the leading expert in the field of animation. In short, they could easily identify the technology area and right partner that were of relevance for their innovation problem.

***Problem Type 4: Grand Challenges***

The projects that fall in category 4 (28.8% of the open innovation projects in our sample) are complex and at the same time the location of relevant technological know-how or solution potentials for solving the grand problems is not accessible. They represent truly 'grand challenges' for firms. Two of our case studies were related to such a grand challenge. In the Evonik Non-vacuum process project, Evonik focused on developing a new technology to eliminate vacuum-based processes in the production of electronic devices. Indeed, this technology is essential for applications such as flexible and printable electronic devices. It is a central emerging technology in the field of chemical materials and related to a very uncertain and emerging technological area. The technology field was very novel and uncertain, and also customers' requirements for the technology were not yet well-defined. Thus, there were multiple factors that influence the process of electronic device production that needed to be taken into consideration and made the problem complex. Further, the potential solution knowledge was beyond the current knowledge of Evonik's scientists or its existing partners. The potentially relevant solution concepts were unknown for Evonik. The Eli Lilly drug design project also related to a grand challenge. The project was focused on drug discovery, which is a relatively complex process as the compounds and molecules interact in a complex and non-linear way. Discovering new chemical structures for drugs implies a level of uncertainty in the potential biological interactions and activities of a compound. This makes the nature of this problem highly complex. Further, the ideal chemical structure for a desired pharmaceutical application is often unknown, and the network of scientists and researchers working on molecules for a wide range of applications is widespread. This makes assessing the location of the best solution very difficult. Figure 4.1 illustrates our problem typology and displays the case example projects used to illustrate the nature of the problem.

**Figure 4.1: Typology of Four Problem Types and Case Study Examples**



### 4.6.2 Empirical Evidence on the Use of Different Open Innovation Modes

Next, we focused on the categorization of our projects with respect to the dominant open innovation mode used to solve the project's innovation problem. In essence, we explored how the 104 open innovation projects group together with respect to the open innovation modes adopted by the project team. To realize this, we conducted a two-step cluster analysis using a log-likelihood similarity measure. We applied a two-step method as our variables are binary (This method can cluster categorical variables as opposed to other methods of clustering such as hierarchical and non- hierarchical cluster analysis, which require continuous variables). To cluster our projects, we used binary variables measuring whether the project used a particular type of different open innovation method or not. Respondents were able to select multiple modes for a particular project. Based on the Silhouette measure of cohesion and separation, the four-cluster solution with cluster quality around 0.5 (considered as a good quality) were selected. The four-cluster solution provided us with interpretable clusters. Also, we checked the validity of the four-cluster solution based on three external variables (breadth of engaging with external sources, depth of engaging with external sources, and IP control) as it is the standard approach to validate clusters (Ketchen & Shook, 1996). ANOVA test showed significant differences in relation to the both breadth (P-value= 0.013) and depth (P-value= 0.015) across four clusters. The results showed that projects applying open innovation platforms and community had interaction with a wide variety of external sources (greater number of sources) compared to those projects with markets and partnerships mode. Also, Chi-square test revealed significant differences regarding the IP control over emerging technologies among four clusters (P-value=0.002). They support the validity of the four-cluster solution. Table 4.6 describes the four clusters of open innovation projects with respect to the clustering variables used. We also present which categories our case examples fall into in this classification

**Table 4.6: Four Clusters of Projects based on Open Innovation Modes**

| Open Innovation Modes<br><br>(Frequency in total sample) | C1: Markets (n=41) | C2: Open Innovation Platforms (n=13) | C3: Community (n=36) | C4: Partnerships (n=14) |
|---|---|---|---|---|
| Markets/Contracts (71.2%) | Yes (100%) | Yes (69.2%) | Yes (66.7%) | No (100%) |
| Partnerships (51%) | No (63.4%) | No (69.2%) | Yes (77.8%) | Yes (11.3%) |
| Firm's Innovation Community (34.6%) | No (100%) | No (100%) | Yes (100%) | No (100%) |
| Open Innovation Platforms (21.2%) | No (100%) | Yes (100%) | No (75%) | No (100%) |
| Case example | Clariant chemical catalyst design | Bosch non-electrochemical energy storage technology<br>Pfizer Prefilled syringes | Evonik non-vacuum process<br>Eli Lilly drug design | HP/DreamWorks rendering movies technology |

Note: C = Cluster; n = Number of projects in each cluster

We will next describe each cluster in more detail. Each cluster represents a project category in which a certain open innovation mode is dominating:

***Cluster 1: Market***

Projects in cluster ‘market’ are dominated by a contractual transactional governance mode (39.4% of the open innovation projects in our sample are represented in this cluster). In comparison to the cluster two and three, projects in this cluster rarely rely on a community or an open innovation platform. In the case “Clariant chemical catalyst design”, we found the use of this mode. To access the required technology for their innovation problem, they negotiated a licensing agreement with Petronas by which Petronas’ technology, “HycaPure Hg” technology for removing mercury from natural gas, can be used by Clariant to complement its portfolio of ActiSorb series adsorbents[23] to provide integrated solutions to meet the requirements of clients. The licensing agreement creates a strong incentive for the solution provider Petronas. It also offers Petronas with strong control over underlying intellectual property rights.

***Cluster 2: Open Innovation Platform***

The second cluster is labeled as Open Innovation Platform (12.5% of the open innovation projects in our sample are included in this cluster). Open innovation projects that fall into this category rely heavily on open innovation platforms, such as innovation contests and tournaments. These platforms make use of strong and powerful incentives to ignite the competition among the participants in the hopes to eventually have access to an innovative solution. The team of the open innovation project related to non-electrochemical energy storage technology run by Bosch falls into this category: They “used one of the existing internet based

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[23] <http://www.catalysts.clariant.com/C12576850036A6E9/2B45555E0DD48E3AC1257CA800227169/$FILE/clariant-and-petronas-sign-licensing-collaboration_en.pdf>. (February, 2016)

platforms for crowd sourcing" to find the most effective non-electrochemical energy storage solutions. They selected NineSigma as an open innovation intermediary[24] due to their reputation as a leading open innovation service provider who offers end-to-end solutions for their clients. Bosch paid a service fee to NineSigma to launch a call for proposal among their network of scientists and researchers. Strong financial incentives motivated the participation in the call. The negotiation of IP right was essential in this case. Pfizer also relied on an open innovation platform to design a tech-enabled locker for prefilled syringes. They decided to work with IdeaConnection.com, an open innovation intermediary that offers to deliver their clients "brilliant", timely, and cost-effective solutions in areas such as R&D-focused problem solving, idea generation, as well as tech-scouting. Pfizer opted for an R&D focused problem solving service as the objective was to learn about already tested solutions that could be potentially implemented. In this case, IdeaConnection also established a competition situation among the participating problem solvers. Clear IP rights were essential to ignite the participation. In both cases, the sponsor needs to at least create the option to gain usage rights to the solution developed by the external problem solver. Both project were highly successful projects, and met the objectives of the sponsor in terms of firm benefits and costs.

***Cluster 3: Open Innovation Community***

This cluster is labeled as open innovation community. It includes 34.6% of the open innovation projects in our sample. These are open innovation projects that are dominated by a firm's own innovation community. They do not make use of open innovation platforms such as contests, crowdsourcing, or open innovation

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[24] NineSigma is an open innovation intermediaries that connects firms with external sources of innovation and technology developers to facilitate innovation.

intermediaries. The Evonik case falls in this category. To find solution concepts to for the elimination of vacuum-based processes in the production of electronic devices, Evonik created their own community that integrated a diverse set of organizations and also individual experts. The community integrated potential customers in the electronics industry, universities and research centers, and equipment suppliers. In this community all partners interacted in a collaborative way, and exchanged knowledge to develop novel solutions. This community was created a joined common pool of knowledge in which social norms complemented legal mechanism (contracts) to facilitate the protection and sharing of know-how within the community. Our Eli Lilly drug design case example that deals with drug discovery also uses a collaborative virtual environment called the Open Innovation Drug Discovery (OIDD) platform that allows external problem solvers to share their new chemical designs with internal Lilly scientists. In this case, digital technologies facilitated the community members to both share as well as protect their sensitive information.

***Cluster 4: Open Innovation Partnerships***

The last cluster is labeled as Partnerships and included 13.5% of the open innovation projects in our sample. This cluster is dominated by partnerships, in which firms engage in collaborative arrangements with other organizations. Our HP/DreamWorks Animation case falls into this category. To develop a new technology for rendering films, HP strategically chose to partner with an animation technology leader (DreamWorks). The collaboration focused on mutual exchange rather than contractual and arm-length relationships. Face-to-face meetings but also virtual collaboration supported the bilateral collaboration.

### *4.6.3 The Interrelationship between Problem Types and Open Innovation Modes*

The most important question that needs to be answered next is: How do problem types and open innovation modes interact? Thus, we performed a Chi-square test to statistically explore whether there is a relationship between problem types and the open innovation modes chosen for a particular open innovation project. We applied the test to explore the preferred open innovation modes for different levels of complexity and hiddenness of knowledge. An overview of the results is summarized in Table 4.7. Also a summary of six complementary open innovation projects including the rationale for choosing particular open innovation mode is provided in Table 4.8.

**Table 4.7: Chi-square Test for Relationship between Problem Types and Open Innovation Modes**

| | | Open Innovation Modes | | | |
|---|---|---|---|---|---|
| | | Market (n=41) | Open Innovation Platform (n=13) | Open Innovation Community (n=36) | Open Innovation Partnerships (n=14) |
| Problem types | Well-Structured | Obs. 12<br>Exp. 9.9 | Obs. 6<br>Exp. 3.1 | Obs. 5<br>Exp. 8.7 | Obs. 2<br>Exp. 3.4 |
| | Holy Grail | Obs. 4<br>Exp. 5.1 | Obs. 4<br>Exp. 1.6 | Obs. 3<br>Exp. 4.5 | Obs. 2<br>Exp. 1.8 |
| | Complex Problems | Obs. 12<br>Exp. 14.2 | Obs. 1<br>Exp. 4.5 | Obs. 18<br>Exp. 12.5 | Obs. 5<br>Exp. 4.8 |
| | Grand Challenges | Obs. 13<br>Exp. 11.8 | Obs. 2<br>Exp. 3.8 | Obs. 10<br>Exp. 10.4 | Obs. 5<br>Exp. 4.0 |
| Chi square= 16.166, df=9, p-value=0.064 | | | | | |

Note: Obs. = Observed frequency of projects; Exp: = Expected frequency of projects; df = degree of freedom

The results reveal clear decision patterns and suggest that the problem type is associated with a particular open innovation mode. Indeed, the preferred open innovation mode is different across four different problem types. The Chi-squared test shows that the differences in adopting open innovation modes are statistically significant across four distinct problem types (Chi-square=16.166 with p-value=0.064). We will discuss this along the four categorizations of problem types: Type 1 – Simple (well-structured) problems, Type 2 - Simple obscure problems (holy grail problems), Type 3 – Complex problems, and Type 4 – Grand Challenges. Well-structured problems tend to ease the decision to engage in a transactional relationship and use open innovation markets to access the external know-how (e.g. via licensing agreements). Such problem types are more frequently associated with markets. In the Clariant chemical catalyst design project, they did not need to have extensive sharing with external partners as the problem was simple and well-structured. And at the same time, they were aware of "HycaPure Hg technology" which allowed for Petronas to solve their problem. Thus, they negotiated a licensing agreement with Petronas. They had to create strong incentives for Petronas to grant an exclusive usage license.

Type 2 problems - holy grail problems – are associated with open innovation platforms. These projects make use of open innovation contests or open innovation intermediaries to increase the diversity of the expertise and knowledge with the hopes to create truly novel 'outlier' solutions. Indeed, open innovation intermediaries such as Ninesigma, Innoconnection.com, or Inncentive propose to their clients, access to unique solutions that are beyond and outside of their existing area of expertise. In our case Bosch and Pfizer required access to a diverse set of technology providers to find appropriate technological solutions. Also, an extensive knowledge sharing between them and their external technology providers was not necessary as they had relatively simple and well-structured problems to be solved. Interestingly, we find that firms also use this mode for problem type 1. Apparently, diversity of solution and access to an outsider perspective may have additional benefits such as external validation of the internally known solution. For simple problems (type 1 and 2), firms tend to adopt either markets or open innovation platforms as they support required incentives to motivate the external partners to engage in the problem solving process. The selection of an appropriate mode from these two modes is affected by different levels of hiddenness of knowledge. If the location of required knowledge is unknown for the project team, they need to access a wide variety of external sources to find a proper solution. Thus, they tend to engage in open innovation platforms. As a result, the selection of the open innovation modes is influenced not only by the separate mechanisms of complexity and hiddenness, but also by the interaction of the two attributes (Heiman & Nickerson, 2004).

Problems type 3, complex problems, are associated with the choice of a firm sponsored open innovation community. This is a rather surprising finding as theoretically, one would expect that managers choose communities to solve grand challenges (Felin & Zenger, 2014). However, we also learn that firms opt for partnerships when trying to solve complex problems (type 3). In our HP/DreamWorks rendering technology project, HP was able to identify the required technological areas as well as the right partner to develop a new rendering technology (i.e., no need to access a wide set of external providers). Likewise, HP and DreamWorks needed to have extensive knowledge sharing to understand all aspects of required technological solutions such as animation technology and data storage and computing. Thus, HP decided to have a mutual collaboration instead of transactional relationships (i.e., contractual). Finally, we learn that a bilateral open innovation partnership is preferred for solving complex problems regardless of the hiddenness of knowledge. In sum, this suggests that grand challenges present truly challenging problems. There is no clear pattern of a preferred open innovation mode for such kind of problems from our survey. However, in our case examples of Evonik and Eli Lilly, we found that they developed a collaborative community, integrating a diverse set of actors to support deep knowledge sharing with these actors to tackle not only complex problem but also unknown technological solutions. In these two cases, project teams had tendency to adopt open innovation partnerships or communities to support the required extensive knowledge sharing (as they had a complex problem). As the location of the required knowledge was unknown for them, they adopted an open innovation community to have access a diverse set of external sources. From these two cases, we learned that the selection of the open innovation modes is affected not only by each attribute, but also by the interaction of two attributes.

## 4.7 Implications

Our study makes several contributions to the lively discussion on how to open up in open innovation, both in research and in practice (Felin & Zenger, 2014). Our research advances the theoretical discussion on the governance of open innovation, but most importantly it has immediate practical implications.

First, our explorative analysis provides empirical insights related to recent more theoretical but holistic and comparative discussion of different governance mode for open innovation (Felin & Zenger, 2014). We empirically show that open innovation projects fall in different categories of innovation problems. Open innovation is used in four types of problems that we classified: Well-structured problems, holy grail problems, complex problems, and also grand challenges.

**Table 4.8: Summary of Six Complementary Open Innovation Projects**

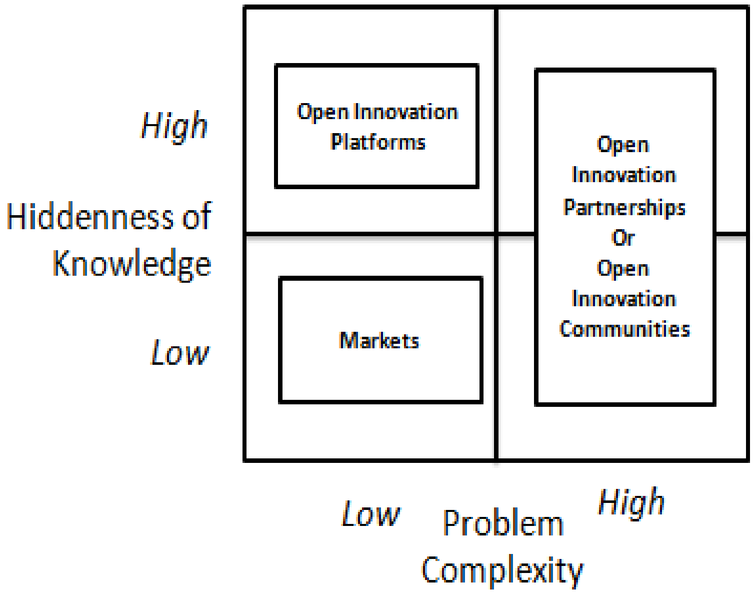
| **Case** | | |
|---|---|---|
| Clariant chemical catalyst design | *Problem Type* | Type 1: Well-structured |
| | *Open Innovation Mode* | Market/contracts: licensing agreement |
| | Rationale: Why this mode? | Extensive sharing with external partners was not necessarily. The problem was simple and they knew where to look for a solution: They were aware of a “HycaPure Hg” technology” that could help them solve their problem. So, they proposed licensing agreement to create incentive for Petronas to give permission of use it. |
| Bosch non-electrochemical energy storage technology | *Problem Type* | Type 2: Holy grail |
| | *Open Innovation Mode* | Open Innovation Platform: using NineSigma as an open innovation intermediary |
| | Rationale: Why this mode? | Extensive knowledge sharing between Bosch and external technology provider was not necessary since developing new non-electrochemical energy storage was relatively simple and well-structured. To increase the diversity and reach, they selected NineSigma to access a large pool of problem solvers. Diversity was key as they truly looked for an outlier solution that could challenge their internal solution concepts. |
| Pfizer Prefilled syringes | *Problem Type* | Type 2: Holy grail |
| | *Open Innovation Mode* | Open Innovation Platform: using IdeaConnection.com as an Open Innovation Intermediary |
| | Rationale: Why this mode? | Diversity and access to truly novel solution concepts was key issue for them. Working with IdeaConnection.com gave this opportunity to Pfizer to have access to a diverse number of problem solvers. |

| | | |
|---|---|---|
| Evonik non-vacuum process | *Problem Type* | Type 4: Grand challenges |
| | *Open Innovation Mode* | Open Innovation Community: creating a diverse community that integrated a diverse set of actors |
| | Rationale: Why this mode? | Evonik initiated the open innovation community support deep knowledge sharing with diverse set of actors to tackle not only complex problem but also unknown technological solutions. The problem was way to complex to be solved with one partner only. More than 50 actors (including individuals) joined the community that started collaborating to develop a new technology solution for the production of electronic devises. |
| Eli Lilly drug design | *Problem Type* | Type 4: Grand challenges |
| | *Open Innovation Mode* | Open Innovation Community: Developed a collaborative virtual environment, called Open Innovation Drug Discover platform (OIDD) |
| | Rationale: Why this mode? | Drug discovery process requires extensive knowledge sharing across diverse set of scientists and researchers as the process is highly complex and the ideal chemical structure is often unknown. The OIDD as a collaborative virtual community allowed Lilly to access the long tail of problem solvers and to support sharing knowledge idea among them. |
| HP/DreamWorks rendering movies technology | *Problem Type* | Type 3: Complex Problem |
| | *Open Innovation Mode* | Open Innovation Partnerships: Partnership agreement through mutual exchange |
| | Rationale: Why this mode? | HP was able to identify the right partner to develop a new rendering technology. HP and DreamWorks needed to have extensive knowledge sharing to understand all aspects of required technological solutions such as animation technology and data storage and computing. HP strategically chose to collaborate with DreamWorks through mutual exchange rather than contractual and arm-length relationships as it could support sharing truly complementary knowledge and expertise among them. |

We also show that managers make use of different open innovation governance modes. We learned that more novel modes such as contests and communities are also of increasing relevance to firms, suggesting that firms have evolved from the early stages of markets and partnerships in open innovation. However, a closer look into the nature of the communities that firms sponsor and create, shows that they deviate from the user communities that follow the principles of OSS, and make their know-how publically available (often labeled as free revealing in the academic discussion). The communities we studied were truly collaborative, followed a joined common objective, and regularly also involved individuals and not just firms. However, despite the collaborative exchange of knowledge, the knowledge created within these communities was not turned into a public good. Clear rules and norms about knowledge sharing and protection guided these communities.

Second, our comparative analysis reveals clear patterns of interrelationships between the nature of the problem to be solved and the open innovation mode chosen. There is a clear preference of a particular open innovation mode for problem type 1 (well-structured problems), problem type 2 (holy grail) and problem type 3 (complex problem). For these three problem types, managers do and should opt for open innovation markets, open innovation platforms, or open innovation partnerships respectively. The results of this study show that the selection of open innovation modes is affected by the interaction of the two attributes as well. For example, for simple problems (type 1 and 2) they can adopt either open innovation markets or open innovation platforms. But, open innovation market is preferred for problem type 1 as the location of knowledge for solving problem is known for project teams so that they can make a contract with external partners to solve their problem. By contrast, for problem type 2, project teams have no idea about the location of the required knowledge. As a result, they prefer to engage in open innovation platforms to access a wide range of potential external sources. Two different open innovation modes are adopted for the simple problem based on the level of hiddenness. Thus, the two attributes should be considered at the same time (the interaction between them) to select the appropriate open innovation mode. This pattern is conforming to prior, more theoretical discussion on the problem fit of different open innovation modes. Interestingly, we found that managers also find alternative uses for open innovation platforms than one would have expected. They are also relevant for problem type 1, well-structured problems, for potential reasons such as external validation of an internal technology (in the sense of an external proof). Problem type 4 – grand challenges remain the most puzzling problem type. If a problem is complex and lacks access to potential solution know-how (hiddenness), we explore a tendency to opt for partnerships rather than – as one would have theoretically assumed – communities. However, at the same time, we do learn that firms make use of firm sponsored open innovation communities in alternative ways. They are used for complex problems rather than for grand challenges. This suggests that managers prefer bilateral interactions with a small group of partners if the problems are truly grant challenges with high complexity and high hiddenness of knowledge. Theoretically, both trial and error learning as well as theory-driven search is the 'mechanisms' that help tacking grant challenges. Diversity of the problem solvers as well as knowledge sharing among them may put these mechanisms to work. However, even though one would assume that communities make best use of both mechanisms, we learn that firms use both partnerships as well as communities to solve them. They even seem to prefer partnerships over communities. Apparently, using communities remains a challenge and requires managers to learn new capabilities to manage the knowledge integration among a large group of actors. Our two case studies on open innovation communities that tackle grant challenges give a first hint about these new capabilities.

**Figure 4.2: Typology of Four Problem Types and Open Innovation Modes**




Our portfolio presented in Figure 4.2 presents a decision framework for managers when pondering about the appropriate open innovation mode. This matrix makes this managerial mode selection, which is itself complex because the selection is affected by the interaction of the two attributes, simple. Rather than providing a complex list of attributes and decision factors, this simple 2x2 matrix provides an opportunity for firms to make decision early in the project. Neither does it require an intensive analysis, nor a lot of costs. However, it is exactly that early stage decision that will have important implications for the success of the project, and also the resources spend at a later stage. Whether managers opt for a partnership or for a community requires a deeper analysis of the need for knowledge sharing and the ability of the firm to facilitate knowledge sharing among a community of innovators.

## 4.8 Conclusion and Future Opportunities

Our paper took a first step into the discussion on the interrelationship between problem types and open innovation modes. It is the first empirical study that compares different open innovation modes and how they link to different problem types. There is much to learn, in particularly in the area of open innovation communities and 'grand challenge' problems. We hope that our framework will inspire both practitioners as well as scholars to experiment more within these different modes, and further sharpen our understanding of the best way to design intellectual property rights (IP), communication channels, and incentives structures for them.

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# Chapter 5: General Conclusions, Implications, and Future Research

The final chapter of this dissertation is allocated to the discussion and integration of the findings of three articles. First, a brief overview of findings concluded from three articles is presented. After that, the major theoretical and practical implications of the findings are discussed. Then, a summary of the limitations of this dissertation is presented, followed by providing suggestions for the future research.

## 5.1 Main Findings

The main aim of this study is to enhance our understanding of governance of open and collaborative innovation and the effect of governance on innovation successes by studying 1) dynamics of collaboration and their role in governance mechanisms, 2) the knowledge sharing-protecting tension and how it can be regulated, and 3) the role of problem attributes in selection of governance mechanisms.

Although the results show an extensive variability in the patterns of dynamics in open and collaborative projects, there is a clear difference in the collaboration dynamics between the successful and less successful collaborative projects. Successful projects have dynamic interactions that are more complex, tightly coupled, and dense than less successful cases. That is, with less successful cases, events seem to happen that are often unconnected to the remaining dynamic interactions, leading to changes in the collaborative projects that are left without an adaptive governance mechanism to respond to these changes. Learning from these changes to adapt governance mechanism is not supported in such a context. Moreover, the dynamic interactions among multiple project characteristics that happen involve fewer different characteristics, thus being less embedded in the institutional culture of the collaborative projects and thus adaptive governance as response to change seems easier to be ignored. In contrast, successful projects often have dynamic interactions that involve all the collaborative project characteristics, often with bilateral relationships and feedback loops between the characteristics. These complex dynamic interactions, including loops, facilitate learning for adapting governance mechanisms and embedding the adaptive governance into the institutional fabric of the projects.

The results indicate that changes in interaction style (cooperation vs. competition) of partners are likely to be part of this complex dynamic pattern for collaborative projects that are identified as successfully completing their objectives. This dynamic pattern begins with tensions caused by differences between the partners in priorities, cultures, interest, etc. which lead to conflicts. If the conflicts are effectively responded with increased use of team-based managerial decision making along with introducing new roles and processes (i.e., formality) then the interaction style between partners becomes increasingly cooperative, open information sharing, over time.

Duality in changes in interaction style is found. That is, changes in interaction style over time are not always from an initial competitive style to a cooperative style. This duality can be explained based on the analysis of sources of dynamics. Between-partner tensions that are left unresolved create a tendency for the partners to evolve toward a competitive interaction style, while the shift from competitive to cooperative is caused by the introduction of procedural formality (introducing new roles, processes, routines, etc. into collaboration process) and with team-based decision making (involving more technical staffs for making decision about how work is organized or problem is solved). This result supports this argument that both communication and structural enhancement are critical to partner cooperation (Zeng & Chen, 2003).

The findings of this study clearly supports this argument that the tension between cooperation (i.e., knowledge sharing) and competition (knowledge protection) in the collaborative projects needs to be regulated, otherwise the tension can slow down the collaboration in achieving its predefined objectives and even stop it prematurely (Bogers, 2011; Das & Teng, 2000; De Rond & Bouchikhi, 2004; Faems, Janssens, & Van Looy, 2010; Heiman & Nickerson, 2004; Jarvenpaa & Välikangas, 2014; Zeng & Chen, 2003). Moreover, this study shows that the tension between cooperation and competition can be regulated by introducing formality into the collaboration process (i.e., joint technology development process), thereby having successful outcomes. That is, to manage the knowledge sharing and protecting tension in collaboration process, introducing formality into joint technology development process has a positive effect on open and collaborative innovation project performance. This result of dissertation seems to support the hypothesis arguing that an alliance is likely to create more economic value as more partners adopt cooperative collaboration strategies (Kumar & Nti, 2004). Moreover, Kumar and Nti (2004) suggest that a cooperative mode of collaboration relied not only on the collaboration strategies of each partner, but also on the governance mechanism managing the alliance.

Moreover, the results indicate that the positive effect of procedural formalization on projects outcomes gets stronger as the problem becomes more complex. This indicates that as the project increases its problem complexity, the critical role of process formality in creating successful innovation outcomes increases. Likewise, the problem attributes (i.e., complexity and hiddenness of required knowledge) affect selection of a particular governance mechanism for solving innovation problem via using knowledge of external partners. Market and contractual governance (such as licensing) is associated with simple problems for which the required solution knowledge can also be easily identified by firms. Open innovation platforms such as contests, intermediaries, tournaments are a proper mechanism in order to solve simple problems with an unknown required knowledge. In such cases, firms may use the crowd to identify hidden knowledge sources. Partnerships (such as alliances and joint ventures) seem to be appropriate governance for complex problems for which the required solution is known for firms. This result is consistent with the argument that the alliance is a proper governance mechanism for sharing complex knowledge among involved partners in collaborative projects (Parmigiani & Rivera-Santos, 2011).

## 5.2 Theoretical Implications

First, the manner in which the analysis and reporting of the studies on the dynamics of IOCs are organized offers a framework providing direction for conducting future research on the IOC dynamics and selecting which aspects of the dynamics the study will focus on. Research is clearly needed on all aspects of the dynamics. Are there other IOC characteristics that were not included that change over the course of the IOC? Are there other sources that affect these IOC characteristics? Are there other patterns of dynamic over time that surface?

Also, the second theoretical contribution of this dissertation is for research on the dynamics of IOCs by finding the presence of dualities in IOC characteristics (such as interaction style between partners) in different forms of collaboration such as alliance, network, etc. This finding appears to support what De Rond and Bouchikhi (2004) refer to as dialectic tensions in alliance between cooperation and competition, individual autonomy and control and other characteristics. In some collaborative projects, for instance, partner firms simultaneously cooperate (i.e., open knowledge sharing) and compete (hiding knowledge) with each other. Bengtsson and Kock (2000) show that partners in coopetitive relationship tend to share and hide knowledge simultaneously. The two interaction styles seem to be needed to ensure effective knowledge sharing while maintaining alertness and visibility to potential partner opportunistic behavior. These dualities suggest dualism as an important descriptor of dynamics in collaborative projects that need to be examined so that critical issues on how partners govern collaboration are not lost (Vlaar, Van Den Bosch, & Volberda, 2007).

Third, the findings of this dissertation have important theoretical contributions for coopetition literature (Bengtsson & Kock, 2000; Bengtsson, Wilson, Bengtsson, Eriksson, & Wincent, 2010; Raza-Ullah, Bengtsson, & Kock, 2014; Ritala &

Hurmelinna-Laukkanen, 2009; Ritala & Hurmelinna-Laukkanen, 2013), arguing the advantages of simultaneous cooperation and competition among partnering firms in collaborative project successes, if managed effectively. The findings of this dissertation suggest that the balance of cooperation and competition seems to be managed by relying more on team-based decision making (i.e., involving more technical workers from the partner firms in managerial decision making) and introducing procedural formality (i.e., introducing new roles, processes, and procedures to collaboration) in projects.

Fourth, this dissertation has theoretical contributions for research on using external knowledge by suggesting that process formalization, virtually ignored in previous studies of engaging in open and collaborative projects, supports legal formalization around IP control to manage the concern over knowledge sharing and opportunistic risk in collaborative innovation projects (Cassiman & Veugelers, 2002; Laursen & Salter, 2014) by reducing the ambiguity that individuals have in terms of what IP-related knowledge needs to be shared and what needs to be protected. The adopting of formal IP control may not address specific activities of individuals from the partnering firms, which can result in sharing IP-related knowledge that should not be shared during the course of interaction (Berends, van Burg, & van Raaij, 2011). Thus, future studies have to pay more attention to the procedural formality that firms need to make sure that open and collaborative projects using external knowledge are likely to have successful innovative outcomes without the loss of critical intellectual property.

Fifth, the findings presented in this dissertation have important implications for interactive self-regulatory theory for sharing and protecting knowledge in IOCs, indicating the critical role that flexible collaboration process plays between interacting individuals who engage in daily sharing and protecting knowledge, in regulation of the sharing-protecting tension (Jarvenpaa & Majchrzak, 2016). This study suggests that flexible interaction is primarily possible not because it implies informal self-organized decision making about knowledge sharing and protecting in an ad-hoc fashion, but instead asserts that decisions that are made based on formalized joint processes. The establishment of formal process makes flexible interaction between individuals from the partners more feasible because of clarity not only about what knowledge should be shared but also about what knowledge should be protected (Salter, Criscuolo, & Ter Wal, 2014).

Sixth, the procedural formality presented in this study has theoretical implications for the literature on relational mechanisms in IOCs, putting great emphasis on the importance of informal elements in creating trust between partner firms to ensure collaboration success (Ring & Van de Ven, 1992, 1994). At first, it seems that there is a paradox between my findings, introducing formality into the collaboration process, and the importance of informality and trust based relationship between partner firms. I believe that, instead of a paradox, process formalization can help the parties manage distrust (particularly trust and distrust coexist between individuals in the collaboration), between individuals in collaboration process, by reducing opportunistic risk of knowledge sharing.

Seventh, several authors have argued for the need for firms interested in IOC and OI to develop a dynamic capability for successful outcomes (Jarvenpaa & Majchrzak, 2016; Schepker, Oh, Martynov, & Poppo, 2014). This study can suggest what such a dynamic capability looks like, and how it is likely to evolve. For example, I introduce process formalization as a critical dynamic capability that needs to be in place for open and collaborative innovation projects to succeed, explaining how successfully an individual on the team is able to manage the tension between knowledge sharing and protecting in the flexible interactive collaboration.

Finally, this dissertation shows that there is a clear pattern of interrelationship between the attributes of the problem (i.e., complexity and hiddenness of required knowledge) to be solved and the governance mechanisms chosen for collaborative projects. This finding provides empirical insights related to recent conceptual comparative discussion of different governance mechanisms for open innovation (Felin & Zenger, 2014). Also, this finding has theoretical implications for literature on IOCs and OI in general and formalization of IOCs literature in particular with suggesting that for studying and building theory we have to consider not only industry and firm level characteristics, but also the role of projects attributes (Du, Leten, & Vanhaverbeke, 2014; West, Salter, Vanhaverbeke, & Chesbrough, 2014).

## 5.3 Practical Implications

The results of this dissertation have several major implications for open and collaborative innovation managers. Collaborative projects are often terminated prior to reaching their initially defined objectives (Ariño & De La Torre, 1998; Makino, Chan, Isobe, & Beamish, 2007; Park & Ungson, 2001). The results of this study provide suggestions to avoid unsuccessful collaborations. Complex dynamic interactions presented in this dissertation suggest that changes in collaborative process that require adaptive responses need to be monitored by managers. Learning acquired from changes needs to be deeply embedded in the fabric of the joint collaboration process to enable the project to adapt its governance to the changes to which it has been exposed. For example, this leaning process could become part of joint meetings between partnering firms to ensure that they apply these lessons learned.

This study shows that introducing formality into the joint technology development process reduces uncertainty about what knowledge should be shared and what knowledge should be protected. Therefore, the knowledge sharing-protecting tension is regulated, thereby reducing failures. Thus, managers need to allocate enough time, at the both the formation and execution phases of project, to specify technological activities and evaluation criteria, such as technological specifications to be followed by involved individuals from partnering firms developing the desired technology. As technical staffs involve in the daily sharing and protecting of knowledge during the course of collaboration, this study suggests that managers invite all individuals involved in the project to more efficiently specify the joint development technology process. Also, this helps individuals gain sufficient information about the technological activities, since they are already involved in the process of specification, therefore making the implementation of the formality easier.

Moreover, this dissertation provides managers with guidelines that support the decision for the selection of the right governance for open and collaborative projects at the earliest stages of the project. First, this dissertation suggests that managers need to carefully analyze the project attributes (i.e., problem attributes) before deciding how to engage in open and collaborative innovation. Two attributes presented in this study help them to quickly position the project in the 2x2 matrix (complexity and hiddenness). Then, managers need to choose a governance mechanism fits with the problem based on the proposed mechanisms in the 2x2 matrix.

## 5.4 Limitations and Future Research

This dissertation has some limitations. First, the relative dearth of studies in this research area suggests the need for more studies on dynamics with conducting longitudinal qualitative case study. Although my analysis and reporting of the studies on dynamics offers a framework for conducting future research and selecting which aspects of dynamics the future studies will focus on, the findings of this study are an artifact of the state of the research in which relatively little detail about the dynamics on collaboration is provided. This suggests that if the dynamics of collaboration are to evolve our understanding of the governance mechanism of collaborative projects, more careful observations is needed.

Second, the results of this study on dynamics are based on 22 collaborative projects using different collaboration mechanisms such as alliances, joint ventures, consortia, etc. that have distinct characteristics that can affect the dynamics collaboration over time. Moreover, the projects are from different industries and managed by different partners, with a variety of organizational structures, all affecting project outcomes. Thus, it was impossible to meet the call for "selection of an appropriate population, [cases of innovation collaborative projects] controls extraneous variation" to develop the findings on dynamics (Eisenhardt, 1989: 537). Thus, there is a need to conduct a nested-cases control study in which all collaborative projects have the same mechanism and come from the same partnering firms and the same industry, thus controlling for critical factors affecting the project outcomes[25].

Third, the findings related to the quantitative part of this dissertation are based on cross-sectional data. Thus, it is impossible to establish causality. Future research applying longitudinal and/or experimental designs can be helpful in establishing clear causality between problem attributes and governance mechanism. Moreover, I have a single respondent from each firm completed the survey. Thus, this study is vulnerable to common-method variance. Although some strategies are applied to avoid this problem when developing the questionnaire, to decrease

[25] For example, please see (Faems, Janssens, Madhok, & Van Looy, 2008; Majchrzak, Cooper, & Neece, 2004)

potential common-method variance, a multi-source approach should be applied in the future studies.

Finally, this dissertation did not study individual-level factors such as motivation affecting the project innovation performance (Clark & Fujimoto, 1991; Leiponen & Helfat, 2010). As a result, future research could study the role of individual level factors in the collaboration process to advance the findings of this study by addressing, for example, the moderation effect of these factors on the relationship between the degree of procedural formalization and project performance.

## 5.5 Conclusion

Using external knowledge through open and collaborative innovation projects with new partners has been recognized as a critical mechanism to successfully solve innovation problems, particularly under the increased dynamics of technological and market change (Browning, Beyer, & Shetler, 1995; Chesbrough, 2003; Foss, Laursen, & Pedersen, 2011; West & Bogers, 2014). The ability to manage the collaboration process with partners to have successful innovation outcomes is a crucial capability. This capability becomes particularly important when firms select a governance mechanism for their open and collaborative projects (Felin & Zenger, 2014; van de Vrande, Vanhaverbeke, & Duysters, 2009), as well as regulate the knowledge sharing-protecting tension during the course of collaboration with external partners. This dissertation has enhanced our understanding of the governance of open and collaborative projects and the effect of governance on innovation successes showing that 1) the tension between knowledge sharing and knowledge protection in the collaborative projects needs to be managed, otherwise this tension can slow down the joint project in achieving its initially defined goals and even stop it prematurely; 2) this tension (i.e., the tension between sharing and protecting) can be regulated by introducing formality into the joint collaboration process (i.e., joint technology development process) which has a positive effect on open and collaborative innovation project performance; 3) the positive effect of process formalization on project performance becomes stronger as the problem becomes more complex; and 4) the two project attributes (complexity and hiddenness of knowledge) affect the selection of a right governance mechanism. Open and collaborative projects often fail due to selection of wrong governance mechanism and lack of ability to regulate the knowledge sharing and protecting tension (De Rond & Bouchikhi, 2004; Ness, 2009). Avoiding failures needs better understanding of how the governance mechanism should be selected, as well as how the tension should be regulated. This dissertation is aimed at advancing this understanding.

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