SEARCHING FOR NEEDLES IN A HAYSTACK: THREE ESSAYS ON THE ROLE OF R&D PARTNERSHIPS IN THE BIO-PHARMACEUTICAL INDUSTRY

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ABSTRACT

SEARCHING FOR NEEDLES IN A HAYSTACK:
THREE ESSAYS ON THE ROLE OF R&D PARTNERSHIPS
IN THE BIO-PHARMACEUTICAL INDUSTRY

Thomas Klueter

Raphael Amit

This dissertation examines the relationships of established and young startup firms in environments characterized by rapid technological change in which exploration, i.e., moving away from current organizational routines and knowledge bases, is crucial for success.

In the first essay, I combine perspectives on organizational myopia and organizational learning to examine how prior successes and prior failures solving R&D problems shape whether established firms go beyond "local search" in partnerships formations with startup firms. In line with the myopia perspective, I find that established firms tend to "overlook" partnering opportunities with novel elements of knowledge as well as opportunities that do not promise payoffs in the immediate future. The study further reveals that prior successes and failures very differently shape these myopic tendencies. While prior failures lead firms to pursue partnerships with novel elements of knowledge, prior successes make firms more receptive to partnerships with payoffs in the distant future.

In the second essay, I draw on the literature on organizational learning and inter-organizational partnering to examine the relationship between startup innovation and startup market valuations. I find that startups pursuing innovations that substantially differ from the solutions pursued by established firms may face severe market value penalties as they lack both legitimacy and access to vital complementary assets. This penalty, however, is attenuated if startups commercialize their innovations through partnerships or if they pursue innovations in areas where established firms have failed in their own internal R&D attempts.

The final essay draws on the literature on inter-organizational learning to more closely examine the ways in which established firms leverage the knowledge accessed from startup firms. I focus on loosely coupled partnerships that involve established firms paying a research partner for access to specific knowledge. While prior research has questioned the ability of firms to devise new and innovative solutions based on such partnerships, I find that innovation benefits from loosely coupled partnerships do not necessarily stem from the sourcing relationship per se but instead are contingent on the established firm's experimental orientation to pursuing risky projects and its availability of financial and managerial resources.

Overall, my dissertation enriches our understanding of the unique interdependencies between established and startup firms in environments characterized by rapid technological change.

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CHAPTER 1: INTRODUCTION

"Now big companies, and not just Big Pharma, big companies I believe, are not any good at doing innovation. There has to be some element of disruptive thinking to have innovation and I can tell you that big companies do everything to avoid any disruptive thinking in their companies. So, you want to work with companies that are a little bit more disruptive in thinking, but bring those competencies together."(Chris Viehbacher, CEO, Sanofi, 2012)

Overview

In rapidly changing technological environments, exploitation, i.e., the refinement of current organizational routines and knowledge bases, does not necessarily lead to success, as existing ways of solving problems become obsolete quickly (March, 1991; Steensma & Corley, 2000). Instead, researchers have stressed that firms in such environments require elements of exploration, i.e., *a conscious effort to move away from current organizational routines and knowledge bases* (Katila & Ahuja, 2002:1184; March, 1991).

Extant research indicates that startup firms, unencumbered by aging and embedded competencies, have advantages in exploration over established industry players[1] (Christensen & Rosenbloom, 1995; Cooper & Schendel, 1976; Foster, 1986; Henderson, 1993; Li & Atuahene-Gima, 2001). At the same time, established firms are not necessarily replaced by the emerging startups as they may retain possession of specialized complementary assets (Hill & Rothaermel, 2003; Rothaermel, 2001; Taylor & Helfat, 2009; Teece, 1986), which results in unique interdependencies between

[1] Established firms in this dissertation are incumbent and mostly older firms, with substantial commercial success in their respective industries with respect to revenue and profits. Conversely, startup firms tend to be much younger and smaller as they have not attained substantial commercial success and, in the context of this dissertation, have not yet commercialized products on the market.

established and emerging startup firms (Arora & Gambardella, 1994a; Hagedoorn, 2002; Rothaermel & Deeds, 2004; Steensma & Corley, 2000).

This dissertation takes an in-depth view of the relationships of established and young startup firms in environments that are characterized by both strong demands for exploration and the retention of specialized complementary assets by established firms. Examples of such industries include the pharmaceutical industry, with the emerging technologies' solutions from biotechnology or the telecommunication industry, confronted with the emergence of wireless telephony (Rothaermel & Hill, 2005).

In three distinct dissertation essays, I examine the relationships of established firms and startups to explicate antecedents and outcomes of their innovation activities. Each of the three essays is a separate piece of research but all are connected, drawing on organizational learning as an important lens to study innovation, clarifying the unique role of partnerships between established and startup firms for innovation, and using the bio-pharmaceutical industry as a common research setting.

I begin each essay by identifying a challenge in established and startup firms' innovation activities, which closely resonates with March's seminal idea that exploration (1991:71), i.e., variation, risk taking and experimentation, may be difficult to achieve. For all papers, in a second step, I consider under which conditions firms more readily pursue exploration or under which conditions challenges associated with exploration may be attenuated.

I will next draw on some of the fundamental theoretical lenses to illuminate the theoretical gaps that motivate my dissertation agenda. At the same time, I will explain why all three essays also have managerial relevance in the bio-pharmaceutical industry.

Relevance – Theory & Practice

Starting with the original work of March and Simon (1958) and the behavioral theory of the firm (Cyert & March, 1963), organizational search processes are considered an important lens through which to study technological innovations and inter-organizational partnerships. Subsequent work on evolutionary economics (Nelson & Winter, 1982) and organizational learning (Huber, 1991; Levitt & March, 1988; March, 1991) have substantially expanded our understanding of organizations' search and innovation activities, while remaining close to the original tenets of the behavioral theory of the firm.

Central to my dissertation is March's (1991) seminal work in distinguishing exploration from exploitation as a unique lens to study innovations activities by established and startup firms. Exploration includes elements of variation and experimentation while exploitation emphasizes efficiency and refinements (March, 1991). The exploration-exploitation framework has been applied to a wide range of innovation activities.[2] For example, in the domain of technological search, exploitation refers to the usage of solutions which utilize familiar (or local) elements of knowledge, while exploration utilizes knowledge which is different from what the firms already know (e.g. Benner & Tushman, 2002; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001; Stuart & Podolny, 1996).[3] Researchers have also applied the exploration-exploitation framework to the actual locus of innovation activities in the value chain (upstream and downstream) (e.g. Lavie & Rosenkopf, 2006; Rothaermel & Deeds, 2004), reflecting

[2] Not discussed in this dissertation is the geographic dimension (Baum, Li, & Usher, 2000b) and the familiarity with partners (Li & Rowley, 2002).

[3] Exploration and exploitation are commonly operationalized through patent data. Distant technologies are those not previously cited by the focal firms, whereas similar technologies have build on patents previously cited by the focal firms (e.g., Rosenkopf & Nerkar, 2001)

firms' preferences to exploit payoffs in the immediate future (Levinthal & March, 1993; March, 1991).

Following these perspectives, exploration in general is often associated with lower returns than exploitation, because exploration is non-routine and hence riskier (March, 1991; Rosenkopf & McGrath, 2011). At the same time, exploration can lead to substantial benefits, in particular in environments in which old competences quickly become obsolete (Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). Extant research indicates that new startup firms may have advantages in exploration and have taken an important role in the generation of new ideas and in pushing an industry's technological change forward (Foster, 1986; Rothaermel, 2001; Tushman & Anderson, 1986). Established firms respond by opening up to external ideas and crossing organizational boundaries to access new and potentially disruptive technological opportunities, as exemplified by the formation of partnerships (Hagedoorn, 1993, 2002; Rothaermel & Deeds, 2004). Value creation by established and startup firms hence stems from combining relevant resources and knowledge bases in innovation (Rothaermel & Boeker, 2008; Teece, 1986).

Despite the increased use of partnerships between established and startup firms (Arora & Gambardella, 1994a; Rothaermel & Deeds, 2004), important challenges to exploration remain and are the focus of this dissertation. I begin my dissertation focusing on established firms that are exposed to a wide range of emerging technological opportunities and examining the partnerships that established firms ultimately pursue. Exploration in forming partnerships may be challenging as the interpretation of external information is guided by firms' histories of knowledge, prior experiences and

organizational routines (Cyert & March, 1963; Levinthal & March, 1993; Levitt & March, 1988). Hence, even when established firms go beyond their boundaries to access external knowledge (Rosenkopf & Almeida, 2003), they may have myopic tendencies as they "overlook" partnering opportunities with novel elements of knowledge and partnering opportunities that do not promise payoffs in the immediate future.

It is important to note that all experience is not created equal. The recognition and interpretation of external opportunities in partnerships formation may also be influenced by prior successes and failures in solving R&D problems, which are known to shape search intensity and organizational learning (Audia, Locke, & Smith, 2000; Kim, Kim, & Miner, 2009; Madsen & Desai, 2010). Following all arguments, I examine in essay 1 (chapter 2) how myopia and prior successes and failures may shape partnership formations by established firms by examining the following research question:

> *Do firms follow myopic tendencies in their choices of startup partners and how are these tendencies shaped by prior failures and successes in R&D?*

This question is highly relevant for established firms in the bio-pharmaceutical industry which, in the last decades, has observed an overall decline in R&D productivity (DiMasi, Hansen, & Grabowski, 2003; Scannell, Blanckley, Boldon, & Warrington, 2012; Taylor, 2003). This is demonstrated in Figure 1 (Sources: FDA; PhRMA) as the newly approved molecular entities in the US (drugs approved by the Food and Drug Administration – FDA) relative to R&D spending have declined. At the same time, the proportion of drugs originating in new startup firms or universities has increased substantially (Figure 2 – dashed line, Sources: FDA, Recap).

Figure 1: Output Bio-Pharmaceutical Industry in the US 1991-2010

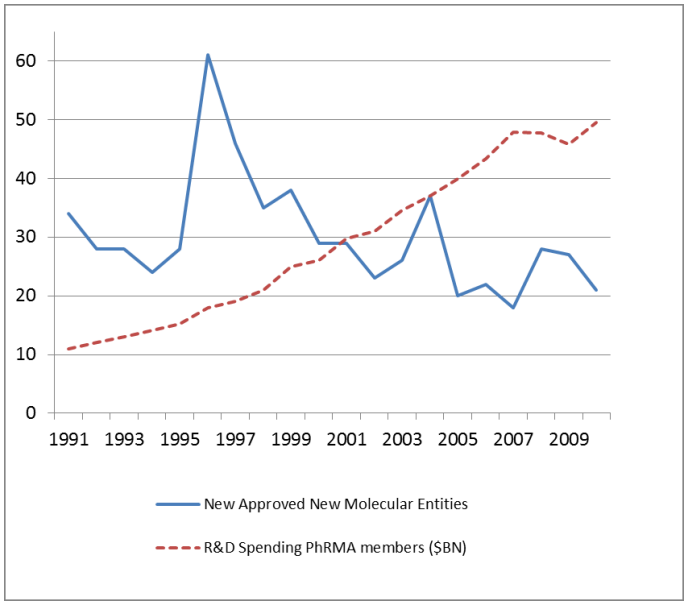
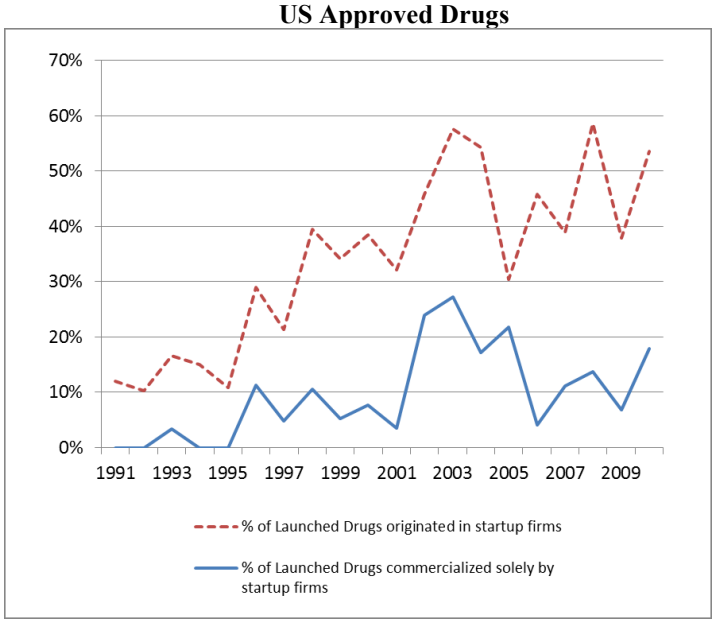


Figure 2: Originators & Commercializers of US Approved Drugs



Combining Figure 1 and Figure 2 reveals substantial challenges to established firms in discovering new innovative solutions. As a result, understanding how established firms search for and recognize emerging partnering opportunities has become increasingly important for established firms (Tyler & Steensma, 1995).

The second essay (chapter 3) examines exploration from the perspective of the startup firms. Following the idea of evolutionary economics and technological change (Abernathy & Clark, 1985; Henderson & Clark, 1990; Tripsas, 1997), exploration is captured by examining how innovations pursued by startup firms differ from the solutions pursued by established industry players (Dahlin & Behrens, 2005; Govindarajan & Kopalle, 2006). I distinguish startups pursuing innovations incremental (local to the established firms) versus startups pursuing more exploratory innovations using knowledge and technologies different from the established firms innovation, which I label radical innovations (Hill & Rothaermel, 2003).

Startups pursuing such radical innovations face an important quandary. On one hand, they have the unique ability to explore and push technological change forward, which may allow them to gain the "attacker's advantage" (Christensen & Rosenbloom, 1995; Cooper & Schendel, 1976; Foster, 1986). On the other hand, pursuing radical innovations may adversely affect the legitimacy associated with new startups and constrain them from accessing important complementary resources to develop and commercialize their technological solutions. Using market valuations as an important lens to view how a startup is perceived by external actors (Aggarwal & Hsu, 2009;

DeCarolis & Deeds, 1999; Stuart, Hoang, & Hybels, 1999; Zott & Amit, 2008), I examine the following research question in essay 2 (chapter 3):

> *What is the relationship between innovation radicalness and startup market valuation and what are the conditions under which startups pursuing radical innovations have higher market valuations?*

The question is highly relevant to the bio-pharmaceutical industry for the following reasons. First, we observe that in the last 20 years, established firms were not replaced by emerging startup firms, which has been ascribed to their retention of specialized downstream complementary assets (Hill & Rothaermel, 2003; Teece, 1986). This is reflected in Figure 2 (solid line) – the percentage of drugs which were ultimately marketed solely by startup firms has risen much less steeply compared to the number of drugs which were originated by those startup firms. Hence, understanding performance consequences for startups pursuing radical innovative solutions is very important.

In a final dissertation essay, I revert to the perspective of the established firms and examine value creation through research partnerships with startup firms. The intent behind these exploration types of partnerships (Koza & Lewin, 1998) is to accelerate the yield from research assets by reducing innovation cycle times and gaining access to valuable new elements of knowledge (Laursen, Leone, & Torrisi, 2010; Leone & Reichstein, 2012; Rosenkopf & Almeida, 2003) .

While prior studies have outlined the benefits accrued by firms that engage in tightly coupled partnerships in the form of joint ventures or alliances (Dyer & Singh, 1998; Mowery, Oxley, & Silverman, 1996; Rothaermel, 2001), loosely coupled partnerships, which involve one firm paying to add or have access to specific knowledge from another firm and to reuse such knowledge created by the research partner (e.g., a

research contract or in-licensing deal), have received limited attention and quite often are not thought to allow firms to reap substantial innovation benefits (Fey & Birkinshaw, 2005; Keil, Maula, Schildt, & Zahra, 2008; Luo, 2008; Mowery et al., 1996). Yet, established firms use the latter type of partnerships intensively (Arora, Fosfuri, & Gambardella, 2001; Arora & Gambardella, 2010; Laursen et al., 2010; Leone & Reichstein, 2012), leading to research question 3:

> *Is a firm's innovative performance influenced by loosely coupled research partnerships, and what are the conditions under which such partnerships increase an established firm's innovative performance?*

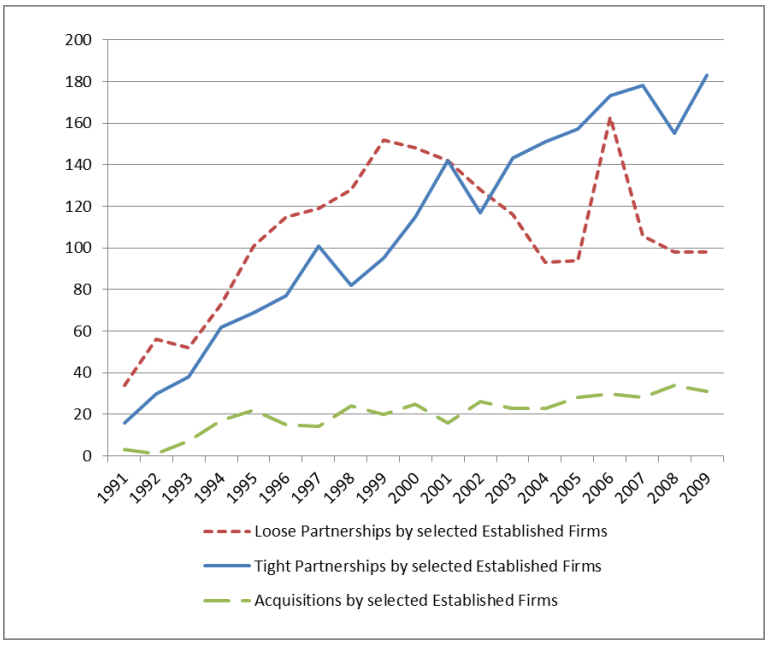
I have already highlighted the difficulties of established firms in the recent decades to conceive of innovative new solutions in the form of marketable products (Figure 1 and Figure 2). Hence, understanding how firms may accrue innovation benefit from accessing knowledge from external partners is crucial. We observe that over the last decades, established firms have substantially increased their partnering with startup firms[4] (Hagedoorn, 1993, 2002), which is shown in Figure 3.

The figure indicates that loosely coupled partnerships (licensing and research contracts) have increased and remain quite prevalent in the industry. It is hence important to understand the benefits that established firms may accrue when engaging in such partnerships.

Next, I provide a more detailed outline for each chapter of the dissertation.

[4] The figure also includes partnerships with universities.

Figure 3: Adaptive Responses by Established Pharmaceutical Firms (Source Recap)



Dissertation Outline

The dissertation comprises three papers probing into innovation and partnering by established and startup firms in environments characterized by rapid technological change.

Chapter 2: Opening Up But Staying Local - Insights from Partnership Formations between Established and Startup Firms

In chapter 2, I begin my investigation of how established firms make sense of emerging external technological opportunities by startups. I take into consideration research on organizational myopia (Levinthal & March, 1993), which suggests that, even when opening up to external opportunities, established firms tend to search "locally" (Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001) as they overlook distant "places," i.e., opportunities that contain novel elements of knowledge and as well as distant "times," i.e., opportunities that are distant from commercialization and immediate payoffs. While this perspective provides important insights into the challenges faced by firms searching for new technologies, it is not explicit when firms would go beyond local search. At the same time, research on organizational learning suggests that organizational actions and search are influenced by events of successes and failures (Argote & Greve, 2007; Madsen & Desai, 2010).[5] This perspective proposes that prior successes and failures may affect search intensity and learning but is imprecise or ambiguous about the type of search (local or distant) in which successes and failures ultimately result (Audia et al., 2000; Greve, 2011; Laursen, 2012; Staw, Sandelands, & Dutton, 1981).

[5] Failure and success in this study relate to events in R&D which are rare and substantially shape the organizational context as they lead to situations of crisis (failure) or long term commercial success (Lampel, Shamsie, & Shapira, 2009; Rerup, 2009).

In chapter 2, I combine both perspectives and investigate how successes and failures shape the reaction of established firms to external partnering opportunities which differ in their degree of technological novelty and distance to commercialization. In a first step, I investigate the "myopia" perspective to verify if established firms indeed tend to "search locally," i.e., overlook solutions with novel elements of knowledge and that are distant from commercialization. More importantly, in a second step, I examine how prior successes and failures in solving R&D problems may determine whether firms go beyond "local search" and pursue partnerships with novel elements of knowledge and opportunities that only promise payoffs in the distant future. I argue that both failures and successes shape a firm's receptivity for distinct external partnering opportunities in very different ways.

I test my predictions by examining partnership formations between the Top 40 established bio-pharmaceutical firms between 1998 and 2007. With this study, I intend to provide insights into how established firms notice, interpret, and respond to emerging exploratory partnering opportunities and explicate the role of prior failures and successes in affecting myopic tendencies in organizational search.

Chapter 3: Swimming Against the Current - Examining the Relationship Between Radical Innovation and Startup Firm Market Value

In the next chapter (chapter 3), I examine how innovations by startup firms differ from those pursued by established industry players. On one hand, startups pursuing radical product innovations, i.e., innovations that *"involve methods and materials that are novel to incumbents"* (Hill & Rothaermel, 2003), are at the heart of Schumpeter's (1942) theory of creative destruction, which suggests that startup firms nimbly push

technological change forward and gain the "attacker's" advantages (Christensen & Rosenbloom, 1995; Cooper & Schendel, 1976; Foster, 1986; Henderson, 1993; Li & Atuahene-Gima, 2001). At the same time, however, established firms often retain possession of specialized downstream complementary assets (Hill & Rothaermel, 2003; Rothaermel, 2001; Taylor & Helfat, 2009), which leads to challenges for startup firms pursuing innovations different from the existing industry conventions and recipes (Spender, 1989).

In this dissertation chapter, I first examine if pursuing radical product innovations generates higher or lower market valuations, a key performance measure for startup firms (DeCarolis & Deeds, 1999; Stuart et al., 1999; Zott & Amit, 2008). Next, I take into account the unique dependencies between startups and established firms and then, in a third step, examine under which conditions pursuing radical product innovation may be associated with higher market valuations for startups.

Drawing on the literature on technological change and inter-organizational partnering (Baum, Calabrese, & Silverman, 2000a; Stinchcombe, 1965; Stuart et al., 1999; Tushman & Anderson, 1986), I argue that pursuing radical ways of solving problems compounds legitimacy issues and resource constraints, leading to lower market valuations for startups. Considering the unique interdependencies between startups and established firms, however, suggests that under distinct conditions, startups pursuing radical innovations may mitigate these constraints. In particular, I examine the formation of commercialization partnerships (Baum et al., 2000a; Stuart et al., 1999) and the maturity of technologies in development (Rothaermel & Boeker, 2008) by the startup, as well as failure in R&D efforts by established firms (Cyert & March, 1963; Madsen &

Desai, 2010) as important conditions mitigating legitimacy and resource constraints for startups pursuing radical innovations.

I test my predictions in a sample of 144 US startups active in drug development with an IPO 1991 and 1999. With this study, I aim to further our understanding of how radical innovations influence startup performance and the unique role played by established firms in shaping this relationship.

Chapter 4: No Strings Attached: Examining the Relationship between Loosely Coupled Research Partnerships and Innovative Performance

In the final essay chapter (chapter 4), I turn to how established firms and startup firms exchange knowledge and technologies to generate new innovative solutions. I focus on loosely coupled partnerships (Orton & Weick, 1990; Steensma & Corley, 2000; Thompson, 1967), which involve one firm paying to have access to specific knowledge from another firm and to reuse such knowledge created by the research partner, as in a research contract or in-licensing deal (Murray & O'Mahony, 2007)[6].

Previous studies have consistently shown that the benefits of tightly coupled partnerships are based on the fact that more often than not, innovation requires a reciprocal exchange and recombination of knowledge from the cooperating parts (Dyer & Singh, 1998; Mowery et al., 1996). In a related vein, it has also been suggested that simply "handing off" research from one partner to another (as in loosely coupled partnerships) may not be enough to allow the in-sourcing firm to innovate (Eisenhardt &

[6] Conversely, tightly coupled partnerships (Steensma & Corley, 2000) are characterized by the reciprocal exchange of knowledge (Eisenhardt & Schoonhoven, 1996), high levels of commitment among the partners and the generation of partnership-specific assets (e.g., joint product development agreements or equity joint ventures) (Sampson, 2007).

Schoonhoven, 1996). It is striking, then, that loosely coupled partnerships are increasingly prevalent in many industries, as exemplified by the widespread use and rapid growth of research contracts and licensing deals in very early stages of the innovation cycle (Nicholls-Nixon & Woo, 2003; Rothaermel & Hess, 2007). Intrigued by the mismatch between previous findings pointing to the limited potential of loosely coupled partnerships to generate innovations on the one hand, and their prevalence in many industries on the other, I examine in this chapter whether, why and when loosely coupled research partnerships may increase a firm's innovative performance.

I argue that innovation benefits from loosely coupled partnerships not only stem from the sourcing relationship per se, but are also closely linked to the in-sourcing firm's experimental orientation to pursue risky projects and its availability of financial slack and managerial resources. I test these hypotheses in the global pharmaceutical industry, using a panel dataset covering the world's Top 50 global pharmaceutical firms between 1998 and 2007. The goal of this study is to demonstrate that, under certain circumstances, loosely coupled research partnerships may provide benefits similar to those attributed only to tightly coupled partnerships.

Chapter 5: Conclusion and Outlook

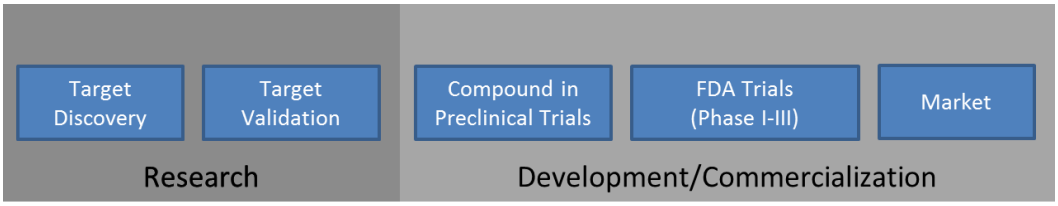
In the final chapter of this dissertation, I provide a summary of the most important insights gained through this dissertation and integrate their findings. I also provide a road-map for future research opportunities arising from the dissertation.

Details of Empirical Context

The empirical context for all my dissertation essays is the bio-pharmaceutical industry which, in the 1990s and 2000s, was characterized by a high degree of knowledge intensity, innovation and partnering (Powell, Koput, & Smith-Doerr, 1996). From the 1980s to 1990s, the pharmaceutical industry also witnessed the emergence of revolutionary therapeutic approaches based on genetic engineering – including but not limited to recombinant proteins, monoclonal antibodies and gene therapy (Sosa, 2011). Hundreds of new Biotechnology firms (NBFs) entrants (labeled startups in this dissertation) pursued these emerging technologies in the hope of dramatically altering the industry landscape (Schweizer, 2005).

Throughout my dissertation, I exploit the unique empirical advantages offered by the bio-pharmaceutical industry, which has clear steps in research and product development (Figure 4).

Figure 4: The Drug Development Process in the Bio-Pharmaceutical Industry



The research stage usually ends with the generation of a molecule or biologic solution, at which time firms tend to file patents for their new innovations. In the development stage, the industry is fairly regulated and includes preclinical trials (clinical development candidate selection and investigation of a new drug preparation), Phase 1 trials (evaluation of drug stability, side effects and dosage), Phase 2 trials (drug's efficacy) and Phase 3 trials (large scale clinical testing). Innovation concludes with the

commercialization of the drug into the market, which starts product life cycle management.

Focusing on innovation associated with compounds in development in all of the essays allows me to capture information in the innovation process, which cannot be derived from patent-based studies. For example, I am able to unambiguously identify if a technology (i.e., a compound) was or was not available for partnering, while, for patents, it is often not clear which patents are already licensed to other parties and hence not available. Patents also do not allow us to identify how far in the development process the technologies are, which is possible through observing the stages of development of compounds. Finally, compounds are at the nexus of research and commercialization and hence represent an important area where managerial decisions (e.g., the allocation of resources) are made. The resources required and committed to products in development far exceed the resources necessary for patenting and in some cases (e.g., in Phase III) can reach 100s of millions of dollars. I note, however, that a downside of focusing on products in development is that the study is harder to replicate in other industries, which do not have product development information as readily available. Table 1 gives an overview of the data sources used in the dissertation, which apply to all dissertation chapters.

Table 1: Bio-Pharmaceutical Industry – Data Sources

	Activity	**Data Source**	**Volume**
Internal R&D	Patenting	Derwent Innovation Index	Millions of patents
	Drug Development	Pharmaprojects Adis	>51000 drug profiles (PP) >26000 drug profiles (Adis)
External R&D	Partnering, Acquisitions	Recombinant Capital Pharmaprojects	>35000 announcements

Partnerships in the Bio-Pharmaceutical Industry

In this dissertation, partnering between established and startup firms is defined in a broad way as it considers all purposive relationships between two or more independent firms that involves the exchange, sharing, or joint development of technological resources or capabilities (Gulati, 1995; Kale & Singh, 2009). Firms can choose among a range of modes to organize such partnerships, from in-licensing of a technology to the joint collaboration in research or development between the partners. While in chapter 2 and chapter 3, I consider partnering per se and am agnostic as to their how these partnerships are organized, I take the mode of partnering more closely into account in chapter 4 by differentiating partnerships emphasizing joint development (labeled tightly coupled partnerships) partnerships without strong reciprocity between the partners (labeled loosely coupled partnerships). Appendix 1 provides some examples of the different types of partnerships which are used in this dissertation.

Within this dissertation, I also consider partnerships between startups and established firms that span different parts of the value chain. Referring back to Figure 4, partnerships can be in the research stage with the intention of coming up with new treatments to be put into development but also at later stages (preclinical and clinical development) when partnerships are pursued for existing technological solutions.[7] The inclusion of distinct stages depends on the research question asked in each chapter. For example, chapter 2 examines the reaction of established firms to emerging partnering opportunities. Startup opportunities in the bio-pharmaceutical industry become highly

[7] Given that startups in all essays are young and nascent firms, we very rarely observe them engaging in partnerships to only market approved products, which is why in general we theorize about partnerships, in which either new knowledge is generated or needs further development until it can be commercialized.

visible once a compound is in development in preclinical or clinical trials. I hence focus in chapter 2 on all partnerships formed in these stages (see Table 2 for an overview). To that end, we carefully combine partnering (Recap) and product development (Pharmaprojects) data to unambiguously identify if a partnerships was made for a specific compound in development. Conversely, chapter 4 focuses on value creation from startups and established firms' research partnerships to generate new innovative ideas. It hence centers on partnerships at an earlier stage (the research stage) between established and startup firms.

Table 2: Partnerships used in dissertation chapters

	Chapter 2	Chapter 2	Chapter 3
Partnerships examined as	Dependent Variable	Moderator	Independent Variable
Value chain activities observed in partnering	Development Stage (Preclinical-Phase III)	All stages	Early Stage (Research)
Distinguish Modes in Analysis	No	No	Yes (Loosely Coupled)
Partnerships	451	1432	770
Types of Partnerships included:			
Pure Licensing	Yes	Yes	Yes
Research Contracts	Yes	Yes	Yes
Joint R&D (Alliance)	Yes	Yes	Control
Joint Venture	Out of scope	Yes	Control
Pure Equity investments	Out of scope	Control	Control
Robustness test excludes pure licensing	Yes	Yes	Yes

In each paper, I acknowledge and discuss the limitations of focusing on specific partnerships, which, at the same time, opens up avenues for future research. Generally out of scope for all dissertation essays are pure equity investments, as in corporate venture capital investments (without evidence that knowledge in the form of patents or

compounds was actually transferred from one firm to the other). Along the same argument, I do not consider option type deals as partnerships.

Scope and Limitations

Two important factors limit the scope of concepts and theory developed in this dissertation. First, the dissertation was conducted in the context of a single industry and the generalizability of the findings and their boundary conditions would require validation through explorations in other empirical contexts.

Moreover, I predominantly focus on partnering as a way through which established and startup firms exchange knowledge and technology. Subsequent studies may take into account alternative modes of knowledge exchange, including acquisitions or corporate venture investments.

Cognizant of these and other limitations, I conclude each essay chapter by outlining the limitations of the specific study.

CHAPTER 2: OPENING UP BUT STAYING LOCAL: INSIGHTS FROM PARTNERSHIP FORMATIONS BETWEEN ESTABLISHED AND STARTUP FIRMS

We are very picky and selective in our due diligence about which opportunities we select. But, failure can come as a surprise and change our perspective of what ultimately works to address a therapeutic need.
(Associate Director, Johnson & Johnson, Business Development, 2012).

An important line of inquiry within the innovation literature highlights that established firms increasingly partner with young and nascent startup firms to gain access to emerging and potentially disruptive technological solutions (e.g. Aldrich, 1999; Anand, Oriani, & Vassolo, 2010; Arora & Gambardella, 1994a; Hagedoorn, 2002; Jiang, Tan, & Thursby, 2011; Rothaermel, 2001; Steensma & Corley, 2000). As a result, understanding how established firms search for and recognize emerging partnering opportunities has become increasingly important (Tyler & Steensma, 1995).

It is helpful to model established firms as interpretive systems (Daft & Weick, 1984) that need to recognize and understand the technological opportunities generated by startups (Lane, Koka, & Pathak, 2006; Todorova & Durisin, 2007). Two important streams of research may inform our understanding of how established firms make sense of their environment and select emerging opportunities for partnering. The first perspective focuses on the challenges of established firms managing technological change (Henderson & Clark, 1990; Hill & Rothaermel, 2003) as the very competencies that established firms worked hard to attain may lead to myopia, i.e. favoring more familiar approaches in solving problems (Levinthal & March, 1993; Levitt & March, 1988). Applying this notion of myopia to emerging partnering opportunities suggests that established firms tend to search "local" (Nelson & Winter, 1982; Rosenkopf & Nerkar,

2001) as they have the tendency to overlook distant "places," i.e., opportunities that contain novel[8] elements of knowledge and to overlook distant "times," i.e., opportunities that are temporally distant from commercialization and immediate payoffs (Levinthal & March, 1993).[9] While this perspective provides important insights into the challenges faced by firms searching for new technologies, it is not explicit as to when firms would go beyond local search and consider opportunities with novel elements of knowledge or with distant payoffs.

A second perspective highlights that not all experiences are created equal and demonstrates how prior successes and failures influence organizational actions and search (Argote & Greve, 2007; Madsen & Desai, 2010).[10] This perspective outlines that successes and failures may affect search intensity and organizational learning but is imprecise or ambiguous about the type of search (local or distant) successes and failures ultimately result in (Audia et al., 2000; Greve, 2011; Laursen, 2012; Staw et al., 1981). Applying these ideas to emerging partnering opportunities suggests that prior successes and failures in solving R&D problems may inherently influence how firms notice, interpret, and respond to emerging partnering opportunities.

In this paper, we combine both perspectives and investigate how successes and failures shape the reactions of established firms to external partnering opportunities

[8] Novelty can have many dimensions (Rosenkopf & McGrath, 2011). In this paper it refers to the technological means through which firms attempt to solve organizational problems. A technology is novel if it represents a solution with elements of knowledge that are new to the firm. Greater novelty indicates more elements of knowledge not previously used to solve a distinct problem.

[9] Accordingly, the two forms of myopia haven been labeled "spatial" and "temporal" myopia (Levinthal & March, 1993)

[10] Failure and success in this study relate to events in R&D which are rare and substantially shape the organizational context as they lead to situations of crisis (failure) or long term commercial success (Lampel et al., 2009; Rerup, 2009).

which differ in their degree of technological novelty and distance to commercialization. In a first step, we investigate the "myopia" perspective and determine if established firms have the tendency to search "locally," i.e., overlook those opportunities with novel elements of knowledge and which are distant from commercialization. In a second step, we examine how prior successes and prior failures solving R&D problems may shape whether firms go beyond "local search" in partnership formations pursue partnerships with novel elements of knowledge and opportunities that only promise payoffs in the distant future.

Doing so allows us to integrate views on both myopia and the role of failures and successes to advance our understanding of organizational search (Greve, 2011; Nelson & Winter, 1982). We argue that firms overlook partnering opportunities with novel elements of knowledge, as they narrow the range of technological alternatives considered feasible for partnering to those in the neighbourhood of already pursued technological solutions.[11] To recognize partnering opportunities with novel elements of knowledge, established firms need to consider a broader range of possible technological alternatives (Gavetti, 2012), which we argue is contingent on experiencing prior successes and failures. While prior failures challenge the established firm's conventional ways of problem solving and allow them to pursue novel elements of knowledge (Cyert & March, 1963; Jansen, Van Den Bosch, & Volberda, 2005; Madsen & Desai, 2010), prior successes may reinforce existing representations of how problems should be solved and guide firms to pursue partnering opportunities in the neighbourhood of previous attempts (Audia et al., 2000; Lant, Milliken, & Batra, 1992).

[11] Greve (2011) terms this type of myopia "positional rigidity."

Firms overlook opportunities distant from commercialization as they build commercialization routines leading to preferences for those opportunities with immediate payoffs (March, 1991). To recognize partnering opportunities that are more distant from commercialization, established firms must be willing to forgo short term for potential long term gains, which we again suggest is shaped by the firm's prior failures and successes in solving R&D problems. Namely, prior successes may generate an organizational context in which established firms more readily consider a long term perspective, allowing them to pursue partnering opportunities with more distant payoff time horizons. Conversely, prior failures may lead firms to fail to consider opportunities which are distant from commercialization as feasible alternatives to solve their problems (Cyert & March, 1963). Altogether, our arguments suggest that failures and successes very differently shape a firm's receptivity towards solutions containing novel elements of knowledge and solutions with payoffs in the distant future.

The context for the study is the global pharmaceutical industry during the period from 1997 to 2006. We assemble a unique dataset that includes information on established firms' internal R&D and external partnering in product development. We examine partnership formations between established firms and new biotechnology firms (henceforth, startups). Within this industry, established firms increasingly rely on startups to generate new technological solutions and then form partnerships with them to develop new products (Arora & Gambardella, 1994a). We identify 852 unique startup partnering opportunities between 1997 and 2006 that could have been pursued by established firms and then examine the partnerships which were ultimately concluded. Our analysis is conducted on the dyadic level between the established firm experiencing failures and

successes solving a range of therapeutic problems (e.g., cancer, neurology) and startups offering new technological solutions in these therapeutic areas.

Consistent with our arguments, we find that, given a range of partnering opportunities, established firms tend to search locally, as they overlook distant "places" (novel technological solutions) and distant "times" (early stage technological solutions). However, once we take into account the firms' prior successes and prior failures, the tendency to search locally does not always hold. In line with our predictions, we find that prior failures increase the likelihood of pursuing novel solutions and prior successes allow firms to tap into solutions which are more distant from commercialization. We also find partial evidence that prior failures may lead firms to prefer partnering opportunities which are close to commercialization (in line with problemistic type search (Cyert & March, 1963)). We do not, however, find any evidence that a prior successes lead established firms to overlook novel technological partnering opportunities (Audia et al., 2000). These results account for unobserved differences across firms and changes over time, and are robust to a number of alternative econometric specifications and operationalization of key variables.

This study is a first attempt to systematically identify the reaction of established firms to emerging technological opportunities by explicitly taking into account forces of myopia as well as successes and failures. While scholars have identified the tendency of firms to remain local in their selection of partnering opportunities (Rothaermel & Boeker, 2008), at most, they have focused on search for novel elements of knowledge but did not

explicitly consider the time dimension (in the form of distance to commercialization)[12] and have only started to explicate the roles of success and failure as important boundary conditions (Greve, 2011).

We demonstrate that when opening up to external startups, established firms follow local patterns. Hence, merely opening up to new external solutions may not be a panacea, as firms may still not add knowledge that substantially differs from what they already know and do not pursue technological opportunities at an early stage of development. At the same time, we explicate the role of prior failures and successes to clarify when firms are more likely to pursue "non-local" partnering opportunities. We hence contribute to research which has attempted to identify the organizational antecedents necessary to overcome myopic challenges in recognizing and seizing knowledge located outside the firm (Cohen & Levinthal, 1990; Danneels & Sethi, 2011; Jansen et al., 2005).

The findings from the study also inform the literature on the role of learning from failures and the related idea of problemistic search (Cyert & March, 1963; Greve, 2011; Madsen & Desai, 2010). We illuminate that failures play an important role in shaping search direction but have a different effect on the two types of myopia. This helps to resolve conflicting arguments that failures lead to both local (Cyert & March, 1963) or distant search in form of "experimentation, change, and innovation" (Levinthal & March, 1993:105). In a similar vein, the study contributes to our understanding of how prior successes influence firm behaviour. While some researchers have suggested that successes may lead to strategic persistence and can actually 'trap' firms from changing

[12] A notable exception is Monteiro (2011), who examines the concept of market "proofness" in the context of seeking external knowledge.

(Audia et al., 2000), we do not find this perspective in the domain of partnership formations to be supported. Conversely, the paper reveals that prior successes may enable firms to consider partnering opportunities with technologies more distant from commercialization.

THEORY AND HYPOTHESES

Recognizing Partnering Opportunities & Local Search

Established firms increasingly cross organizational boundaries and access new and potentially disruptive technological opportunities by forming partnerships (Hagedoorn, 1993, 2002; Rothaermel & Deeds, 2004). Startups, i.e., young and nascent firms, have taken an important role in the generation of new ideas and are believed to substantially push technological change forward (Foster, 1986; Rothaermel, 2001). The result is that in some industries, a division of innovative labor has emerged in which startups initiate new innovative solutions and then partner with established firms that possess the complementary assets to develop and commercialize the startups' technologies (Arora & Gambardella, 1994a; Rothaermel & Deeds, 2004).

Before established firms can pursue any partnerships with startup firms, they, in a first step, need to recognize and understand the startup's potentially valuable external technological opportunities (Arora & Gambardella, 1994b; Lane et al., 2006; Todorova & Durisin, 2007). This, however, may be challenging as the interpretation of external information may be subject to organizational myopia, which inhibits firms from pursuing distinct types of technological solutions. Two salient forms of myopia (Levinthal & March, 1993) are reflected in firms' tendencies to a) overlook distant "places", i.e., opportunities that contain novel elements of knowledge and b) distant "times," i.e.,

opportunities which are distant from commercialization in the formation of partnerships by established firms.[13] Next, we explore each form of myopia in the context of partnership formations.

Overlooking novel partnering opportunities: It is well-known that firms' internal R&D attempts tend to be in the neighborhood and are local to what they already know (Katz & Allen, 1982; Lane & Lubatkin, 1998; Leonard-Barton, 1992; Nelson & Winter, 1982). In a similar vein, firms may not consider technological solutions that are distant to their prior ways of solving problems when evaluating a range of partnering opportunities.

Over time, organizations build distinct competencies, which shape their fundamental cause-and-effect representations of how problems and solutions are interrelated (Fleming & Sorenson, 2004; Itami & Roehl, 1991; Lei, Hitt, & Bettis, 1996). While this facilitates the recognition of partnering opportunities close to prior technological solutions, it, at the same time, makes it challenging to identify "distant" ones i.e., partnering opportunities with elements of knowledge novel to the established firms (Levinthal & March, 1993; Todorova & Durisin, 2007). First, partnering opportunities that attempt to solve problems in different ways may not be recognized by established firms as they do not conform to the current logics of problem-solving (Danneels, 2007; Prahalad & Bettis, 1986; Winter, 2000). Firms often define ex ante what technological solutions are considered feasible, which is guided by their internal preferences in solving problems (Dijksterhuis, Van den Bosch, & Volberda, 1999). Once firms direct their attention and position their "radars" (e.g., those employees responsible for providing information about new technologies to the firm) towards a subset of

[13] Other myopic tendencies, unrelated to the technological solutions of potential partners are related to the choice of geographic location (Baum et al., 2000b) or the choice of partners (Li & Rowley, 2002).

solutions in the external environment, they are constrained from considering technological solutions that depart from the agreed subset of possible alternatives (Jansen et al., 2005; Monteiro, 2011).[14]

Second, firms consist of coalitions with divergent interests that compete for power and control over scarce resources (Bower, 1970; Cyert & March, 1963; Pfeffer, 1992; Reitzig & Sorenson, 2012). This may lead firms to not consider partnering opportunities which do not support and reinforce previous internal R&D attempts (Jansen et al., 2005; Todorova & Durisin, 2007). In the extreme case, organizational coalitions may actively resist novel technological solutions, especially if they are perceived to render internal competencies obsolete (Gilbert, 2005; Hill & Rothaermel, 2003) or if they violate industry recipes (Spender, 1989) that represent legitimate solutions within the industry. Combining those arguments, we expect myopia to be salient in partnership formations as firms overlook those opportunities with novel elements of knowledge.

Hypothesis 1: The likelihood of an established firm forming a partnership with a new startup decreases with the novelty of the startup's technological solutions to the established firm.

Overlooking opportunities distant from commercialization: A general tendency of firms is to prefer short term over future gains (March, 1991). Applying the idea to the recognition of emerging technological opportunities suggests that firms may prefer opportunities closer to commercialization, while overlooking opportunities which are at an early stage of development.

[14] As an example, Henderson and Clark (1990) demonstrate how external new ways of problem solving in the photolithographic alignment equipment industry were screened out by established firms. In a similar vein, Rothaermel and Boeker (2008) found strong support for the idea that technological similarities drive partnership formation between established firms and startups.

Over time, established firms invest substantially in complementary assets and build competences and routines to develop and commercialize new products (Nelson & Winter, 1982; Teece, 1986). Simultaneously, aging and larger firms gradually shift their emphasis from future- (exploration) to short term-oriented gains (exploitation) as the existence of complementary assets (e.g., substantial experience in product development, a large sales force) allows established firms to effectively create immediate value (March, 1991). Accordingly, researchers have suggested that as a general industry pattern, partnerships with more immediate payoffs will be more prevalent than those that require more time to generate value (Koza & Lewin, 1998). A technology at an early stage of development is associated with high uncertainties that stem from doubts about the technology per se and its applicability to commercial domains (Ahuja & Morris Lampert, 2001; van de Vrande, Vanhaverbeke, & Duysters, 2009). Moreover, early stage technologies have not yet revealed how well they will fit existing commercialization routines, which increases potential adaptation costs for established firms. Given the distinguished competencies and routines of established firms in commercializing new products (Gilbert, 2005), established firms may prefer those partnering opportunities which can be readily converted into immediate returns. At the same time, internal coalitions may prefer immediate payoffs and lower risks to maintain and strengthen their positions of power, as evidenced by top management preferences of short over long term gains (Sanchez, 1995; Tyler & Steensma, 1995).

Combining all arguments, established firms exposed to a range of external partnering opportunities may overlook those which are distant from commercialization. While extant research has not tested this relationship explicitly, there is evidence that

established firms at least pay more attention to solutions which are already commercialized and have a proven track records (Monteiro, 2011). We follow this argument and suggest that firms may shy away from partnering opportunities with outcomes distant in "time."

Hypothesis 2: The likelihood of an established firm forming a partnership with a new startup decreases the more distant the startup's technological solutions are from commercialization.

Firms that overlook novel technological solutions may be confined to pursuing technological solutions similar to their own internal problem-solving attempts but miss technological solutions that can be disruptive and render the firm's existing competences obsolete (Gavetti, 2012; Tushman & Anderson, 1986). In a similar vein, recognizing technological opportunities at an early stage allows firms to have first mover advantages and avoid substantial premiums paid at a later stage of development due to the increased bargaining power of the technology supplier (Adegbesan & Higgins, 2011; Rothaermel & Boeker, 2008). It is hence important to understand when firms pursue partnering opportunities with novel and early stage technologies. To that end, we suggest considering a firm's prior successes and failures as possible contingencies which are known to influence intensity and direction of organizational search and shape organizational learning in general (Argote & Miron-Spektor, 2011; Greve, 2011; Madsen & Desai, 2010). Hence, we next explore prior successes and failures as important boundary conditions for the types of solutions established firms ultimately pursue in partnering activities.

Failure, Success and Local Search

Extant research highlights the role of experiencing failure and success as important drivers affecting organizational change (Argote & Miron-Spektor, 2011; Cyert & March, 1963; Greve, 2003b). In a similar vein, prior failures and successes may influence how firms interpret and make sense of emerging external partnering opportunities.

Motivated by the behavioral theory of the firm, researchers have shown that organizational actions may be differently affected by events of failures and successes (Baum & Dahlin, 2007; Madsen & Desai, 2010). In the R&D context, firms make substantial financial and organizational investments and develop expectations about the likelihood that their R&D initiatives will succeed. Ultimately, this leads to events of failures and successes as R&D initiatives to which the firms have committed substantial resources either fail or lead to to new marketable products. We argue that distinguishing events of successes and failures helps us understand a firm's tendency to overlook distant "places" and "times" when it chooses among a range of partnering opportunities. The idea follows previous research which identified that prior successes and failures affect organizational learning (Madsen & Desai, 2010; Shepherd, Patzelt, & Wolfe, 2011), R&D search intensity (Chen & Miller, 2007; Greve, 2003b) and organizational risk-taking (Audia & Greve, 2006; Greve, 2011). We extend this perspective in the direction of technological search and highlight that a firm's prior failures and successes differentially shape the likelihood of partnership formations for opportunities with novel elements of knowledge and opportunities which are distant from commercialization.

Failure & Novelty: Organizational knowledge is not static; firms continuously rely on prior experiences to draw new inferences from previous problem-solving attempts (Cyert & March, 1963; Huber, 1991). Experiencing failures may influence a firm's willingness to pursue partnering opportunities with novel technological solutions.

Researchers have long argued that a firm's perception of the external environment may be shaped by events that force it to react to given stimuli (Zahra & George, 2002). In particular, experiencing failure in problem-solving attempts may serve as such a stimulus and most likely broadens the range of alternative solutions that established firms will consider feasible when searching among partnering opportunities. First, prior failures serve as an impetus for established firms to re-evaluate their conventional technological solutions and challenges their current logic as to how problems and solutions are interrelated (Greve, 1998; Jansen et al., 2005; Kaplan & Tripsas, 2008; Lampel et al., 2009). Prior failures hence increase the range of possible alternatives considered to solve R&D problems (Cyert & March, 1963; Madsen & Desai, 2010), which in turn increases the likelihood that firms will form partnerships for more technologically distant startup opportunities. At the same time, startups developing solutions that are similar to those of the established firm may become less attractive, as established firms may not wish to pursue solutions that are close to those that have previously failed.

Second, prior failures alter the power structure within the firm and the units making decisions about which partnering opportunity to pursue. Extant research has shown that failure puts substantial pressure on the firm from external stakeholders (Abrahamson & Park, 1994; Girotra, Terwiesch, & Ulrich, 2010; Salancik & Pfeffer, 1978). Applied to the R&D context, failure compels internal coalitions to change

direction in the types of solutions used to solve problems. It is also more likely that failure alters a firm's internal power structure, which directly affects the resource allocation process in such a way that internal coalitions cannot use external initiatives as a mere extension of internal R&D activities. This increases the likelihood that partnerships are formed with startups pursuing technological solutions novel to the firm.

Taken together, our arguments suggest that when exposed to a range of possible partnering opportunities, established firms are more likely to seek technological solutions with novel elements of knowledge if the firm has experienced failures in the past.

Hypothesis 3a: An established firm's prior failures solving R&D problems positively moderate the relationship between the novelty of the startup's technological solutions and the likelihood of forming a partnership with the startup.

Success & Novelty: In a similar vein, prior successes in R&D may also influence a firm's willingness to pursue partnering opportunities with novel technological solutions. It is well known that prior success leads to confidence in firms about their existing routines and ways of solving problems and helps firms specialize in problem-solving (Audia et al., 2000). As such, prior successes may reinforce existing representations of cause and effect and further guide firms towards partnering opportunities enhancing the firm's specialized knowledge. Increasing specialization, however, may further lead firms onto paths of local search (Levinthal & March, 1993) and exacerbate their tendency of "overlooking" novel partnering opportunities. This is supported by prior research, which indicates that successes indeed cause firms to not challenge existing assumptions and can limit the variety of information processed (Lant & Montgomery, 1987; Sitkin & Pablo,

1992). The result is that successes may "trap" firms (Audia et al., 2000; Leonard-Barton, 1992) into specialized knowledge paths.

Prior successes also strengthen the power structure of units within the firm (Levinthal & March, 1993), increasing their discretion to allocate resources. Given that there is no external pressure to change direction, it is likely that coalitions tend to use their discretion to further specialize and reinforce existing R&D paths. Hence, firms with prior successes most likely will not pursue novel solutions which, in the extreme case, challenge their existing (and successful) ways of solving problems.

Combined, our arguments imply that when exposed to a range of possible partnering opportunities, established firms that have experienced successes in R&D adhere to existing problem-solving routines, exacerbating their tendencies to search locally and "overlook" partnering opportunities with novel elements of knowledge.

Hypothesis 3b: An established firm's prior successes solving R&D problems negatively moderate the relationship between the novelty of the startup's technological solutions and the likelihood of forming a partnership with the startup.

The proposed effect of hypotheses 3a and 3b are shown in Figure 5 and 6.

Figure 5: Chapter 2 – Conceptual Hypothesis 3a

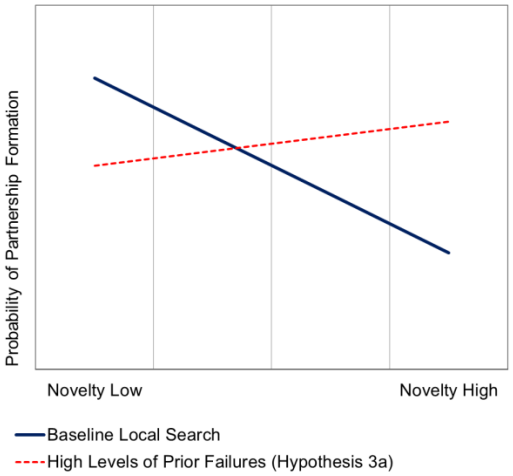
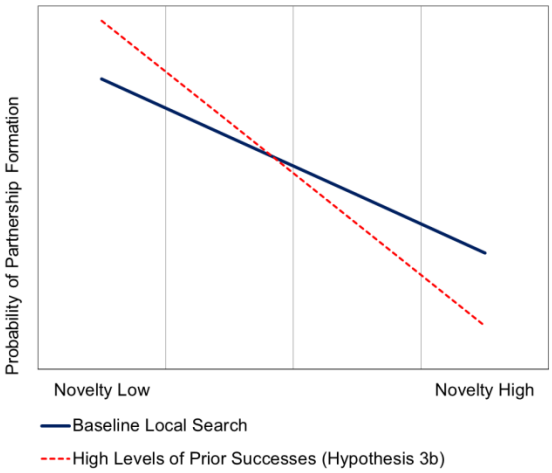


Figure 6: Chapter 2 - Conceptual Hypothesis 3b



Basically, we expect that prior failures will flatten and potentially reverse (hypothesis 3a) a firm's tendencies to search locally, i.e., overlooking novel technological solutions (Figure 5). Conversely, Figure 6 shows the expected reinforcing effect of prior successes on local search, which is reflected by a steepening of the local search curve.

In a comparable vein, prior failures and successes may very differently affect the established firm's receptivity towards partnering opportunities that are distant from commercialization, i.e., at an early stage of development. We explore this next.

Failure & Distance to Commercialization: We identified that prior failures induce established firms to change direction by pursuing partnering opportunities with novel elements of knowledge. At the same time, however, several explanations indicate that prior failures may intensify myopic tendencies towards solutions at an early stage of development. First, failures may create a sense of urgency when evaluating partnering opportunities. Extant research has suggested that firms facing crises and situations of

failures try to avoid the repetition of this experience in subsequent attempts (Madsen & Desai, 2010). While this implies the pursuit of novel ways of solving problems, it, at the same time, suggests that firms with a history of failures pursue partnering opportunities with a higher likelihood of success as exemplified by technologies closer to commercialization. The idea resonates with the observation that when experiencing a crisis, firms sometimes limit the range of information processed towards those that have immediate performance outcomes (Staw et al., 1981) and that firms confronted with problems search "problemistically," i.e., are motivated towards specific solutions (Cyert & March, 1992:170). Given the long time lags in innovation, partnering opportunities that are distant from commercialization may not be considered as feasible alternatives the more firms have experienced prior failures, as such opportunities do not promise immediate payoffs.

Similarly, coalitions with prior failures may be dominated by efficiency concerns (Staw et al., 1981) to seek technological opportunities which can be easily integrated, provide immediate results and have a lower risk of further undermining the coalition's power. The result is that the more coalitions have experienced failures, the more actively they avoid opportunities distant from commercialization because they do not want to be accountable for decisions that will not have an immediate impact on the firm's top and bottom lines and that potentially, may lead to another failure. In summary, both arguments suggest that partnering opportunities with technologies distant from commercialization may not be perceived as feasible solutions for firms which have experienced large number of failures.

Hypothesis 4a: An established firm's prior failures solving R&D problems negatively moderate the relationship between the distance from commercialization of the startup's technological solutions and the likelihood of forming a partnership with the startup.

Success & Distance to Commercialization: Prior successes may quite differently shape a firm's willingness to take a long-term approach when considering a range of possible partnering opportunities (Levinthal & March, 1981). The aforementioned tendency to further specialize after experiencing success may allow firms to more clearly understand specific problems (Kim et al., 2009) and apply their knowledge towards partnering opportunities which are more uncertain to commercialize, as with opportunities distant from commercialization. Moreover, prior successes allow firms to attend to a broader time horizon in general as they face less urgency to address specific problems. This may mean that firms can stick to existing plans, which usually combine both short term and long term considerations. The result is that prior successes allow firms to more readily enrich their partnering decisions with partnering opportunities more distant from commercialization.

Firm coalitions that have experienced prior successes may also find it easier to take accountability for decisions which will not have immediate performance outcomes as they are less pressured towards efficiency (Staw et al., 1981). This resonates with Cyert and March's (1992:189) suggestion that "success tends to breed slack" that acts as a buffer for "risky" decisions, ultimately allowing firms to be more lenient in allocating resources to early stage partnering opportunities. Taking all of these arguments together, we posit that successes have the opposite effect from failures in influencing the relationship of early partnering opportunities (i.e., distant from commercialization) and

the likelihood that established firms will pursue these opportunities through partnership formations.

Hypothesis 4b: An established firm's prior successes in solving R&D problems positively moderate the relationship between the distance from commercialization of the startup's technological solutions and the likelihood of forming a partnership with the startup.

The proposed effect of hypotheses 4a and 4b are shown in Figure 7 and 8. Basically, we expect that prior failures reinforce local search tendencies, i.e., overlooking technological solutions distant from commercialization, which is reflected by a steepening of the local search curve in Figure 7 (Hypothesis 4a). Conversely, Figure 8 shows reverse effect as we expect prior successes to flatten and potentially reverse (Hypothesis 4b) firms' tendencies to search locally

Figure 7: Chapter 2 - Conceptual Hypothesis 4a

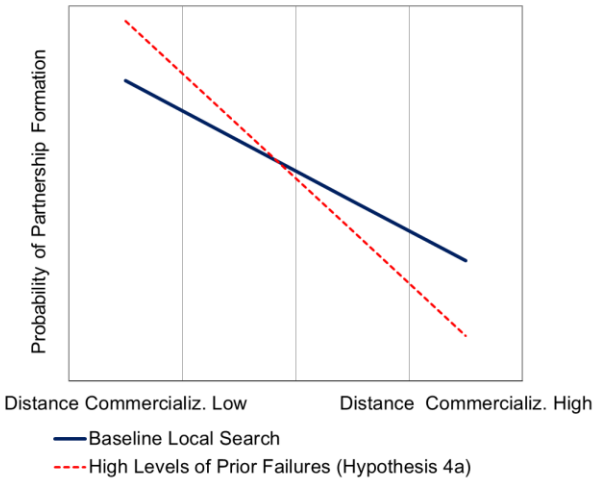
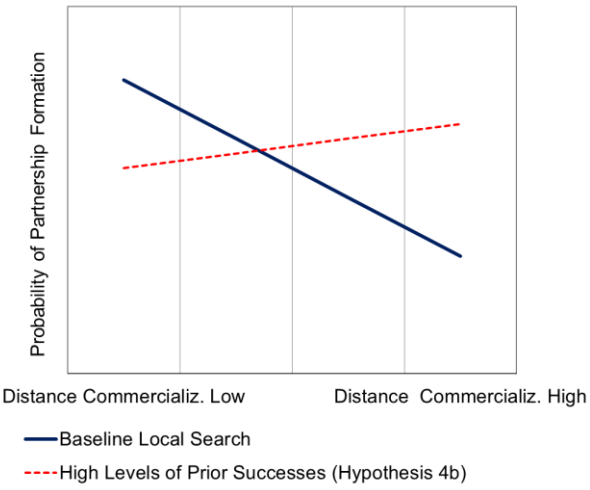


Figure 8: Chapter 2 - Conceptual Hypothesis 4b



METHODS

Background - Partnerships in the Bio-Pharmaceutical Industry

To test our hypotheses, it was mandatory to identify a range of partnering opportunities that established firms could pursue as well as capture those partnerships which were ultimately formed. Both types are observable in the bio-pharmaceutical industry in the form of compounds that represent technological solutions. The bio-pharmceutical industry is also characterized by very frequent partnership formations (Arora & Gambardella, 1994a; Rothaermel & Deeds, 2004). Our data come from various sources, including Recombinant Capital (ReCap), Pharmaprojects and Adis R&D Insights.[15]

Sample

Our sample included the top 40 publicly traded pharmaceutical firms (by sales in 1997)[16] which were actively pursuing new drug development[17] and that are actively searching for new technologies through partnerships.[18] Limiting the sample to the leading firms ensured that we observed a large portion of partnerships in the industry and at the same time, facilitated the data collection process across multiple databases. This

[15] ReCap is a database tracking partnerships in the life science industry (Schilling, 2009). Pharmaprojects and Adis R&D Insights are databases tracking new drug development in the pharmaceutical industry (Girotra et al., 2010; Hess & Rothaermel, 2011). Additional databases used for control variables are Compustat and the Derwent Innovation Index.

[16] We limited ourselves to the Top 40 firms to strike a balance between the number of firms included and the number of total observations based on a risk-set approach. Firms beyond the Top 40 contribute an equal number of observations, but tend to have fewer realized partnerships, substantially increasing the sample without adding new information. Results are very similar using the Top 50 firms.

[17] Active drug development was measured as new compounds in development in Pharmaprojects in 1997. This way, we excluded firms only pursuing generic drugs, formulation technology or diagnostics. Sample firms had to be actively developing novel therapeutics as evidence in their activity in Pharmaprojects pre 1997. The majority of the firms in our sample are incorporated in the US (45%), followed by Europe (35%) and Japan (20%).

[18] Evidenced by any partnering activity between 1997 and 2006, which we extract from Recap

approach is consistent with prior research examining established firms' management of technological change (Anand et al., 2010; Kaplan & Tripsas, 2008; Rothaermel, 2001). They include established pharmaceutical firms (e.g., Merck & Co. and Pfizer) as well as three biotechnology firms with established product portfolios (Amgen, Genentech and Chiron).[19] The focal firms are among the largest and most active publicly listed companies in drug development and, based on the global revenue figures from 1997, account for approximately 70% of all worldwide sales of globally listed pharmaceutical firms. The average revenue for all firms in the sample is $13.6BN.

We identified opportunities for partnering by observing partnerships with startups in preclinical trials (clinical development candidate selection and investigation of a new drug preparation), Phase 1 trials (evaluation of drug stability, side effects and dosage), Phase 2 trials (drug's efficacy) and Phase 3 trials (large scale clinical testing) between established and new startup firms.[20] We limited ourselves to these stages as startups have usually filed patents and signalled their intent to further develop their technologies through partnering. Put differently, at those stages, partnering opportunities are clearly visible to established firms.

Using Recap, we identified 311 startup partners trading (preclinical-Phase III) with the Top 40 established firms between 1997 and 2006, which we used as a basis to generate a set of partnering opportunities for each established firm in a given years. We

[19] While we treated Amgen and Genentech as established firms in 1997, we excluded them in robustness tests completed to verify our results to limit the sample to established firms that started in the chemical-based drug development paradigm.

[20] We defined startups as those firms founded in or after 1985 (during the biotechnology revolution) which did not yet have a commercialized product on the market in 1997 (examples include 3-Dimensional Pharmaceuticals, Actelion or Nektar Therapeutics). We took such a long time window because reaching Phase III trials involves a very long time period (12 years and more).

first considered that partnering opportunity were available in the year before an actual partnership was concluded. Based on this analysis, we identified 429 years in which startup firms had technology available for partnering.[21] To complement these partnering opportunities, we examined in which other years, between and inclusive of 1996 to 2005, the 311 startups had technologies (i.e., compounds) available for partnering. By tracking the pipelines of the small startups and determining if any compounds of the firms were flagged as a "Licensing Opportunity" in Pharmaprojects,[22] we identified an additional 423 partnering opportunities by startups, which represented years in which a compound became available by the startup. We combined the 429 observations (based on partnering) and 423 observations (based on technology availability) into one risk set for years in which startups had technologies available for partnering. We then made the assumption that each established firm could observe and evaluate all 852 possible partnering opportunities, leading to 34,080 possible combinations between startups with partnering opportunities and established firms between 1997 and 2006.[23]

[21] These 429 opportunities lead to 451 partnerships ultimately formed, as we observed 20 cases in which a startup partnered with more than one established firm in a given year. We also found 5 cases in which a startup and an established firm formed 2 or 3 partnerships in a given year. Due to the small number, we opted to keep our analysis to a simple analysis of partnership formed or not formed (and not an intensity measure).

[22] Pharmaprojects report a licensing opportunity if Pharmaprojects has received information from the pharmaceutical company concerned that the product is available for licensing. This information can come in the form of a press release, annual report, information reported at conference or from a direct communication with the company (taken from Pharmaprojects online manual)

[23] Established firms merge (e.g., Aventis and Sanofi-Synthelabo; Bayer and Schering AG) so that not all 40 initial firms are active in all years, reducing the sample. Further, the construction of the independent variables and missing data reduce the final sample. In robustness tests, we demonstrated that results hold, with a larger sample.

Measures

Dependent Variable:

Partnership Formed – We coded the dependent variable as a binary variable taking the value of 1 if an established firm did form a partnership with a new startup firm, which had partnering opportunities (preclinical-Phase 3) available in the prior year and 0 otherwise. In total, we observe 451 formed partnerships.

Independent Variables:

Novelty of partnering opportunity: To arrive at a measure for *Novelty*, we compared partnering opportunities available from new startups to the recent and ongoing drug development of the established pharmaceutical firms. We took into consideration fine-grained product development data using Pharmaprojects and observed the compounds at risk of being partnered from the startups and compared them to the drug development of established firms.

It is important to understand that biotechnology as a term is often associated with all new firms that were founded after the biotechnology revolution in the early 1980s. Biotechnology in a narrow sense means the development of large protein-based molecules as therapeutic solutions (e.g., recombinant proteins or monoclonal antibodies). However, most of therapeutic solutions, even those developed by small biotechnology firms, are still chemical-based small molecules. In our sample, the underlying compounds associated with the partnering opportunities can be divided into 38% biologics (large molecules), 58% chemicals (small molecule), with the remainder derived from natural plants.

Not all chemistry-based solutions are similar as they differ as to which mechanisms in the human bodies they address, a critical element of scientific and technological knowledge incorporated in therapeutic solutions (Lane & Lubatkin, 1998). To identify novelty, we hence incorporated the underlying material of the solution (biologics, chemicals and natural products) and the mechanism of action.[24] While, in principle, the origin of material gives a distinction between chemistry and the various derivatives of biotechnology, the mechanism of action classifies the pharmacological effect through which the drug may have an effect in the human body.[25]

In addition to all other experience-based independent variables, we chose a window of 4 years in drug development initiatives by established firms to examine how the partnering oportunites relate to the drug development experience (the origin of material and mechanism of action) by the established firms. Appendix 2 shows the way in which the variable *Novelty* is constructed for a specific startup-established firm combination. *Novelty* takes scores between 0 and 2, with 0 indicating that the established firm has used the same mechanism and origin of material in the broad therapeutic domain and a value of 2 if the startup's technological opportunity uses a mechanism and origin of

[24] We further inferred the relevance of the mechanism of action and the origin of material by reviewing the literature on drug discovery (e.g. Swinney & Anthony, 2011). Also, we examined the search guidelines outlined by pharmaceutical firms, which explicitly take into account the mechanism of action of potential drugs and the distinction between chemistry and biologics. An example can be found at http://www.merck.com/licensing/areas_of_interest.pdf.

[25] For example, Cox-2 inhibitors (one of our mechanism of action categories) prevent the production of PHG (prostaglandin) from arachidonic acid, which causes inflammation. Pharmaprojects contains thousands of mechanisms, and we employed a consulting firm to assess which mechanisms could be aggregated to reflect an important category of knowledge associated with the drug in development. A pharmacology expert with 26 years in drug development and a biotechnology graduate student did the classification separately (resulting in 310 unique pharmacology codes in our sample). We report our results based on the classification by the consulting firm after clarifying where some of the mismatches between the student and the PhD expert originated (overall agreement between the two classifications was 93%). Using the original code from Pharmaprojects leads to very similar results to the ones reported. The conversion table from the pharmaceutical consultant can be downloaded under : http://bit.ly/12SHdto

material previously not used by the established firm in a therapeutic area.[26] For example, if the opportunity is in the therapeutic domain of cancer, we examined if the mechanism of action and origin of material was used by the established firm in previous problem solving attempts in treating cancer. Examining technological opportunities at the therapeutic level is consistent with research that has examined partnership formations between established and startup firms (Diestre & Rajagopalan, 2012).

We argue that higher scores of novelty signal a strong departure from prior problem solving attempts as firms need to incorporate new knowledge in both the origin of material and mechanism of action. Whenever we identified more than one compound available for partnering by a startup in a given year, we averaged the novelty score as illustrated in the example in Appendix 2.

Distance of partnering opportunity to Commercialization: We captured the *Distance to Commercialization* by determining in which stage of the bio-pharmaceutical drug approval process the compound was at the time it became available for partnering. We distinguished the stages as being Preclinical (0), Phase I (1), Phase II (2) and Phase III (3). For a startup having more than one compound available for partnering, we selected the latest stage of all available compounds.[27] The variable *Distance to Commercialization* is reverse coded, so that Phase III opportunities receive as less distant from commercialization receives a score of (0) and preclinical opportunities, the most distant category from commercialization in our sample receive the highest scores (3).

[26] Throughout the analysis, we excluded partnering opportunities if the established firms had no experience whatsoever in a broad therapeutic areas as it is unlikely that established firms actively search for new partnering opportunities in such areas (see robustness tests).

[27] Results are robust using the average stage.

Moderators:

Prior Failures and Successes: Using the history of drug development for each established firm, we determined if firms had experienced successes or failures in the therapeutic area of the technological opportunity (see Appendix 3). Successes are rare in the bio-pharmaceutical industry, with less than 30 total new drugs approved in many after 1996. We measured *Prior Successes* as the number of successful drugs launched in the last 4 years in the therapeutic area addressed by the startup's technological solutions (Diestre & Rajagopalan, 2012) (see Appendix 3).[28] We only considered successes when we had evidence of regulatory approval in either the US, Europe or Japan.

Given that most attempts in R&D are ultimately abandoned, we did not consider it realistic to call an early stage departure from drug development a failure. We adopted the perspective that failures can be defined as alternative outcomes to successes, which means that firms discontinued product development attempts to which they had committed substantial resources and time (Girotra et al., 2010). These commitments are particularly large once bio-pharmaceutical firms start efficacy and large scale clinical testing, which is at Phase 2 and Phase 3 of the drug development process. At these stages, firms develop expectations of success that, if not met, result in experiences of failure (DiMasi et al., 2003; Shepherd et al., 2011). Similar to *Prior Successes,* we used a window of four years (Diestre & Rajagopalan, 2012) and counted the number of Phase 2 and Phase 3 failures within the broad therapeutic area of the partnering opportunity to generate the variable *Prior Failures*.[29]

[28] As a result, failure and success are rather rare events even for large bio-pharmaceutical firms (Lampel et al., 2009).

[29] At Phase II, firms are expected to have passed the proof of concept stage.

When a startup had technological opportunities spanning more than one broad therapeutic area, we averaged the number of failures and successes per compound to calculate an overall score indicating the average *Prior Successes* and *Prior* F*ailures* by the established firms in the therapeutic domains addressed by the startup.

Controls:

We controlled for various factors that could drive partnering formation. First, we took into account that startups with a larger number of available compounds (*Compounds Available*) in a given year may be more attractive for partnering. Moreover, we controlled for the main therapeutic area in which the startup is active. We also generated several dyadic measures between established firm and startup which could drive partnership formation. We used ReCap to capture partnerships within the same research community, which we defined by the broad therapeutic areas (e.g., cancer) of the startup firm. Prior research indicates that being part of a network and research community may affect subsequent partnering behavior (Gulati, 1999). ReCap indicates the therapeutic area in the "disease" field, by which we could classify them to one of the broad 13 therapeutic areas.[30] *Partnerships* is a count of all agreements in the past four years by the established firms in the same therapeutic area of the partnering opportunity. While the startups are all young firms and do not have a large history of partnering with established firms, we still controlled through an indicator variable if the established firm and the startup had a previous partnership (*Prior Partnership*), which is well-known to drive subsequent partnership formations (Rothaermel & Boeker, 2008). Given that it may be

[30] We matched the therapeutic area in Recap to the therapeutic area from Pharmaprojects using a conversion table, which can be downloaded under: http://bit.ly/ZIoSdJ

difficult to spot opportunities outside the firm's geographic boundaries (Rosenkopf & Almeida, 2003), we also captured geographic differences between startups and established firms by adding the indicator variable *Same Country*, which is 1 if firms have their HQ in the same country. Finally, we also examined the overlap of knowledge on the technical level between the startup and the established firm. Following prior research, we proxied this overlap between the established firm and the startup's overall knowledge basis (independent from the available opportunities in a given year) through their overlap in patenting activity (Diestre & Rajagopalan, 2012; Jaffe, 1986). We used the method suggested by Sampson (2007) to calculate the technological proximity based on patents between two firms (i and j). The distribution of knowledge is captured by a multidimensional vector $F_i = (F_i^1 \dots F_i^s)$, where F_i^s represents the number of patents assigned to firm i in patent class s.[31] K*nowledge overlap* between established firm i and startup j is defined as:

$$Knowledge\ Overlap = \frac{F_i F_j'}{\sqrt{(F_i F_j')(F_i F_j')}}$$

The variable is 1 when firms are identical in their patenting (strong overlap) and 0 if they are completely orthogonal (no overlap).

We also controlled for the overall activity of an established firm in the therapeutic domains addressed by the technological opportunities of the startup. First, we controlled for the established firm's total number of projects (preclinical to Phase 3) in the therapeutic domains of the partnering opportunity (*Project Pipeline),* as established firms

[31] We used a four year window and consider all 4digit IPCs associated with a patent family in Derwent, which more thoroughly captures the firms' underlying knowledge bases (Benner & Waldfogel, 2008).

may tend to partner in areas in which they are most active. We also considered if the established firm has a history of addressing the same indication in the broad therapeutic area (e.g., Alzheimer's as subcategory within neurogenerative diseases). The variable *Prior Indication* is 1 if the firm has already had projects addressing this indication in the prior four years and 0 if not.[32] We controlled for the historic tendency to explore new elements of knowledge in a therapeutic area *Exploration Orientation* as a ratio of projects in which firms deviated (in the mechanism of action or origin of material) from what they already knew internally versus all projects initiated in a given therapeutic area (i.e., the variable *New Projects*) in a 4 year timeframe. *Exploration Orientation* is a ratio which is bounded between 0 and 1. A higher score reveals a greater tendency of firms to explore new knowledge. We also proxied for the availability of complementary assets by determining if the established firm had any Top selling drug (*Top 100 Drug*)[33] in the therapeutic areas addressed by the startup (indicator variable).

Additionally, we added various financial controls of the established firms and available resources, as they may affect partnership formation. We used the *Current Ratio* to proxy "financial slack" by the firm in a given year, which is the ratio of its current assets divided by its current liabilities (Greve, 2003b). We also included *Total Assets* (logged) as a proxy for the firm's size and performance in the form of Return on Assets (*RoA*), which is known to affect firm search (Chen & Miller, 2007).

[32] The information about indication is from Pharmaprojects. In general, this information is not always complete as many drugs are categorized into an "Other" category, in particular, those designated for the treatment of cancer.

[33] We obtained the Top 100 selling drugs from drugs.com and Verispan and linked them to the therapeutic area through Pharmaprojects.

Empirical specification

We examined the full risk set as well as a choice-based sample with 4 control cases (unrealized in the same year) per realized partnership[34] (a similar approach has been used for example by Hansen & Løvås, 2004). Throughout our analysis, we added firm fixed effects using logistic regression analysis wherein the fixed effect is specified for the established firm. This means that the variation explained will be within (and not across) firms. We note that the full risk set approach has been criticized as the total number of realized deals is low (around 1.32%) compared to the unrealized ones, which may affect standard errors (Sorenson & Stuart, 2001). We mitigated these concerns by additionally examining a choice-based sampling approach. Following the guidelines set by King and Zeng (2001), we included all partnering opportunities realized plus a small number (4) of partnering opportunities for which partnerships did not occur; recently, similar techniques have been used to study dyadic partnership formations (Mitsuhashi & Greve, 2009) or in the evaluation of partnering opportunities (Tyler & Steensma, 1995).[35] We employed logistic regression with clustered standard errors. We verified that choice-based results are robust using the rare logit modification suggested by King and Zeng (2001) as, for each realized partnership. we added 4 control cases. All independent variables are constructed with a lag structure so that we observed all independent variables in t-1, when we defined a partnering opportunity as available and then observed partnering formation in the next year.

[34] The sample is reduce to 2255 (451 partnerships + 4*451 control cases)

[35] The paper outlines various partnering scenarios, which are evaluated by all managers participating in the study.

Table 3: Chapter 2 - Summary Statistics and Correlation Table

	:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Partnership Formation	1.00																	
2	Startup Age	0.01	1.00																
3	Compounds Available	0.02	0.01	1.00															
4	Partnerships (TA)	0.06	0.03	-0.03	1.00														
5	Prior Tie	0.06	0.13	0.03	0.09	1.00													
6	Same Country	0.02	0.05	-0.01	0.03	0.06	1.00												
7	Overlap Knowledge	0.03	0.12	0.03	0.16	0.09	0.07	1.00											
8	New Projects (TA)	0.06	0.00	-0.05	0.66	0.09	0.00	0.15	1.00										
9	Exploration (TA)	0.00	-0.02	0.03	-0.01	-0.01	0.01	-0.06	-0.10	1.00									
10	Prior Indication	0.04	0.01	-0.03	0.25	0.05	-0.03	0.13	0.27	0.00	1.00								
11	Top 100 Drug (TA)	0.04	0.03	0.09	0.26	0.07	0.01	0.12	0.34	-0.03	0.17	1.00							
12	Total Assets	0.04	0.07	-0.04	0.28	0.09	-0.05	-0.10	0.39	-0.04	0.24	0.35	1.00						
13	Return on Assets	0.02	-0.02	-0.01	0.11	0.03	0.08	0.01	0.20	-0.05	0.07	0.18	0.24	1.00					
14	Financial Slack	-0.02	0.00	0.01	-0.10	-0.04	0.05	0.16	-0.17	0.01	-0.07	-0.05	-0.44	-0.14	1.00				
15	Prior Failures (TA)	0.03	-0.01	-0.02	0.30	0.04	-0.08	0.11	0.44	-0.08	0.19	0.25	0.24	0.08	-0.09	1.00			
16	Success (TA)	0.05	0.00	-0.02	0.43	0.06	0.00	0.13	0.44	-0.09	0.18	0.33	0.22	0.12	-0.06	0.21	1.00		
17	Novelty	-0.04	-0.03	0.03	-0.29	-0.07	0.01	-0.11	-0.30	-0.01	-0.27	-0.15	-0.26	-0.06	0.11	-0.18	-0.19	1.00	
18	Distance Commercialization	-0.02	-0.11	0.13	0.02	0.00	-0.02	0.02	0.01	0.00	0.01	0.03	0.01	-0.01	0.01	0.01	0.02	0.02	1.00
	mean	0.02	7.75	1.58	2.33	0.06	0.35	0.67	5.00	0.51	0.79	0.32	9.20	0.12	2.51	0.83	0.70	0.96	2.17
	sd	0.13	5.36	1.06	2.67	0.23	0.48	0.15	4.77	0.32	0.38	0.47	1.28	0.12	2.33	1.13	0.86	0.67	1.02
	min	0.00	0.00	1.00	0.00	0.00	0.00	0.07	0.75	0.00	0.00	0.00	4.40	-0.16	0.68	0.00	0.00	0.00	0.00
	max	1.00	19.00	10.00	18.00	1.00	1.00	0.97	34.00	1.00	1.00	1.00	11.73	0.38	18.39	9.00	6.00	2.00	3.00

n=27697 (based on Full Sample), TA – based on therapeutic area of partnering opportunity

RESULTS

Table 3 shows the summary statistics and correlation table. Examining the correlations, we do not find evidence that multicollinearity might be a cause of concern. The mean VIF for the full models is below 3.34 and individual VIFs for the independent variables and moderators are below 2.33.

We next examine both the entire sample and the choice-based sample (1 realized partnering opportunity 4 unrealized) in parallel to test our hypotheses (Table 4). Model 1a/1b show the effect of the control variables on the likelihood of partnership formation. Consistent with prior research, we find that geographic proximity (*Same Country*) and *Prior Partnering* have a positive direct effect on the likelihood of forming a partnerships with a startup. Moreover, we find that established firms pursue partnerships in problem areas where they were successful in launching new drugs (*Success*), already having experience in the therapeutic indication (*Prior Indication*). The number of *Compounds Available* by startups is also an important factor influencing partnership formation. In the full sample, we find evidence that *Knowledge Overlap* affects partnership formation but the result does not hold in the choice-based model. Surprisingly, we do not find evidence suggesting that the overall activity in a therapeutic area (*New Projects*) drives partnership formation and also find no direct effect of *Failure*.

Model 2a/2b add the *Novelty* and *Distance to Commercialization* measures of the partnering opportunity to test Hypothesis 1 and Hypothesis 2. We expected the two forms of myopia to have a negative effect on partnership formation. As can be seen in both models, *Novelty* has a strong negative effect on the likelihood of partnership formation.

Table 4: Chapter 2 - Results – Logit - Full and Choice Based Sample

DV Partnership Formation	(1a) Full Sample	(1b) Choice Based	(2a) Full Sample	(2b) Choice Based
Firm Fixed Effects	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y
Main Therapy Area Effect	Y	Y	Y	Y
Startup Age	0.002	0.006	-0.003	-0.001
	(0.013)	(0.014)	(0.013)	(0.013)
Compounds Available	0.115**	0.129**	0.146***	0.160***
	(0.041)	(0.041)	(0.040)	(0.040)
Partnerships (TA)	0.030	0.031	0.027	0.026
	(0.035)	(0.027)	(0.035)	(0.028)
Prior Tie	0.768***	0.871***	0.770***	0.901***
	(0.135)	(0.138)	(0.136)	(0.138)
Same Country	0.421**	0.437**	0.414**	0.437**
	(0.140)	(0.157)	(0.141)	(0.161)
Overlap Knowledge	0.987*	0.811	0.958*	0.830
	(0.384)	(0.512)	(0.382)	(0.517)
Project Pipeline (TA)	0.018	0.003	0.017	-0.001
	(0.022)	(0.016)	(0.022)	(0.016)
Exploration Orient. (TA)	0.250	0.301	0.241	0.304
	(0.175)	(0.195)	(0.173)	(0.190)
Prior Indication	0.605***	0.601***	0.542**	0.609**
	(0.191)	(0.191)	(0.178)	(0.193)
Top 100 Drug (TA)	0.357+	0.349*	0.347+	0.339*
	(0.184)	(0.152)	(0.182)	(0.156)
Total Assets	0.295	0.047	0.284	0.031
	(0.247)	(0.059)	(0.250)	(0.051)
Return on Assets	1.141	-0.102	1.173	-0.147
	(0.909)	(0.293)	(0.918)	(0.269)
Financial Slack	-0.094	-0.034	-0.094	-0.028
	(0.085)	(0.026)	(0.085)	(0.024)
Prior Failures (TA)	0.025	0.058	0.021	0.059
	(0.051)	(0.047)	(0.052)	(0.049)
Prior Successes (TA)	0.138*	0.151*	0.135*	0.147*
	(0.068)	(0.066)	(0.067)	(0.068)
Novelty			-0.221**	-0.234**
			(0.075)	(0.087)
Distance Commercializat.			-0.190***	-0.205***
			(0.052)	(0.055)
Novelty X Prior Failures				
Novelty X Prior Successes				
Constant	-9.033***	-3.470***	-8.899***	-3.257***
	(2.602)	(0.719)	(2.631)	(0.639)
Log Likelihood	-2127.76	-1071.79	-2115.88	-1061.51
Observations	27697	2255	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001 (TA based on therapeutic area of opportunity)

Table 4 (continued) : Chapter 2 - Results – Logit - Full and Choice Based Sample

DV Partnership Formation	(3a) Full Sample	(3b) Choice Based	(4a) Full Sample	(4b) Choice Based
Firm & Year Fixed Effects	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y
Main Therapy Area Effect	Y	Y	Y	Y
Startup Age	-0.003	-0.000	-0.003	-0.000
	(0.013)	(0.014)	(0.013)	(0.014)
Compounds Available	0.149***	0.161***	0.147***	0.160***
	(0.040)	(0.039)	(0.039)	(0.039)
Partnerships (TA)	0.030	0.031	0.029	0.031
	(0.034)	(0.026)	(0.035)	(0.026)
Prior Tie	0.770***	0.914***	0.771***	0.906***
	(0.136)	(0.138)	(0.136)	(0.139)
Same Country	0.413**	0.423**	0.415**	0.438**
	(0.141)	(0.163)	(0.141)	(0.159)
Overlap Knowledge	0.957*	0.851+	0.957*	0.858+
	(0.382)	(0.509)	(0.384)	(0.515)
Project Pipeline (TA)	0.017	-0.002	0.018	-0.002
	(0.021)	(0.016)	(0.021)	(0.016)
Exploration Orient. (TA)	0.224	0.284	0.233	0.283
	(0.174)	(0.190)	(0.174)	(0.191)
Prior Indication	0.514**	0.584**	0.526**	0.587**
	(0.179)	(0.196)	(0.180)	(0.195)
Top 100 Drug (TA)	0.338+	0.324*	0.341+	0.323*
	(0.181)	(0.155)	(0.180)	(0.153)
Total Assets	0.283	0.022	0.284	0.029
	(0.253)	(0.054)	(0.252)	(0.057)
Return on Assets	1.170	-0.167	1.165	-0.149
	(0.918)	(0.276)	(0.924)	(0.283)
Financial Slack	-0.092	-0.028	-0.092	-0.026
	(0.085)	(0.025)	(0.085)	(0.025)
Prior Failures (TA)	0.073	0.087	0.021	0.062
	(0.052)	(0.061)	(0.052)	(0.050)
Prior Successes (TA)	0.138*	0.153*	0.173*	0.228**
	(0.066)	(0.066)	(0.071)	(0.076)
Novelty	-0.282***	-0.318***	-0.231**	-0.280**
	(0.076)	(0.090)	(0.078)	(0.097)
Distance Commercializat.	-0.192***	-0.205***	-0.191***	-0.204***
	(0.052)	(0.055)	(0.052)	(0.055)
Novelty X Prior Failures	0.140***	0.179***		
	(0.040)	(0.047)		
Novelty X Prior Successes			0.082	0.123
			(0.071)	(0.076)
Constant	-8.876***	-3.131***	-8.899***	-3.251***
	(2.660)	(0.653)	(2.648)	(0.688)
Log Likelihood	-2113.19	-1057.96	-2115.25	-1059.49
Observations	27697	2255	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001 (TA based on therapeutic area of opportunity)

In a similar vein, the *Distance to Commercialization* of the partnering opportunity significantly reduces the likelihood of subsequent partnership formation (the marginal effects are equally significant at $p<0.01$ holding all other variables at their mean values).

To test Hypotheses 3a,b and 4a,b, we added interactions to the model. We started in Model 3a/3b by interacting *Novelty* with *Prior Failures*. Supporting Hypothesis 3a, we find a positive effect of the interaction, indicating that firms that have experienced failure in solving therapeutic problems related to the partnering opportunity are more likely to pursue partnerships with novel elements of knowledge. We demonstrate this effect graphically in Figure 9, where we plot the moderation of *Novelty* at various levels of *Prior Failures*.

Figure 9: Chapter 2 - Moderation Novelty and Prior Failures

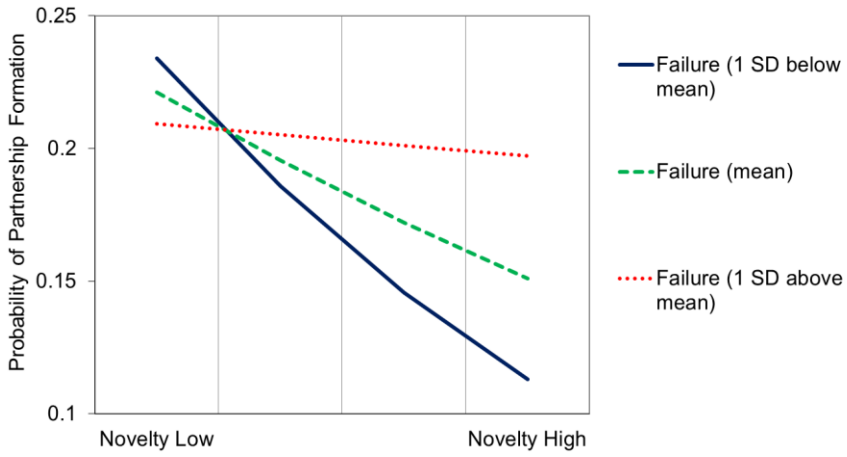


Figure 9 indicates the persistent tendency of established firms to search for partnering opportunities in the neighborhood of existing solutions. We see, however, that this tendency is much less salient once firms have experienced failures and is reversed when failures in the therapeutic areas addressed by the startup firm are at very high levels. Overall, the results provide support for Hypothesis 3a.

Table 5: Chapter 2 - Results – Logit - Full and Choice Based Sample – Continued

DV Partnership Formation	(5a) Full Sample	(5b) Choice Based	(6a) Full Sample	(6b) Choice Based
Firm Fixed and Year Effects	Y	Y	Y	Y
Main Therapy Area Effect	Y	Y	Y	Y
Startup Age	-0.003	-0.000	-0.003	-0.001
	(0.013)	(0.014)	(0.013)	(0.013)
Compounds Available	0.146***	0.159***	0.152***	0.160***
	(0.040)	(0.040)	(0.039)	(0.039)
Partnerships (TA)	0.027	0.025	0.027	0.025
	(0.035)	(0.028)	(0.035)	(0.026)
Prior Tie	0.775***	0.912***	0.760***	0.890***
	(0.135)	(0.137)	(0.137)	(0.135)
Same Country	0.415**	0.447**	0.413**	0.443**
	(0.140)	(0.159)	(0.142)	(0.162)
Overlap Knowledge	0.947*	0.781	0.944*	0.871+
	(0.383)	(0.517)	(0.394)	(0.503)
Project Pipeline (TA)	0.018	-0.001	0.016	-0.001
	(0.021)	(0.016)	(0.022)	(0.016)
Exploration Orient. (TA)	0.239	0.296	0.245	0.311
	(0.173)	(0.189)	(0.173)	(0.191)
Prior Indication	0.542**	0.603**	0.550**	0.632***
	(0.179)	(0.192)	(0.177)	(0.191)
Top 100 Drug (TA)	0.348+	0.337*	0.349+	0.343*
	(0.182)	(0.154)	(0.182)	(0.158)
Total Assets	0.284	0.035	0.285	0.034
	(0.250)	(0.053)	(0.247)	(0.056)
Return on Assets	1.174	-0.117	1.167	-0.168
	(0.920)	(0.270)	(0.922)	(0.268)
Financial Slack	-0.094	-0.028	-0.093	-0.031
	(0.085)	(0.024)	(0.085)	(0.024)
Prior Failures (TA)	0.014	0.057	0.022	0.050
	(0.054)	(0.049)	(0.052)	(0.049)
Prior Successes (TA)	0.135*	0.156*	0.142*	0.153*
	(0.067)	(0.067)	(0.063)	(0.063)
Novelty	-0.219**	-0.234**	-0.226**	-0.229**
	(0.075)	(0.087)	(0.075)	(0.087)
Distance Commercialization	-0.171**	-0.171**	-0.249***	-0.260***
	(0.053)	(0.064)	(0.057)	(0.064)
Novelty X Prior Failures				
Novelty X Prior Successes				
Distance Comm. x Failures	-0.051+	-0.069+		
	(0.029)	(0.039)		
Distance Comm. x Successes			0.132**	0.145**
			(0.042)	(0.054)
Constant	-8.897***	-3.261***	-8.948***	-3.334***
	(2.636)	(0.640)	(2.601)	(0.678)
Log Likelihood	-2114.26	-1060.11	-2111.20	-1057.71
Observations	27697	2255	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001, (TA based on therapeutic area of the opportunity)

Table 5 (continued): Chapter 2 - Results – Logit - Full and Choice Based Sample – Continued

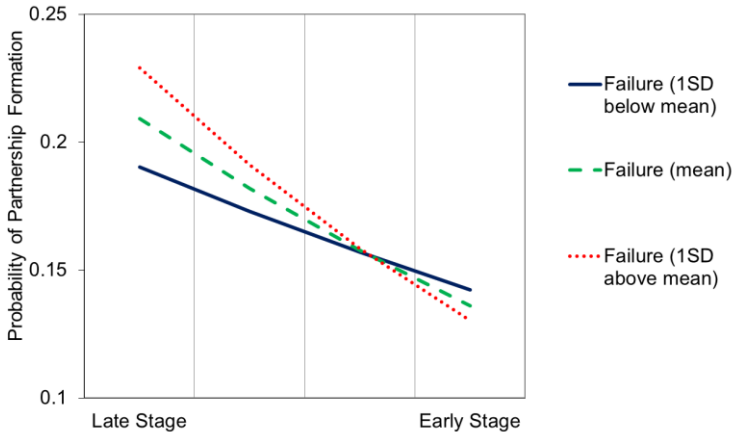
DV Partnership Formation	(7a) Full Sample	(7b) Choice Based
Firm and Year Fixed Effects	Y	Y
Main Therapy Area Effect	Y	Y
Startup Age	-0.003	-0.000
	(0.013)	(0.014)
Compounds Available	0.156***	0.161***
	(0.039)	(0.039)
Partnerships (TA)	0.031	0.031
	(0.035)	(0.024)
Prior Tie	0.768***	0.916***
	(0.137)	(0.135)
Same Country	0.411**	0.444**
	(0.141)	(0.159)
Overlap Knowledge	0.935*	0.857+
	(0.386)	(0.492)
Project Pipeline (TA)	0.016	-0.004
	(0.021)	(0.016)
Exploration Orient. (TA)	0.223	0.267
	(0.176)	(0.192)
Prior Indication	0.518**	0.590**
	(0.178)	(0.193)
Top 100 Drug (TA)	0.339+	0.315*
	(0.180)	(0.154)
Total Assets	0.283	0.030
	(0.250)	(0.065)
Return on Assets	1.153	-0.154
	(0.928)	(0.286)
Financial Slack	-0.090	-0.029
	(0.085)	(0.027)
Prior Failures (TA)	0.060	0.085
	(0.052)	(0.062)
Prior Successes (TA)	0.160*	0.224**
	(0.067)	(0.071)
Novelty	-0.295***	-0.352***
	(0.077)	(0.095)
Distance Commercialization	-0.223***	-0.222**
	(0.057)	(0.071)
Novelty X Prior Failures	0.139**	0.166***
	(0.044)	(0.045)
Novelty X Prior Successes	0.028	0.120
	(0.074)	(0.074)
Distance Comm. x Failures	-0.076*	-0.087+
	(0.032)	(0.045)
Distance Comm. x Successes	0.156***	0.157**
	(0.045)	(0.054)
Constant	-8.909***	-3.232***
	(2.633)	(0.727)
Log Likelihood	-2106.21	-1050.98
Observations	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001, (TA based on therapeutic area of the opportunity)

Hypothesis 3b predicted an opposite effect as a history of success would reinforce local tendencies and lead firms to not consider opportunities with novel elements of knowledge. When interacting *Novelty* and *Prior Successes* (Model 4a/4b respectively), we do not find the predicted effect. Instead of the expected negative interaction, we find a positive albeit insignificant effect. We hence do not find support for Hypothesis 3b, which suggested that *Prior Successes* would lead firms to seek technological solutions knowledge in the neighborhood of previous problem-solving attempts.

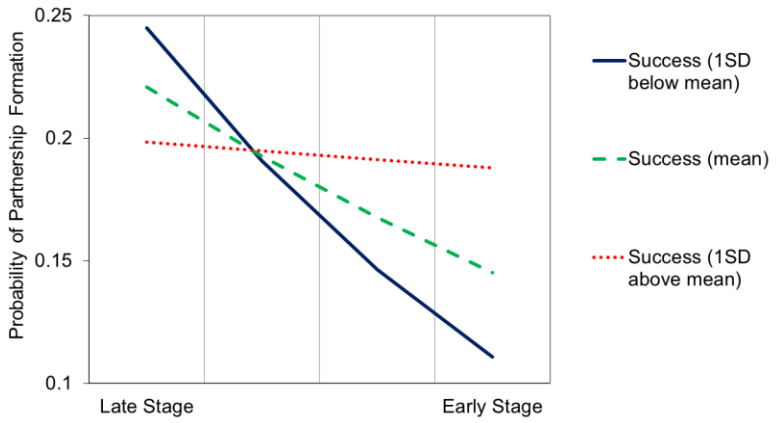
We next tested Hypotheses 4a. Models 5a/5b (Table 5) show the interaction of *Distance to Commercialization* with *Prior Failures.* We do not observe overall strong support for the theorized effect as we only find marginal significance for the moderation of *Prior Failures* and *Distance to Commercialization,* which is low given the number of observations. This effect is graphically explored in Figure 10. It gives at least partial support for Hypothesis 4a, that at high levels of *Prior Failures*, established firms at least marginally prefer partnering opportunities that are close to commercialization.

Figure 10: Chapter 2 - Moderation Distance to Commercialization and Prior Failures



We observe the opposite effect in Models 6a/6b, which examine the interaction of *Distance to Commercialization* and *Prior Successes.* Namely, the more *Prior Successes*, the more firms tend to pursue partnering opportunities distant to commercialization. The effect is demonstrated graphically in Figure 11 and supports Hypothesis 4b. Overall, the findings for Hypothesis 4a and 4b indicate that failures and successes quite differently shape the relationship of *Distance to Commercialization* and *Partnership Formation* but the effect of *Prior Failures* is only marginally supported through our empirical results.

Figure 11: Chapter 2 - Moderation Distance to Commercialization and Prior Successes



Model 7a/7b demonstrate that all interactions that were supported individually also hold in a full model. Interestingly, these models show that when considering both interactions of *Distance of Commercialization* with *Prior Successes* and *Prior Failures* simultaneously, we indeed find that they have the expected opposite effects on the likelihood of partnerships formations (at least in the full model). While *Prior Failures* lead firms to shy away from opportunities distant from commercialization (early stage), *Prior Successes* have the opposite effect as firms more readily pursue early stage

solutions. Both *Prior Failures* and *Prior Successes* are correlated at 0.21, which may affect the result. However, their level of correlation does not cause concern in terms of multicolinearity, lending some support for Hypothesis 4a, while 4b remains supported in the full model.

Table 6 showcases the marginal effects of *Novelty* and *Distance to Commercialization* at different levels of the moderators. We examined the 25th and 75th percentile value of *Prior Failures* and *Prior Successes*, which again supports Hypotheses 3a, 4a (partially) and 4b.

Table 6: Chapter 2 - Marginal effects:

Marginal Effects of Novelty/Distance to Commercialization at different levels of moderators:

STATA - Margins	Novelty	Distance to Commercialization
When Prior Failures is at 25th percentile	-0.0611*** (0.0138)	-0.0182 (0.0116)
When Prior Failures is at 75th percentile	-0.0320* (0.0149)	-0.0411*** (0.0090)
Changes in the marginal effect	0.0709**	0.0229+
When Prior Successes is at 25th percentile	not significant	-0.0452*** (0.0108)
When Prior Successes is at 75th percentile	not significant	-0.0224* (0.0092)
Changes in the marginal effect	not significant	0.0228*

Robustness Tests: We conducted several additional checks to establish the robustness of the findings (Table 7). First, we relaxed the assumption that all established firms in the sample were at risk of establishing a partnership in a given year. Omitting those years in which an established firm did not pursue a partnership equally supports our

results (Model R1).[36] In a similar vein, we show that results are robust when considering a risk set which includes those partnering opportunities in which the established firms had no prior experience in the broad therapeutic area (R2). We note that in this model, we would have to assume that firms would search for technologies in therapeutic areas, in which they are not currently active, which is very rarely observed in our data. In a final check related to the sample, we also excluded firms which had substantial revenues but were not founded in the chemistry-based drug development paradigm (Amgen, Genentech and Chiron). Results remain robust when we only consider established firms that traditionally focused on chemistry-based drug development.

We also operationalized our key variables in different ways. Namely, we used indicator variables for *Prior Failures* and *Prior Successes,* in which failures and successes are operationalized by binary variables (Models R3a and R3b). The results are very similar to using the count variables in Tables 4 and 5. We alternatively deployed a depreciated failure and success experience in which we considered the complete drug development history (starting 1988) and a discount factor of 80% each year (Model R4a, R4b). Again, results are in line with the main findings. However, it is interesting to note that the significance for the *Distance to Commercialization* and *Failure* interaction in models R4a and R4b is slightly lower than before.[37] We conducted further robustness tests, operationalizing *Novelty* and *Distance to Commercialization* differently. Namely,

[36] The result of a two-stage Heckman (1977) estimation, including the inverse Mills ratio generated from a first stage (formed partnership in a given year), also provides support for our hypotheses even if we only consider years in which firms formed a partnership (results available from the authors).

[37] Both *Prior Failures* and *Prior Successes* hold when operationalized as cumulative counts of the prior 3 years only and *Prior Failures* holds when only capturing Phase III and not Phase II discontinuations.

we individually examined if *Novelty* constructed using only the origin of material or only the mechanism of action lead to similar results.[38] This is shown in model R5a/b and R6a/b, which support our main results but with slightly weaker significance. Namely, the choice based model, in which we operationalize *Novelty* through the mechanism of action only, leads to a marginally significant effect for the interaction with failure. Still, when examining the moderations, we observe that both operationalization show quite similar effects, further supporting our findings.

[38] The two alternative variables are correlated at 0.16.

Table 7: Chapter 2 - Robustness Tests – Logit - DV Partnership Formation

DV Partnership Formation	(R1) Sample: Only Years in which firms had at least one partnership	(R2) Sample: All therapy codes (including where firms not active)	(R3a) Full Sample: Failure & Success - indicators	(R3b) Choice Based: Failure & Success - indicators	(R4a) Full Sample: Failure & Success - depreciated stock	(R4b) Choice Based: Failure & Success - depreciated stock
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y	Y	Y
Main Therapy Area E.	Y	Y	Y	Y	Y	Y
Failure (TA)	0.052 (0.044)	0.064 (0.052)	0.115 (0.124)	0.087 (0.149)	0.001 (0.058)	0.066 (0.065)
Success (TA)	0.162** (0.061)	0.191** (0.068)	0.537*** (0.138)	0.649*** (0.142)	0.212* (0.087)	0.297** (0.098)
Novelty	-0.311*** (0.079)	-0.375*** (0.072)	-0.419*** (0.125)	-0.469** (0.150)	-0.274*** (0.075)	-0.331*** (0.094)
Distance Commercializ.	-0.221*** (0.057)	-0.230*** (0.057)	-0.325** (0.103)	-0.318* (0.139)	-0.212*** (0.053)	-0.219*** (0.062)
Novelty X Prior Failures	0.141*** (0.039)	0.162*** (0.045)	0.342** (0.119)	0.269+ (0.142)	0.159** (0.057)	0.162** (0.061)
Novelty X Success	0.033 (0.070)	0.076 (0.069)	-0.009 (0.167)	0.125 (0.154)	0.062 (0.081)	0.128 (0.083)
Distance Com. x Failures	-0.071* (0.030)	-0.074* (0.031)	-0.200+ (0.112)	-0.212+ (0.123)	-0.076+ (0.041)	-0.077+ (0.042)
Distance Com. x Successes	0.150*** (0.044)	0.165*** (0.045)	0.400** (0.124)	0.392** (0.149)	0.132** (0.050)	0.152** (0.053)
Constant	-6.167*** (1.116)	-9.005*** (2.406)	-9.230*** (2.590)	-3.426*** (0.838)	-9.023*** (2.629)	-3.112*** (0.694)
Log Likelihood	-1953.56	-2260.37	-2099.86	-1047.91	-2107.35	-1052.13
Observations	16683	33532	27697	2255	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001; variables not shown but included in the models: Startup Age, Compounds Available, Partnerships, Prior Tie, Same Country, Overlap Knowledge, New Projects, Exploration Orientation (not in R2), Prior Indication, Top 100 Drug, Total Assets, Return on Assets, Financial Slack

Table 7 (continued): Chapter 2 - Robustness Tests – Logit - DV Partnership Formation

DV Partnership Formation	(R5a) Full Sample: Novelty – Origin of Material	(R5b) Choice Based: Novelty – Origin of Material	(R6a) Full Sample: Novelty – Mechanism of Action	(R6b) Choice Based: Novelty – Mechanism of Action	(R7a) Full Sample: Distance Comm. indicator	(R7b) Choice Based: Distance Comm. indicator
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y	Y	Y
Main Therapy Area E.	Y	Y	Y	Y	Y	Y
Failure (TA)	-0.032 (0.063)	0.008 (0.053)	-0.056 (0.071)	-0.057 (0.061)	-0.001 (0.061)	0.042 (0.050)
Success (TA)	0.141* (0.062)	0.138* (0.065)	0.137 (0.075)	0.138+ (0.076)	0.272*** (0.078)	0.330*** (0.083)
Novelty	-0.249* (0.125)	-0.303* (0.142)	-0.236* (0.099)	-0.315** (0.121)	-0.298*** (0.077)	-0.359*** (0.096)
Distance Commercializ.	-0.227*** (0.057)	-0.227** (0.069)	-0.222*** (0.057)	-0.224** (0.069)	0.439*** (0.129)	0.457** (0.158)
Novelty X Prior Failures	0.190* (0.095)	0.199* (0.094)	0.118+ (0.067)	0.196* (0.076)	0.140** (0.044)	0.175*** (0.044)
Novelty X Success	0.027 (0.119)	0.171 (0.141)	0.039 (0.090)	0.085 (0.099)	0.028 (0.074)	0.120 (0.074)
Distance Com. x Failures	-0.078* (0.032)	-0.089* (0.038)	-0.077* (0.032)	-0.089* (0.039)	-0.1901+ (0.098)	-0.231+ (0.123)
Distance Com. x Successes	0.156*** (0.045)	0.158** (0.054)	0.153*** (0.045)	0.161** (0.054)	0.380*** (0.093)	0.354** (0.113)
Constant	-8.907*** (2.629)	-3.128*** (0.772)	-8.937*** (2.595)	-3.120*** (0.709)	-8.996*** (2.638)	-3.349*** (0.749)
Log Likelihood	-2109.22	-1054.42	-2110.48	-1054.58	-2106.73	-1050.37
Observations	27697	2255	27697	2255	27697	2255

+ p<.10, * p<.05, ** p<.01, *** p<.001; variables not shown but included in the models: Startup Age, Compounds Available, Partnerships, Prior Tie, Same Country, Overlap Knowledge, New Projects, Exploration Orientation (not in R2), Prior Indication, Top 100 Drug, Total Assets, Return on Assets, Financial Slack

It is also interesting to note that while the Origin of Material strongly predicts myopia (Hypothesis 1), we do not find this effect significant from the Mechanism of Action (negative effect but significance at $p<0.13$). Finally, we operationalized *Distance to Commercialization* through an indicator variable, in which we split opportunities if they are before proof of concept (preclinical-Phase) or after (Phase II and Phase III). We also ran additional graphical checks using the inteff command in STATA to understand the interaction effects (Ai & Norton, 2003; Zelner, 2009). Graphical inspection is recommended to investigate whether most observations have a Z-statistic above 2 (for hypotheses 3a and 4b) and below 2 (for hypotheses 3b and 4a). Appendix 4 indeed showcases that for all significant interactions, we find that the majority of observations are above/below significant at $p<0.05$ further strengthening our results.

DISCUSSION

This paper examines how established firms react to emerging technological opportunities from startup firms, which are considered an important generator of innovative and often radical technological solutions. We take into account that the interpretation, recognition and pursuit of partnering opportunities is influenced by myopic tendencies, as firms tend to overlook technological solutions that are novel or that will result in payoffs in the distant future. We hence demonstrate that merely opening up to external startups does not necessarily alleviate the tendency of firms to search locally with respect to novelty and distance to commercialization of partnering opportunities.

We further consider that the recognition of external opportunities may be shaped by a firm's prior successes and failures. We combine both perspectives and investigate how successes and failures shape the reaction of established firms to external partnering

opportunities that differ both in their degree of technological novelty to the established firm and their distance to commercialization.

In doing so, we clarify how prior failures and prior successes differently shape the two forms of myopia. While prior failures generate an organizational environment in which firms become more open to novel ways of solving problems, they, at the same time, may push firms to seek partnering opportunities which promise immediate payoffs. Conversely, prior successes may enable firms to take the long term perspective of adding partnering opportunities with more distant payoffs. The study hence argues for the value of integrating perspectives on myopia and local search with studies examining events of failures and successes (Greve, 2011; Laursen, 2012) to understand decisions made concerning firm partnering.

While recent studies have examined if failures or successes have a stronger effect on organizational learning (Madsen & Desai, 2010), the insight of our study is that prior failures and prior successes cannot unambiguously be associated with a distinct search directions as they influence the various forms of myopia in different ways. For example, while failures challenge the firm's current assumptions, they simultaneously generate urgency, leading not only to pursuing opportunities with novel elements of knowledge but also opportunities with immediate payoffs. At the same time, we do not find evidence that prior successes "trap" organizations into local paths (Audia et al., 2000). Conversely, in our setting, a history of successes may generate an organizational environment in which firms consider partnering opportunities more distant from commercialization. Hence, both failures and successes may play an important role in adding variety of different forms to firms' innovation pipelines.

We also shed light on some underlying activities that may shape a firm's ability to recognize external partnering opportunities. While previous researchers have generally emphasized the importance of internal R&D per se in sensing and seizing external technological solutions (Cohen & Levinthal, 1990), we provide a more nuanced view as to how prior success and failure in R&D shape this ability. Given that firms today continue to face scrutiny of their own internal investments in R&D and are heavily penalized for failure, we argue that this study reveals that failure may actually have some benefits as it opens the firms up towards new ways of problem-solving.

The study has a number of limitations, which should provide ample opportunities for future research. First, it was conducted in the context of a single industry and the generalizability of our findings and their boundary conditions would need to be validated through explorations in other empirical contexts. The bio-pharmaceutical industry as a research context, however, allows us to readily capture success and failure in R&D, which is challenging in other industry settings. In addition, while, in pharmaceutical partnering, opportunities can be readily identified, this may not be possible in other industries. Relying on patents may not be the best strategy as it is unclear if patents are actually available for partnering or licensing by the startup firm.

Second, and in a similar vein, the study currently only considers reactions to emerging external technological opportunities through partnering. However, established firms possess a broad variety of tools to tap into external knowledge, including acquisitions or CVC investments (Keil et al., 2008; Nicholls-Nixon & Woo, 2003). The study hence only captures a subset of actions at the disposal of established firms. Restricting our analysis to partnering, however, allows us to identify an unambiguous risk

set of opportunities available for partnering. With an acquisition, firms gain access to the full knowledge of a startup, including all patents and prior projects – it is hence more difficult to define what really was at risk before the acquisition transaction took place. Conversely, partnering is limited to specific products in development, which allows us to more accurately identify technological opportunities versus those pursued. The expansion of the study to include acquisitions, however, provides an interesting area for future research as there may be differences in what type of opportunities firms partner for and acquire.

Finally, the partnerships observed in this study only constitute a subset of all partnerships in which established firms engage. In this study, we do not capture very early stage discovery partnerships or commercialization partnerships that occur when drugs are already approved. Future research may attempt to expand the study to a broader set of value chain activities. Given that it is difficult to unambiguously identify the partnering opportunities when no compound is yet available, we opted to exclude very early stage research partnerships (at discovery stage). An important limitation hence is that the startups we observe already have some history and products in development, which in the bio-pharmaceutical industry can take already a decade of research. At the same time, firms already having commercialized compounds available may behave very differently in partnering as incentives and bargaining power change substantially (Adegbesan & Higgins, 2011). Firms with such partnering opportunities may themselves have already invested in complementary assets and started their transition to become more like established industry players, which mostly likely changes the dynamics in partnership formations.

CONCLUSION

We combine perspectives on organizational myopia and organizational learning to investigate how prior successes and failures shape the reaction of established firms to external partnering opportunities. Comparing potential and realized partnerships between established and startup firms, we illustrate that myopic tendencies are highly salient in the partnering formation process between established and startup firms. However, we also outline the role of prior failures and successes in illustrating when firms go beyond local search in partnership formation. We find that while prior failures are important to firms' consideration of novel technological solutions, prior successes can make them more receptive to solutions at an earlier stage of development. Hence, both failures and successes may make firms more receptive to different types of emerging partnering opportunities.

CHAPTER 3: SWIMMING AGAINST THE CURRENT: EXAMINING THE RELATIONSHIP BETWEEN RADICAL INNOVATION AND STARTUP FIRM MARKET VALUE

An important line of inquiry within the technological change literature highlights that in environments characterized by rapid technological change, new startup firms frequently emerge that challenge the ways in which incumbent firms solve problems and come up with radically new solutions and products (Christensen & Rosenbloom, 1995; Foster, 1986; Tushman & Anderson, 1986). Radical innovations, i.e., innovations that are "*based on a substantially new technology relative to what already exists"* (Govindarajan & Kopalle, 2006:13) and *"involve methods and materials that are novel to incumbents"* (Hill & Rothaermel, 2003) are at the heart of Schumpeter's (1942) theory of creative destruction, which suggests that startup firms – unencumbered by aging and embedded competencies – nimbly push technological change forward and ultimately gain the "attacker's" advantages (Christensen & Rosenbloom, 1995; Cooper & Schendel, 1976; Foster, 1986; Henderson, 1993; Li & Atuahene-Gima, 2001).

At the same time, however, established firms often retain possession of specialized downstream complementary assets (Hill & Rothaermel, 2003; Rothaermel, 2001; Taylor & Helfat, 2009), which leads to challenges for startup firms pursuing innovations different from the existing industry conventions and recipes (Spender, 1989). It is, hence, not surprising that empirical findings testing the relationship of radical

innovation and performance outcomes for startup firms remain inconclusive at best (Li & Atuahene-Gima, 2001). [39]

In this paper, we consider startup firms located in an industry in which established firms retain control of downstream complementary assets. In a first step, we examine if pursuing radical product innovations in such a setting generates higher or lower market valuations, a key performance indicator for startup firms (Aggarwal & Hsu, 2009; DeCarolis & Deeds, 1999; Stuart et al., 1999; Zott & Amit, 2008). We next take into account the unique dependencies between startups and established firms and, in a second step, examine under which conditions pursuing radical product innovation may be associated with higher market valuations for startups.

Drawing on the literature on startup performance and inter-organizational partnering (Baum et al., 2000a; Stinchcombe, 1965; Stuart et al., 1999; Tushman & Anderson, 1986), we argue that pursuing radical ways of solving problems compound legitimacy issues and resource constraints leading to lower market valuations for startups. Considering the unique interdependencies between startups and established firms, however, suggests that under distinct conditions, startups pursuing radical innovations may mitigate these constraints. In particular, we examine the formation of commercialization partnerships (Baum et al., 2000a; Stuart et al., 1999) and the maturity of technologies in development (Rothaermel & Boeker, 2008) by the startup, as well as failure in R&D efforts by established firms (Cyert & March, 1963; Madsen & Desai, 2010) as important conditions mitigating legitimacy and resource constraints for startups pursuing radical innovations.

[39] Li and colleagues are not explicit about the radicalness of innovation but consider innovations new to the firm and /or the market as product innovation in general.

We test our hypotheses in the global biopharmaceutical industry by examining the product innovation by New Biotechnology Firms (labeled startups in this paper). In the 1990s, hundreds of biotechnology entrants pursued the bio-pharmaceutical industry in the hope of dramatically altering the industry landscape (Arora & Gambardella, 1994a; Schweizer, 2005). We assembled a unique panel dataset that includes information on 144 startups with an IPO during the 1991-1999 and track them between 1991 and 2008. By comparing the startups' products in development to those of incumbent firms in the industry, we are able to generate a unique time-variant measure for innovation radicalness, which avoids any ex post classification of the radical nature of the startups' technological solutions (Dahlin & Behrens, 2005).

Consistent with our arguments, we find that there is a severe penalty associated with pursuing radical product innovation in an industry where established firms remain in possession of important complementary assets. At the same time, however, this penalty is substantially reversed for startups forming commercialization partnerships and for those startups pursuing radical innovations in therapeutic areas where incumbent firms experience failures in their own product development attempts. We find only limited evidence that the downsides of pursuing radical innovations may be offset by the maturity of the startup's technological solutions. Our results account for unobserved differences across firms and over time, and are robust to a number of alternative econometric specifications and operationalization of key variables.

This study is a first attempt to systematically and longitudinally identify radical product innovations for startup firms, while taking into account the unique dependencies between startups and established firms. Previous studies have predominantly focused on

established firms and their ability to cope with radical technological change per se (Hill & Rothaermel, 2003; Rothaermel & Hill, 2005), but have less taken into account the consequences for startups pursuing radical innovations when established firms retain complementary assets.

We show that in environments where established firms retain complementary assets, there are no clear attacker's advantages (Christensen & Rosenbloom, 1995; Foster, 1986) and startups pursuing radical innovations are actually penalized in their market value. This complements the literature on the liability of newness and smallness (Freeman, Carroll, & Hannan, 1983; Stinchcombe, 1965), which has identified that young and nascent firms are facing a unique set of challenges threatening their survival. We suggest and find that to fully comprehend the severity of challenges for startup firms, it is important to differentiate how new and young firms are positioned in their innovation attempts versus the established firms.

To our knowledge, our study is also the first to consider failure by incumbent firms as an important environmental factor influencing the relationship between radical product innovations and startup market valuations. While scholars previously considered failure by other players in the industry as an important driver of vicarious learning (Argote & Miron-Spektor, 2011; Madsen & Desai, 2010), we demonstrate that in an environment where established firms tend to "set" the rules for the industry (Abernathy & Clark, 1985; Martin & Mitchell, 1998), benefits from failure by established firms are accrued by startups pursuing more radical innovations. Methodologically, the paper extends studies on innovation radicalness, which have started to define radicalness not as an ex post, but as a dynamic construct through the comparison of current R&D initiatives

by the startup versus the ones pursued by established industry players (Dahlin & Behrens, 2005).

THEORY AND HYPOTHESES

Swimming Against the Current - Pursuing Radical Innovations

Startup firms frequently challenge the ways in which incumbent firms solve problems (Christensen & Rosenbloom, 1995; Schumpeter, 1942; Tushman & Anderson, 1986) and introduce radical technological innovations that differ substantially to what already exists in the industry (Govindarajan & Kopalle, 2006:13). At the same time, however, startups that reject industry conventions and select technological solutions outside the range of acceptability of the industry may be perceived as less reliable and legitimate (Suchman, 1995). These challenges are particularly severe in industries where established firms' complementary assets are preserved as startups may depend on established firms for developing their radical technological solutions. In such environments, pursuing radical innovations is associated with substantial challenges, which may adversely affect a startup's market value.

First, startups with radical innovations face ambiguity as to whether their technological solutions are actually feasible and legitimate technological alternatives for the industry (Sanders & Boivie, 2004). Technological solutions at the initial stage of their lifecycle are often a mix of poorly defined tacit "know-how" and cannot be easily evaluated (Mowery & Rosenberg, 1989:7). This is particular salient for radical product innovations that lack comparable industry templates and cannot be easily juxtaposed to existing product development attempts of established firms (Jensen & Szulanski, 2007). Technological solutions that do not conform to the existing conventions and industry

recipes set by established firms may not be considered feasible alternatives as they violate existing cause-and-effect representations of how problems and solutions are interrelated (Itami & Roehl, 1991; Lei et al., 1996; Spender, 1989). As a result, startups which pursue radical innovations may be less visible and are not legitimate to their environment,[40] which we expect to result in a discount in their market value.

Second, and related to the first point, startups pursuing radical innovations face challenges in securing the necessary assets, be they financial (Dushnitsky & Shaver, 2009), network related (Ahuja, Polidoro, & Mitchell, 2009; Baum et al., 2000a) or organizational (Marx, Strumsky, & Fleming, 2009), to transform their preliminary ideas into new products (Teece, 1986). When complementary assets are retained by incumbents, startups may be unable to commercialize the technology on their own but instead participate in the division of innovative labor and partner with established industry players (Arora & Gambardella, 1994a; Rothaermel, 2001). However, these established firms prefer partnering with new startups that pursue technological innovations similar to their own R&D (Rothaermel & Boeker, 2008) while "overlooking" innovations with elements of knowledge novel to them (chapter 2). Absent access to complementary resources from established firms, however, startups pursuing radical product innovations face severe obstacles in developing and commercializing their products. The problem is exacerbated as radical innovations often require substantial investments to modify development tools and commercial channels and hence require more resources in the first place (Maine & Garnsey, 2006; Schoonhoven, Eisenhardt, &

[40] The observations apply to all stakeholders, who feel uncertain about the trustworthiness and predictability of startups pursuing radical innovations, leading to a lack of legitimacy (Choi & Shepherd, 2005; Suchman, 1995).

Lyman, 1990). All arguments taken together suggest that startups pursuing radical product innovations face severe challenges, as the technological solutions of such startups lack legitimacy and the startups themselves face difficulties in assembling all required resources leading to adverse effects in the startup's market value.

> *Hypothesis 1: In an industry where established firms retain control over complementary assets, the more radical a startup's innovation, the lower the startup's market value.*

Given that pursuing radical innovations is associated with a lack of legitimacy and resource constraints, it is important to determine when startups can mitigate these challenges. The radicalness of innovation stems from startups pursuing innovations different from those of established firms. Hence, it may be important to further examine the relationship between startups and established industry firms. Next, we outline how forming commercialization partnerships with external partners as well as the failure in R&D attempts by established firms affect the startup's legitimacy and resource availability.

Formation of Commercialization Partnerships

Researchers have long argued that partnering is a key strategy for startups' commercialization attempts (Aggarwal & Hsu, 2009; Henderson, Orsenigo, & Pisano, 1999; Rothaermel & Deeds, 2004). Startups pursuing radical innovations may benefit in particular from the formation of such partnerships as they resolve issues of legitimacy and resource constraints.

An important form of partnerships for startups is to engage with another party that utilizes the startup's technology with the intention of development and commercialization

(henceforth, commercialization partnerships).[41] It is well-known that startups enjoy direct benefits when forming commercialization partnerships that positively affect market value (DeCarolis & Deeds, 1999; Stuart et al., 1999). At the same time, commercialization partnerships may "alter the system of constraints and dependencies confronting the organizations" (Salancik & Pfeffer, 1978:267), which is particularly salient for startups pursuing radical innovations. First, finding partners to develop and commercialize technological solutions is an important signal that validates the usefulness of the startup's radical innovations and hence provides legitimacy (Hsu & Ziedonis, 2008; Spence, 1973). The formation of partnerships provides valuable information to outside stakeholders and increases the perceived quality and reliability of the startup's products in development (Gulati, 1998). This is particularly useful for firms that lacked legitimacy in the first place, as their innovations were perceived as "too" radical compared to the incumbent industry players. In a similar vein, Stuart and colleagues (1999) demonstrated endorsement effects in partnerships[42] as firms with higher uncertainty[43] benefited most from forming partnerships with high reputation firms. We extend this argument and consider the radicalness of the startup's innovations as a key cause for legitimacy constraints so that startups pursuing radical innovations benefit mostly when forming commercialization partnerships.

Second, beyond the signaling value, the formation of commercialization partnerships provides concrete resources to the startup firms. Given the elevated resource needs of startups pursuing radical innovations (Maine & Garnsey, 2006), forming

[41] An alternative type of partnership is that the startup sources-in knowledge or technologies to create value.
[42] The authors examine the prominence of partners rather than partnerships per se.
[43] Uncertainty was captured by the age of the startups in this study.

commercialization partnerships may allow them to share the risks in development and commercialization and endow them with the necessary resources to develop and commercialize their technologies. Moreover, engaging in commercialization partnerships also gives firms better access to network resources (Gulati, 1998). We identified that startups pursuing radical innovations often have difficulty finding new partners. However, once such poorly embedded firms are able to conclude a partnership, they become more embedded in the network, making it more likely that they are able to secure additional resources through subsequent partnering (Ahuja et al., 2009). Taking all arguments together, we expect startups pursuing radical product innovations to disproportionally benefit from the formation commercialization partnerships.

> *Hypotheses 2: Forming commercialization partnerships positively moderates the relationship between the radicalness of a startup's innovation and that startup's market value.*

While the formation of commercialization partnerships with external partners may be driven by the startup firms themselves, environmental factors may also affect the legitimacy of startups pursuing radical innovations (Li & Atuahene-Gima, 2001). We next examine incumbent firms' failures in product development as important events shaping both legitimacy and resource availability for startups.

Failure in product development by established firms

Failure by another organization has been identified as an important mechanism through which firms can learn to avoid similar mistakes (Haunschild & Sullivan, 2002). At the same time, failure by established industry firms may not only be associated with learning (Argote & Miron-Spektor, 2011; Kim & Miner, 2007; Madsen & Desai, 2010)

but also improves the legitimacy of radical technological solutions that depart from existing industry conventions.

Extant research indicates that incumbent firms pursue dominant designs which serve as an initial orientation point and shape expectations for all other firms in the industry (Klepper, 1997; Spender, 1989; Utterback, 1987). Failure of problem-solving attempts by incumbent firms may trigger substantial shifts in the industry as to which ways of solving problems are considered feasible.[44] This benefits startups with technological solutions pursuing radical innovations that lacked legitimacy in the first place. First, failure in product innovation by incumbents serves as an impetus for all industry players to re-evaluate their conventional technological solutions and challenges their current logic as to how problems and solutions are interrelated (Greve, 1998; Jansen et al., 2005; Lampel et al., 2009). This may positively alter legitimacy for startups pursuing radical product innovation, especially as they provide alternative solutions to the conventional ways of solving problems. Indeed, research on vicarious learning suggests that other industry actors can benefit from failure as they learn what actions to avoid (Baum & Dahlin, 2007; Kim & Miner, 2007; Madsen & Desai, 2010). We extend this argument by highlighting that as firms avoid solutions that have failed, the pursuit of alternative ways of solving problems may become more legitimate. The role of failure in triggering an industry re-evaluation resonates with studies which have identified that experiencing failure tend to increase search intensity (Chen & Miller, 2007; Greve,

[44] For example, in our context, Pfizer discovered in Phase III that Torcetrapib, a drug targeting cardiovascular diseases, had an imbalance of mortality and cardiovascular events. The drug was an inhibitor of cholesterol ester transfer protein (CETP) for the treatment of atherosclerosis and many other incumbent firms were pursuing projects using CETP. Subsequently, incumbent firms discarded cholesterol ester transfer protein (CETP) and looked for new ways of solving the atherosclerosis challenge.

2003b) and organizational risk-taking (Audia & Greve, 2006; Greve, 2011). Following these arguments, we consider failure by established firms a key environmental factor, leading industry players to consider a broader range of possible alternatives so that startups that do not conform to conventional ways of solving problems are considered to be more legitimate.

Second, given that failure leads incumbents to consider alternative paths to solve problems, they may allocate more resources towards startups pursuing radical innovations. Extant research shows that failure may change the pattern of resource allocation by incumbent firms as external stakeholders put substantial pressure on established firms to change direction (Abrahamson & Park, 1994; Cyert & March, 1992:43; Salancik & Pfeffer, 1978; Useem, 1996). The result is that failure may shift resource allocation by incumbents to more likely consider partnerships with startups pursuing technological solutions which were previously not considered by the established firms (chapter 2). Put differently, failure by established firms may lead to an environment in which resources more readily flow towards startups pursuing radical innovations. Taking both arguments in tandem, we expect that failure by established firms in the industry provides an important contingency for pursing radical innovations.

> *Hypotheses 3: Failure in product innovation by incumbent firms positively moderates the relationship between the radicalness of a startup's innovation and the startup's market value.*

Innovation Maturity

While both commercialization partnerships and industry failures depend substantially on other firms in the industry, startups may also mitigate legitimacy

concerns and resource constraints by demonstrating that their radical innovations are feasible industry solutions.

The more a startup's technological solutions mature, i.e., move closer to commercialization, the technologies become codified, thus increasing the amount of information available about them. Moreover, more mature innovations have an existing track record and may even have working prototypes and templates demonstrating their effectiveness (Jensen & Thursby, 2001; Mowery & Rosenberg, 1989). Moving technological solutions downstream towards commercialization is also associated with achieving intermediate milestones, which, in our context (bio-pharmaceuticals), is reflected in intermediate approvals by regulatory authorities.

The more information about the innovation becomes available, the easier it is for outsiders to evaluate its technology. Working prototypes reduce uncertainty about the technology's replicability (Jensen & Szulanski, 2007) as they signal competence (Rothaermel & Boeker, 2008), which reduces ambiguity about the technology's potential value. Put differently, the more mature the startup's innovations, the more likely it is that they can be successfully commercialized, which increases legitimacy with external stakeholders. While these direct benefits of having more mature innovations are well understood, it stands to reason that startups pursuing radical innovations benefit particularly when they hold more mature innovations. Firms pursuing radical innovations lacked existing industry prototypes and were not perceived as feasible industry solutions in the first place. It also seems reasonable that startups pursuing radical innovations may benefit most when their technological solutions become more legitimate industry solutions as signaled by their maturity.

Having more mature technologies also indicates a transition for startups as they become independent from established firms in commercializing their technologies. Schoonhoven, Eisenhardt and Lyman (1990) explicitly argued that progress in product innovation is important for startups to gain cash flow for financial independence. At the same time, startups with more mature innovations may have more bargaining power over the established firms when forming partnerships, which is beneficial to their resource availability (Adegbesan & Higgins, 2011). Hence, we expect that startups pursuing radical product innovations benefit disproportionally from having more mature innovations that have cleared substantial hurdles in the innovation process.

Hypotheses 4: The maturity of a startup's innovation positively moderates the relationship between the radicalness of a startup's innovation and the startup's market value.

METHODS

Background - Bio-Pharmaceutical Industry

We chose the bio-pharmaceutical industry as a research setting in which to test our hypotheses. It is an industry which has seen a continous influx of new startups trying to devise new and innovative therapeutic solutions (Rothaermel & Deeds, 2004). We captured innovation by these startups by their products in development as we could readily compare products in development by incumbent and startup firms. We limited our analysis to startups pursuing innovative new drug development, which are new chemical molecules (small-molecule) or biological-based solutions (protein, monoclonal, gene therapy, etc.), rather than startups pursuing re-formulations or generic drugs. Products in the pharmaceutical industry become visible once firms move them into preclinical trials, which begin when a firm has discovered a chemical compound or biological-based large

molecule that is considered to be an appropriate candidate for development. Only 2.5% of compounds identified in research (target identification, lead identification and lead optimization) are considered for such development (Giovannetti & Morrison, 2000; Hess & Rothaermel, 2011), and the development stages following (i.e., clinical trials) are the most resource intensive steps in the innovation process (Rydzewski, 2008). A unique characteristic of the industry in the 1990s was that firms went public very early in the development process, a point at which the product may have only been in the preclinical or early clinical stages (Burns, 2005). We were hence are able to capture the value of such firms based on publicly available information despite the fact that those startups at IPO generated minimal revenue and (with the exception of two startups) had substantial negative income at IPO. Our data merged various sources, including SDC (Securities Data Company), ReCap (Recombinant Capital), Pharmaprojects and Adis R&D Insights and Compustat[45].

Sample

We queried SDC to obtain a list of biopharmaceutical firms with an IPO in 1991 and 1999 active in drug development and observe the market value of these firms from 1991-2008. During the 1990s, new biotechnology firms usually became public at a very early stage at which they had no foreseeable revenues. To be included in the sample, the startup a) had to be founded after 1984, so we only capture firms in the late biotechnology era (Rothaermel & Deeds, 2004) so, in 1990, were at most 5 years old; b)

[45] SDC provides detailed information on new issues of shares in the stock market. Pharmaprojects and Adis R&D Insights are databases tracking new drug development in the pharmaceutical industry (Girotra et al., 2010; Sosa, 2011). ReCap, a proprietary database tracking partnerships in the life science industry, is considered to be one of the most comprehensive publicly available data sources (Schilling, 2009).

had an IPO during 1991 and 1999 on an American stock market (usually NASDAQ); c) did not have any approved product at IPO; and d) engaged in innovative new drug development (i.e., had compounds visible in Pharmaprojects). Using these criteria, we identified 144 startups for which we had both financial and product development data available and tracked them up to the year 2008, leading to 1559 firm-year observations. The sample included firms like Cephalon, MedImmune, which became multi-billion dollar businesses.

Measures

Dependent Variable – Market Value:

We used the market capitalization of equity based on Compustat (in $M in every year at year end) as dependent variable. Given the skewed nature of this variable, we took the natural log of the *Market Value* as dependent variable. Measures of realized performance, such as ROA, ROE, or Tobin's q, are less appropriate as dependent variables as the startup firms often have few tangible assets and limited revenues (as well as mostly negative earnings) (DeCarolis & Deeds, 1999; Lavie, 2007; Sanders & Boivie, 2004; Zott & Amit, 2008). *Market Value* V is calculated as: V = p * s, where p is the price of the firm's shares on the last day of the year, and s is the total number of shares outstanding at that time. We log-transformed *Market Value* to achieve the desirable statistical properties under the linearity, homoskedasticity, and independence assumptions (Aggarwal & Hsu, 2009).

Independent Variable –Innovation Radicalness:

To arrive at a measure for radical innovation, we compared products in development (i.e., compounds) from startups to the ongoing drug development of major established pharmaceutical firms. This entailed taking into consideration fine-grained product development using Pharmaprojects and examining over 8000 R&D projects pursued by incumbent and startup firms between 1991 and 2008.[46]

It is important to understand that biotechnology as a term is often associated with all new firms that were founded following the biotechnology revolution in the early 1980s. Biotechnology in a narrow sense means the development of large protein-based molecules as therapeutic solutions (e.g., recombinant proteins or monoclonal antibodies). However, most of therapeutic solutions, even those developed by small biotechnology firms, are still chemical-based small molecules. But not all chemistry based solutions are similar as they differ as to which mechanisms in the human bodies they attempt to address, a critical element of scientific and technological knowledge incorporated in therapeutic solutions (Lane & Lubatkin, 1998).[47] To examine radicalness, we considered small (chemistry-based) and large (biology-based) molecules as well as naturally derived molecules and examined how they differed from the drug development initiatives by incumbent firms (Dahlin & Behrens, 2005; Govindarajan & Kopalle, 2006) .

We started by identifying the therapeutic area of the drug in development (from Pharmaprojects, 13 broad categories in total, including, for example, cancer or

[46] Two researchers independently constructed the history based on the information from Pharmaprojects on each drug. Missing data was complemented through a second database (ADIS Insights) and searches on the web. When researchers did not find the same date, we used the earlier one found, if it was from a credible news source.

[47] For our sample of 144 sample firms, 35.5% of all drugs are biologic based, 61.5% are chemical based (small molecule) and the remainder are derived from natural plants.

dermatology). Next, we examined the underlying material of the solution and its mechanism of action.[48] The origin of material links very closely to the large vs. small molecule distinction and includes different type of biological-based technologies (e.g., a proteins, monoclonal antibody or viral vector) as well as chemical-based solutions and natural products (derived from plants). The mechanism of action classifies the pharmacological effect through which the drug may have an effect in the human body.[49] Previous research has tended to distinguish only chemistry- and biology-based solutions, but was not able to identify variety within the chemistry-based products, which still represents the majority of all drugs candidates. Pharmaprojects contains over 2000 mechanisms, and we employed a consulting firm to assess which mechanisms could be aggregated to reflect an important category of knowledge associate with drugs in development. A pharmacology expert with 26 years in drug development and a biotechnology graduate student did the classification separately (resulting in 340 unique pharmacology codes in our sample).[50]

We then compared both elements, origin of material and mechanism of action of the startups' products in development with products in development of incumbent firms that are active in the same therapeutic area for the same year.[51] Put differently, we

[48] We inferred the relevance of the mechanism of action and the origin of material through interviews with scientists responsible for technological search at Merck and Johnson & Johnson and by examining the search guidelines outlined by pharmaceutical firms. An example can be found at http://www.merck.com/licensing/areas_of_interest.pdf.

[49] For example, Cox (Cyclooxygenase)-2 inhibitors (one of our mechanism of action categories) prevents the production of PHG (prostaglandin) which may cause inflammation.

[50] We report our results based on the classification by the consulting firm after clarifying where some of the mismatches between the student and the PhD expert originated (overall agreement between the two classifications was 93%). Using the original code from Pharmaprojects leads to very similar results. The conversion table from the pharmaceutical consultant can be downloaded under : http://bit.ly/12SHdto

[51] We took the Top established international 50 firms active in drug development based on revenue in 1991 (these include firms like Merck & Co, Pfizer, Eli Lilly) to identify incumbent firms active in a therapeutic

captured if, in a given therapeutic area (e.g., cancer), the startups used: a) the same mechanism of action; and b) the same origin of material is deployed by established firms. We assigned a value of one if one of the two elements was not used by an established firm and a value of two if both elements were new to the firm. We then averaged all scores (startup vs. Top 50 established firms) to arrive at an average measure of technological radicalness, which is similar to the idea of Dahlin's and Behrens's (2005) to measure radical innovation measure as average overlap to other industry players. A technological radicalness score of zero indicates that the startup does nothing new (with respect to mechanism and origin of material) as all established firm active in the therapeutic area work on the same type of solution. Conversely, a radicalness score of 2 indicates that none of the established firms active in a therapeutic area had products in development similar to the ones of the startup.[52] Appendix 5 provides a simplified example of the way in which *Innovation Radicalness* was calculated for a startup in a given year.

Moderators:

Commercialization Partnerships: We counted the number of Commercialization Partnerships a startup pursued in a given year using Recap (Rothaermel & Deeds, 2004; Stuart, 2000; Stuart et al., 1999). Recap indicates which firm in a partnership is the technology provider, allowing us to explicitly distinguish *Commercialization*

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area. We, however, observed several horizontal mergers between these firms (e.g., Astra merging with Zeneca). As an alternative, we extract the Top internal 100 pharmaceutical firms in 1991 and for each year, take the Top 50 (remaining) firms up to 2008 as incumbents. The results are unchanged using 50 incumbent firms in each year. The R&D budget of these large established R&D firms dwarfed those of our sample firms; a single firm in the Top 10 R&D spenders (e.g., Merck & Co) invested more in R&D than all sample firms in a given year in the 1990s.

[52] The actual minimum and maximum values are 0.13 and 1.95 respectively.

Partnerships, which we define as any partnerships in which an in-sourcing firm (usually larger than the startup) deploys the startups technologies or compounds. These commercialization partnerships can be at an early or late stage of the drug development process and usually entail upfront payments and royalty fees for the startup firm (Burns, 2005).

Incumbent Failure: Failure is very common in innovation, which is why we limited ourselves to a few substantial failure events within the industry. Extant research indicates that late stage failure can have profound consequences for pharmaceutical firms (Girotra et al., 2010). Failure hence is defined as product development attempts in which the firm committed substantial resources but ultimately failed, which is at the stage of Phase III large scale clinical trials.[53] To arrive at an overall measure for *Incumbent Failure* for the startup in a given year, we counted the number of failed product development attempts in the year for the Top 50 bio-pharmaceutical (based on the identification in 1991) in the therapeutic areas addressed by the startup. Using this measure, we can generate a unique *Failure Incumbent* score for each startup in each year. We demonstrate the calculation of this variable in Appendix 6.

To capture *Innovation Maturity*, we generated two measures. First, *Late Stage Projects* is a count of products in development (DeCarolis & Deeds, 1999) which have reached proof of concept, which usually is either in Phase II or Phase III (late stage clinical trials). Moving products in development down the value chain signals the viability of the innovative solution as well as its approval by regulatory authorities which must approve intermediate steps in the clinical trial process. While *Late Stage Projects*

[53] We verify that the effect holds when including Phase II failure, which also has a high likelihood of leading to a new product.

are rather frequent, we observed only 65 actual drugs being approved for active startup biotechnology firms with an IPO in 1991-1999. Still, as an alternative variable for *Innovation Maturity,* we captured the approval of a drug in a given year as an indicator variable. We limited ourselves to approvals in the US, Europe and Japan so that *Approved Drug* is 1 if the startup received the regulatory approval for a drug in a given year and 0 if no drugs were approved.

Controls

We controlled for various factors that may affect the firm's market value. First, we controlled for various financial measures, including a firm's size *Total Assets* (logged) and the firm's availability of financial resources through the *Current Ratio (*both measures taken from Compustat). Firm size has been associated with the liability of smallness (Freeman et al., 1983) and a high *Current Ratio* signals the availability of financial resources in the form of financial slack (Patzelt, Shepherd, Deeds, & Bradley, 2008), which may affect market value.

Second, we took into consideration that firms have a broad range of tools with which to engage with other partners (Keil et al., 2008; van de Vrande et al., 2009). Extant research has highlighted that partnering per se and not only commercialization partnerships may affect startup performance (Baum et al., 2000a). We used ReCap to count partnerships in which the startup sourced-in knowledge from other firms (i.e., was the client of the transaction). The knowledge flow represented by the variable *Sourcing Partnerships* is in the opposite direction compared to *Commercialization Partnerships* as it is through them that a startup acquires and assembles new (mostly early stage) technologies and knowledge.

Acquisition is an indicator variable that is 1 if the startup acquired a company in a given year and 0 otherwise. The information is taken from Recap. Moreover, we added an indicator if the startup received an *Equity* investment (value 1 and 0 if no equity investment) by another firm in a given year, which may affect the startup's market value (Lerner, Shane, & Tsai, 2003). Given that startups themselves are frequently acquired (usually by larger incumbent firms) and this may affect startup market value in advance, we added an indicator *Year before Acquisition* to the analysis, which takes 1 in the year prior to the acquisition (when no more market values are available for the startup at year end). The value is 0 in all other years. Following previous research, we also included firm *Age* in our analysis, which has been used a proxy for a firm's liability of newness (Freeman et al., 1983; Rothaermel & Boeker, 2008; Stuart et al., 1999).

Finally, we captured other activities related to the new product development of the startup directly, using Pharmaprojects. Similar to *Late Stage Project*, we also counted the number of *Early Stage Projects* in a given year by a startup (in preclinical and Phase I). While not a proxy for maturity, *Early Stage Projects* represent the future of the development pipeline of the firm, which may affect market value. Given that market performance may be sensitive to the ultimate failure in product innovation by the startups themselves, we also added indicator variables for the startups' own *Development Failure* in Phase III (1 if the firm had a failure in a given year, 0 if not). To capture very early stage R&D activities, we counted the number of *Patent Applications* of the startup in a given year using data from the Derwent Innovation Index.

Finally, in a similar vein to the *Failure Incumbent* variable, we counted the number of successful drugs by incumbent firms (*Success Incumbents*) in the therapeutic

areas in which the startup is active. We considered the final approval of a drug as an event of success and hence counted the number of drugs approved by the Top 50 incumbent firms. Appendix 6 shows a simplified example of how the *Success Incumbents* variable is generated. Again, *Success Incumbents* varies over time and for each startup, as it is dependent on the therapeutic areas in which the startup is active.

Empirical specification

The dependent variable (log *Market Value*) is a continuous and normally distributed variable, making an OLS regression approach appropriate. We had an unbalanced panel during the years 1991 and 2008. To control for unobserved firm-level and year-level heterogeneity, we included firm and year fixed effects (estimations are done using STATA xtreg procedure with FE option). This means that the variation explained will be within each firm. We clustered the standard error on the level of the startups for robust estimates. All variables used in interactions are mean centered. As the dependent variable is captured at year end, we did not lag our independent variables (see robustness tests).

RESULTS

Table 8 shows the summary statistics and correlation table. Examining the correlations, we did not find evidence that multicollinearity might be a cause of concern. The mean VIF for the final models is below 2.44 and individual VIFs for independent

and moderation variables are below 4,[54] all well below the recommended cutoff levels (Cohen, Cohen, West, & Aiken, 2003)[55].

[54] Age as control has the highest VIF with 6.8 – taken age out of the model does not change the results.

[55] We further examined multicollinearity through the collin command in STATA. Neither tolerance nor conditioning index raised any concerns.

Table 8: Chapter 3 - Summary Statistics & Correlation Table

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Market Value (log)	1.00																
2	Total Assets (MM)	0.59	1.00															
3	Financial Slack	0.02	-0.04	1.00														
4	Year before Acq. (0,1)	0.12	0.16	-0.02	1.00													
5	Development Failure (0,1)	0.00	0.02	-0.02	0.00	1.00												
6	Approved Drug (0,1)	0.19	0.12	-0.03	-0.01	0.01	1.00											
7	Startup Age	0.13	0.22	-0.16	-0.02	0.04	0.05	1.00										
8	Patent Applications (log)	0.26	0.16	-0.02	0.01	0.06	0.05	0.00	1.00									
9	Late Stage Projects	0.28	0.18	-0.06	0.05	0.10	0.07	0.24	0.23	1.00								
10	Early Stage Projects	0.23	0.19	-0.07	0.08	0.08	0.04	0.00	0.22	0.28	1.00							
11	Equity Investment (0,1)	0.04	-0.03	-0.05	0.05	0.00	-0.01	-0.13	0.02	-0.01	0.07	1.00						
12	Acquisition (0,1)	-0.03	0.04	-0.07	0.02	0.02	0.02	0.08	0.01	0.06	0.03	0.08	1.00					
13	Sourcing Partnerships	0.27	0.33	-0.05	0.10	-0.01	0.01	-0.03	0.10	0.07	0.28	0.07	0.04	1.00				
14	Commercializ. Partnership	0.21	0.13	-0.10	0.09	0.00	0.05	-0.06	0.09	0.14	0.27	0.36	0.09	0.26	1.00			
15	Failure (Incumbents)	0.18	0.09	-0.04	0.12	0.09	0.06	0.07	0.12	0.26	0.41	0.09	0.07	0.08	0.16	1.00		
16	Approved (Incumbents)	0.11	0.05	-0.06	0.06	0.06	0.05	-0.06	0.16	0.23	0.46	0.09	0.01	0.09	0.19	0.51	1.00	
17	Innovation Radicalness	-0.15	-0.18	0.13	-0.04	-0.03	-0.10	-0.19	-0.07	-0.18	0.00	0.05	-0.04	0.03	0.01	-0.06	0.00	1.00
	mean	5.19	156.50	8.87	0.16	0.03	0.04	8.21	2.1	1.61	4.60	0.17	0.08	0.74	0.96	4.86	5.83	1.14
	sd	1.47	360.34	10.62	0.48	0.17	0.18	5.11	1.90	1.57	3.76	0.38	0.26	1.23	1.45	4.33	4.77	0.36
	min	-0.14	0.94	0.13	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
	max	10.75	7018.5	140.29	5.00	1.00	1.00	22.00	7.44	7.00	17.00	1.00	1.00	8.00	9.00	19.00	20.00	1.95

n=1559

Table 9: Chapter 3 - Results – OLS - DV Market Value (Log)

	(M1)	(M2)	(M3)	(M4)
Firm and Year Fixed Effects	Y	Y	Y	Y
Total Assets (MM)	0.900***	0.857***	0.887***	0.867***
	(0.133)	(0.136)	(0.138)	(0.135)
Financial Slack	0.007	0.006	0.006	0.006
	(0.006)	(0.006)	(0.006)	(0.006)
Year before Acquisition (0,1)	0.064	0.066	0.061	0.070
	(0.056)	(0.057)	(0.057)	(0.056)
Development Failure (0,1)	-0.290+	-0.297+	-0.265+	-0.287+
	(0.155)	(0.154)	(0.155)	(0.150)
Approved Drug (0,1)	0.383***	0.370***	0.390***	0.392***
	(0.109)	(0.109)	(0.108)	(0.107)
Startup Age	-0.024	-0.039+	-0.042*	-0.044*
	(0.021)	(0.020)	(0.020)	(0.021)
Patent Applications	0.079	0.065	0.069	0.070
	(0.077)	(0.066)	(0.071)	(0.071)
Late Stage Projects	0.094*	0.094*	0.095*	0.099*
	(0.037)	(0.038)	(0.037)	(0.038)
Early Stage Projects	-0.002	-0.003	-0.004	-0.002
	(0.011)	(0.011)	(0.011)	(0.011)
Equity Investment (0,1)	0.102	0.109	0.094	0.103
	(0.072)	(0.071)	(0.072)	(0.071)
Acquisition (0,1)	-0.445***	-0.446***	-0.450***	-0.436***
	(0.105)	(0.105)	(0.105)	(0.104)
Sourcing Partnerships	0.038	0.039	0.037	0.037
	(0.024)	(0.024)	(0.024)	(0.023)
Commercialization	0.065**	0.065**	0.072**	0.064**
Partnerships	(0.024)	(0.023)	(0.022)	(0.023)
Failure (Incumbents)	0.006	0.006	0.006	0.008
	(0.010)	(0.010)	(0.010)	(0.010)
Approved (Incumbents)	0.006	0.006	0.006	0.005
	(0.009)	(0.009)	(0.009)	(0.009)
Innovation Radicalness		-0.533*	-0.675**	-0.715**
		(0.238)	(0.250)	(0.243)
Innovation Radicalness X			0.201**	
Commerc. Partnerships			(0.061)	
Innov. Radicalness X				0.048**
Failure (Incumbent)				(0.017)
Innov. Radicalness X				
Late Stage Projects				
Innov. Radicalness X				
Approved Drug				
Constant	4.279***	4.499***	4.542***	4.574***
	(0.282)	(0.271)	(0.269)	(0.274)
Log Likelihood	-1851.75	-1844.00	-1837.55	-1839.72
Observations	1559	1559	1559	1559
Number of Firms	144	144	144	144
R^2	0.33	0.35	0.36	0.36

+ p<.10, * p<.05, ** p<.01, *** p<.001

Table 9 (continued): Chapter 3 - Results – OLS - DV Market Value (Log)

	(M5)	(M6)	(M7)
Firm and Year Fixed Effects	Y	Y	Y
Total Assets (MM)	0.873***	0.864***	0.899***
	(0.139)	(0.137)	(0.139)
Financial Slack	0.006	0.006	0.006
	(0.006)	(0.006)	(0.006)
Year before Acquisition (0,1)	0.071	0.060	0.059
	(0.057)	(0.057)	(0.056)
Development Failure (0,1)	-0.276+	-0.296+	-0.259+
	(0.149)	(0.154)	(0.152)
Approved Drug (0,1)	0.368***	0.536***	0.562***
	(0.105)	(0.154)	(0.150)
Startup Age	-0.043*	-0.040+	-0.047*
	(0.020)	(0.020)	(0.020)
Patent Applications	0.070	0.069	0.067
	(0.071)	(0.067)	(0.067)
Late Stage Projects	0.107**	0.092*	0.098**
	(0.039)	(0.037)	(0.037)
Early Stage Projects	-0.003	-0.003	-0.003
	(0.011)	(0.011)	(0.011)
Equity Investment (0,1)	0.098	0.110	0.090
	(0.070)	(0.070)	(0.072)
Acquisition (0,1)	-0.434***	-0.447***	-0.442***
	(0.103)	(0.104)	(0.103)
Sourcing Partnerships	0.035	0.039	0.037
	(0.024)	(0.024)	(0.024)
Commercialization	0.066**	0.066**	0.071**
Partnerships	(0.023)	(0.023)	(0.022)
Failure (Incumbents)	0.006	0.006	0.007
	(0.010)	(0.010)	(0.010)
Approved (Incumbents)	0.006	0.006	0.005
	(0.009)	(0.009)	(0.009)
Innovation Radicalness	-0.765**	-0.546*	-0.869***
	(0.262)	(0.237)	(0.253)
Innovation Radicalness X			0.184**
Commerc. Partnerships			(0.060)
Innov. Radicalness X			0.042**
Failure (Incumbent)			(0.016)
Innov. Radicalness X	0.131		
Late Stage Projects	(0.080)		
Innov. Radicalness X		0.781+	0.780+
Approved Drug		(0.412)	(0.410)
Constant	4.567***	4.514***	4.619***
	(0.274)	(0.271)	(0.274)
Log Likelihood	-1839.20	-1841.38	-1831.84
Observations	1559	1559	1559
Number of Firms	144	144	144
R^2	0.35	0.36	0.37

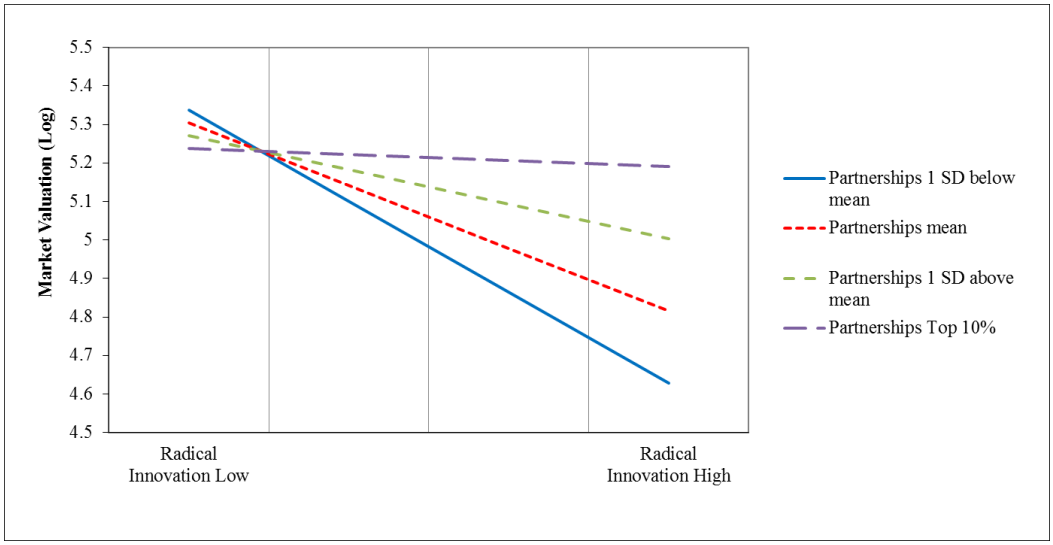
+ p<.10, * p<.05, ** p<.01, *** p<.001

Table 9 shows the regression results. Model 1 only includes the control variables. Consistent with prior literature, we find a positive direct effect from *Commercialization Partnerships*, which have been identified as an important driver for startup performance. Clearly, market value is also a function of firm size (*Total Assets*). The number of *Late Stage Projects* also drives market value but we see no effect from the number of *Early Stage Projects*. While market value is positively affected by the *Approval* of a drug by the startup, we also observed that *Acquisitions* by the startup tend to lower market value. This is consistent with the ideas that acquirers quite often pay a premium for acquisitions and that small firms undertake acquisitions when they have performed poorly and need to team up with another firm (Anand & Delios, 2002). *Age* has a negative (albeit not significant) effect, which is very different from prior studies (Stuart et al., 1999). However, we note that the negative age effect is fully driven by the year 2008 (the year of the financial crisis – see robustness tests). Finally, *Failures* in drug development by the startup at least marginally show a negative effect on market value.

In Hypothesis 1, we predicted that *Innovation Radicalness* has a negative effect on *Market Value*. This prediction is supported as demonstrated in Model 2. The more radical the startup's product innovations, the lower the startup's market value. This confirms that pursuing radical innovations is associated with market value penalties. In the next models, we examine the moderation effects with *Innovation Radicalness*. In Hypothesis 2 we predicted that the negative effect of *Innovation Radicalness* would be reversed if firm engage in *Commercialization Partnerships.* We test the effect, entering the interaction in Model 3. Consistent with Hypothesis 2, we find a positive interaction

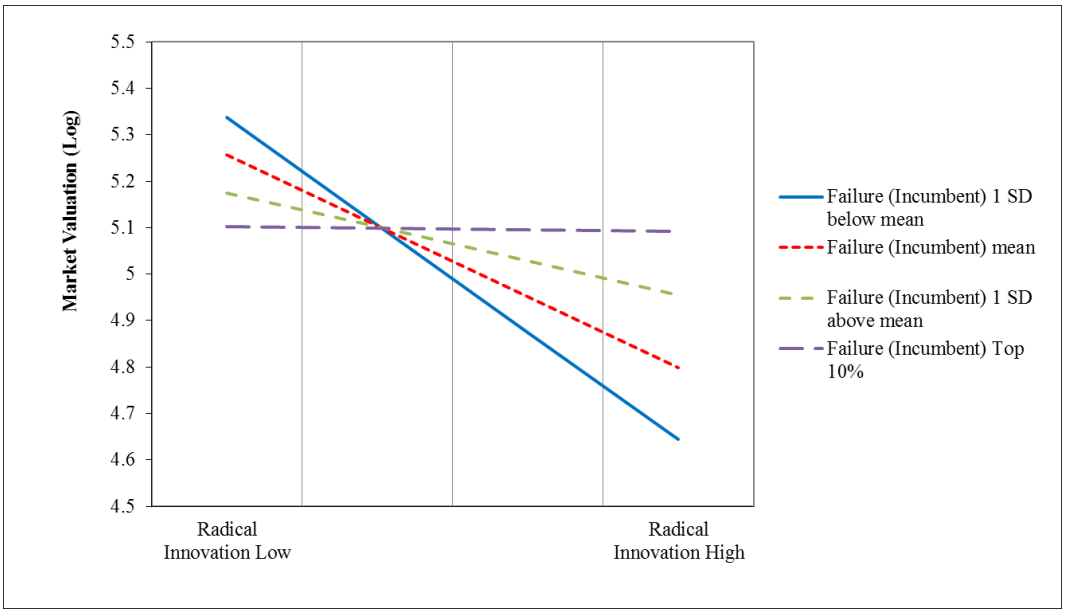
effect, indicating that the penalty of pursuing highly disruptive technological solutions is reversed once firms are pursuing partnerships to develop and commercialize their radical innovations. We demonstrate the effect of this interaction graphically in Figure 12, which shows that the effect of innovation radicalness for startups forming partnerships is far less steep. Only at very high values for *Commercialization Partnerships*, however, is the market value penalty actually reversed.

Figure 12: Chapter 3 - Moderation Radical Innovation and Commercialization Partnerships



In Model 4, we add the interaction *Innovation Radicalness* and *Failure (Incumbents)* to test Hypothesis 3. In line with our expectations, we find a positive moderation, indicating that startups pursuing more radical innovations benefit the more incumbent firms have failed in own product development attempts. The interaction is plotted graphically in Figure 13. It indicates that startups with low radicalness in innovation have an advantage at low failure rates of established firms whereas startups with high innovation radicalness receive higher valuations (or are not penalized) when incumbent firms have experienced more failures, supporting Hypothesis 3.

Figure 13: Chapter 3 - Moderation Radical Innovation and Failure Established Firms



Finally, we examine Hypothesis 4, which predicted that the penalty of pursuing radical innovations may be reversed once startups are able to move their product innovations close to commercialization (*Innovation Maturity*). We test the *Late Stage Projects* (Model 5) as well as the *Approved Drugs* (Model 6) as potential moderator. We observe marginal support for our prediction as the *Approved Drugs* interaction is only marginally significant - so we cannot reject the Null-Hypothesis that *Innovation Maturity* has no effect on the relationship between *Radical Innovation* and startup *Market Value*. Hypothesis 4, hence, does not receive support. Model 7 shows the full model with all interactions and demonstrates that results remain robust in the full model for Hypothesis 1, 2 and 3, while the non-effect (or only marginal effect) for Hypothesis 4 remains.

Table 10: Chapter 3 - Robustness Tests – OLS - DV Market Value (Log)

	(R1) Q1	(R2) MV/AT	(R3)	(R4)
Firm & year Fixed Effects	Y	Y	Y	Y
Approved Drug (0,1)	0.440**	1.194***	0.390***	0.398***
	(0.156)	(0.344)	(0.108)	(0.108)
Sourcing Partnerships	0.023	-0.031	0.037	
	(0.024)	(0.053)	(0.024)	
Commercialization Partnerships	0.072**	0.051	0.072**	
	(0.023)	(0.049)	(0.022)	
Failure (Incumbents)	0.005	0.024	0.006	0.004
	(0.009)	(0.020)	(0.010)	(0.010)
Approved (Incumbents)	0.006	0.021	0.006	0.006
	(0.009)	(0.021)	(0.009)	(0.009)
Innovation Radicalness	-0.977***	-1.427**	-0.677**	-0.598*
	(0.256)	(0.458)	(0.243)	(0.246)
Innovation Radicalness X Commercialization Partnerships	0.178**	0.328*	0.201**	
	(0.061)	(0.127)	(0.062)	
Innov. Radicalness X Failure (Incumbent)	0.044**	0.132**		
	(0.016)	(0.040)		
Innov. Radicalness X Approved Drug	0.720+	1.450		
	(0.426)	(0.933)		
Innov. Radicalness X Sourcing Partner.			0.004	
			(0.071)	
Commercialization Partner (Top 50)				0.097***
				(0.029)
Innovation Radicalness X Commercialization Partner (Top 50)				0.233*
				(0.093)
Sourcing Partner (Top 50)				0.035
				(0.094)
Innov. Radicalness X Sourcing Partner (Top 50)				0.132
				(0.270)
Commercialization Partner (0,1)				
Failure PII/III (Inc.)				
Innovation Radicalness X Commercialization Partner (0,1)				
Innov. Radicalness X Failure PII/III (Inc.)				
Innov. Radicalness X Approved (Inc.)				
Innov. Radicalness X Development Failure				
Log Likelihood	-1777.93	-3144.90	-1837.55	-1846.18
Observations (144 firms)	1559	1559	1559	1559
R^2	0.38	0.21	0.36	0.35

+ p<.10, * p<.05, ** p<.01, *** p<.001 , not shown but included in the models: Total Assets (MM), Financial Slack, Year before Acquisition, Development Failure, Startup Age, Patent Applications, Early Stage Projects, Equity Investment, Acquisition and the constant

Table 10 (continued): Chapter 3 - Robustness Tests – OLS - DV Market Value (Log)

	(R5)	(R6)	(R7)
Firm & year Fixed Effects	Y	Y	Y
Approved Drug (0,1)	0.407***	0.389***	0.535***
	(0.105)	(0.107)	(0.153)
Sourcing Partnerships	0.033	0.036	0.039
	(0.024)	(0.023)	(0.024)
Commercialization Partnerships		0.064**	0.065**
		(0.023)	(0.023)
Failure (Incumbents)		0.008	0.006
		(0.010)	(0.010)
Approved (Incumbents)	0.003	0.005	0.006
	(0.009)	(0.009)	(0.009)
Innovation Radicalness	-0.915**	-0.655**	-0.539*
	(0.273)	(0.249)	(0.237)
Innovation Radicalness X Commercialization Partnerships			
Innov. Radicalness X Failure (Incumbent)		0.057***	
		(0.016)	
Innov. Radicalness X Approved Drug			0.710+
			(0.403)
Innov. Radicalness X Sourcing Partner.			
Commercialization Partner (Top 50)			
Innovation Radicalness X Commercialization Partner (Top 50)			
Sourcing Partner (Top 50)			
Innov. Radicalness X Sourcing Partner (Top 50)			
Commercialization Partner (0,1)	0.200***		
	(0.055)		
Failure PII/III (Inc.)	0.004		
	(0.006)		
Innovation Radicalness X Commercialization Partner (0,1)	0.426**		
	(0.135)		
Innov. Radicalness X Failure PII/III (Inc.)	0.022*		
	(0.010)		
Innov. Radicalness X Approved (Inc.)		-0.020	
		(0.022)	
Innov. Radicalness X Development Failure			-0.247
			(0.456)
Log Likelihood	-1799.34	-1839.15	-1841.18
Observations (144 firms)	1539	1559	1559
R^2	0.36	0.36	0.35

+ p<.10, * p<.05, ** p<.01, *** p<.001 , not shown but included in the models: Total Assets (MM), Financial Slack, Year before Acquisition, Development Failure, Startup Age, Patent Applications, Early Stage Projects, Equity Investment, Acquisition and the constant

Robustness Test

We conducted several additional checks to establish the robustness of the findings (Table 10 and Table 11). First, we used different operationalizations of the dependent variable. Model R1 used the market value a quarter following a focal year to establish a clear lag structure. Model R2 used a weighted dependent variable, in which market value is divided by total assets. Both models confirmed the results reported in our main results.

Next, we examined the alternative explanation for Hypothesis 2, i.e., partnering per se that may allow startups with high *Innovation Radicalness* to generate more value. While model R3 shows the positive interaction with *Commercialization Partnerships*, we did not find similar effects for *Insourcing Partnerships.* It suggests that is indeed the usage and validation of the startup's technology and knowledge by other firms that is responsible for the effect. Given that we included all commercialization partnerships, we next limited the partnerships to the Top 50 incumbent firms. The results in model R4 confirm the pattern that *Commercialization Partnerships* positively moderate the *Innovation Radicalness* and *Market Value* relationship (albeit with lower levels of significance). Using the non-Top 50 firms Commercialization partnerships (results available from the authors) does not lead to a different finding, suggesting that *Commercialization Partnerships* with the Top 50 established firms as well as other firms providing the resources to commercialize the technologies have the positive moderation effect.

In model R5, we tested the alternative explanation that the effect from established firms drug development may only be driven by rare events in the drug development in the industry (Lampel et al., 2009). We hence compared the effect of drug development

Failure by incumbents with success (*Approved (Incumbents)*). The results demonstrate that the positive moderation is attributed to Failure of incumbents. Interestingly the *Approved Drugs (Incumbents)* measure is negative but not significant, which suggests that failure and success by established players may very differently affect startup's market values when pursuing radical innovations.

In Model R6, we tested another alternative explanation and compared *Approved Drugs* and *Development Failure* by the startups as potential moderators. We find that *Approved Drugs* are marginally significant but the Failure Drug interaction is negative and not significant.

In model R7, we operationalized key independent variables differently. Namely, *Incumbent Failure* was proxied by using both Phase III and Phase II failures by the Top 50 incumbent firms. Results remained robust but were slightly weaker with respect to significance. It is hence clear, that the moderation effect is predominantly driven by substantial failure (Phase III) and rare events in the industry (Lampel et al., 2009). Once we consider only earlier stage discontinuation as failure (e.g. Phase I failure), we indeed do not find the moderation effect to hold (results available from the authors). In model R7 we operationalized *Commercialization Partnerships* as an indicator rather than a count variable leading to strong support for our results.

In alternative robustness tests (Table 11), we examined shorter time windows by looking at a maximum of 10 observations per startup after their IPO (Model R8), again supporting our main results. We also ran all models excluding the year 2008 (the year of the financial crisis and stock market crash), confirming the main results reported (Model R9). The negative effect of age disappears without the 2008 observations.

Table 11: Chapter 3 - Robustness Tests 2 – OLS - DV Market Value (Log)

	(R8)	(R9)	(R10)
Firm Fixed Effects	Y	Y	Y
Year Effects	Y	Y	Y
Total Assets	0.754*	0.888***	19.105***
	(0.356)	(0.164)	(1.680)
Financial Slack	0.007	0.006	-0.005
	(0.006)	(0.006)	(0.003)
Year before Acquisition	0.079	0.059	
	(0.061)	(0.055)	
Development Failure	-0.289+	-0.268+	
	(0.153)	(0.153)	
Approved Drug	0.297**	0.539***	
	(0.109)	(0.140)	
Startup Age	-0.044	0.004	0.060**
	(0.040)	(0.020)	(0.020)
Patent Applications	0.047	0.049	0.006
	(0.045)	(0.045)	(0.029)
Late Stage Projects	0.107*	0.095*	0.099
	(0.046)	(0.037)	(0.060)
Early Stage Projects	-0.012	-0.007	-0.001
	(0.015)	(0.011)	(0.022)
Equity Investment (0,1)	0.105	0.087	0.201
	(0.066)	(0.068)	(0.143)
Acquisition (0,1)	-0.474***	-0.427***	0.954***
	(0.117)	(0.105)	(0.173)
Sourcing Partnerships	0.051*	0.043+	0.069+
	(0.023)	(0.023)	(0.039)
Commercialization Partnerships	0.062*	0.075**	0.050
	(0.025)	(0.024)	(0.032)
Failure (Incumbents)	0.006	0.001	-0.074**
	(0.010)	(0.009)	(0.026)
Approved (Incumbents)	0.016+	0.012	0.012
	(0.009)	(0.008)	(0.019)
Innovation Radicalness	-0.919**	-0.901***	-0.415*
	(0.290)	(0.258)	(0.208)
Innovation Radicalness X Comm. Partnerships	0.181*	0.184**	0.052
	(0.073)	(0.063)	(0.080)
Innov. Radicalness X Failure (Incumbent)	0.052*	0.046**	0.153**
	(0.021)	(0.016)	(0.046)
Innov. Radicalness X Approved Drug	0.286	0.640+	
	(0.348)	(0.358)	
Constant	4.664***	4.573***	2.936***
	(0.263)	(0.275)	(0.307)
Log Likelihood	-1374.36	-1661.86	-115.54
Observations	1254	1486	144
R2	0.36	0.36	0.73

+ p<.10, * p<.05, ** p<.01, *** p<.001

Table 11 (continued): Chapter 3 - Robustness Tests 2 – OLS - DV Market Value (Log)

	(R11) Origin of Material	(R12) Origin of Material	(R13) Mechanism of Action	(R14) Mechanism of Action
Firm Fixed Effects	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y
Total Assets	0.878***	0.894***	0.881***	0.917***
	(0.130)	(0.133)	(0.136)	(0.134)
Financial Slack	0.006	0.006	0.007	0.007
	(0.006)	(0.006)	(0.006)	(0.006)
Year before Acquisition	0.063	0.063	0.067	0.055
	(0.056)	(0.055)	(0.056)	(0.056)
Development Failure	-0.310*	-0.300+	-0.288+	-0.248
	(0.152)	(0.152)	(0.155)	(0.154)
Approved Drug	0.378***	0.161	0.378***	-0.433
	(0.108)	(0.167)	(0.109)	(0.361)
Startup Age	-0.039+	-0.045*	-0.027	-0.031
	(0.021)	(0.021)	(0.020)	(0.020)
Patent Applications	0.050	0.052	0.051	0.050
	(0.047)	(0.056)	(0.051)	(0.049)
Late Stage Projects	0.104**	0.102**	0.093*	0.102**
	(0.039)	(0.038)	(0.037)	(0.038)
Early Stage Projects	-0.004	-0.004	-0.001	-0.001
	(0.011)	(0.011)	(0.011)	(0.011)
Equity Investment (0,1)	0.112	0.099	0.104	0.095
	(0.071)	(0.074)	(0.072)	(0.070)
Acquisition (0,1)	-0.450***	-0.440***	-0.445***	-0.452***
	(0.103)	(0.101)	(0.105)	(0.105)
Sourcing Partnerships	0.035	0.038	0.039	0.032
	(0.024)	(0.024)	(0.024)	(0.024)
Commercialization Partnerships	0.063**	-0.002	0.066**	-0.151*
	(0.023)	(0.036)	(0.024)	(0.076)
Failure (Incumbents)	0.003	-0.014	0.004	-0.034
	(0.009)	(0.013)	(0.009)	(0.027)
Approved (Incumbents)	0.007	0.008	0.005	0.003
	(0.008)	(0.008)	(0.008)	(0.008)
Innovation Radicalness	-0.923*	-1.340***	-0.387	-0.789*
	(0.365)	(0.390)	(0.313)	(0.363)
Innovation Radicalness X Comm. Partnerships		0.175*		0.286**
		(0.082)		(0.100)
Innov. Radicalness X Failure (Incumbent)		0.049*		0.053+
		(0.023)		(0.031)
Innov. Radicalness X Approved Drug		0.801		1.237*
		(0.509)		(0.575)
Constant	4.838***	5.099***	4.554***	4.993***
	(0.335)	(0.355)	(0.381)	(0.406)
Log Likelihood	-1841.30	-1834.59	-1851.04	-1842.94
Observations	1559	1559	1559	1559
R2	0.35	0.36	0.35	0.36

+ p<.10, * p<.05, ** p<.01, *** p<.001

Model R10 shows the results of using the first available year and market value of the startup as dependent variables. We have 144 IPOs resulting in 144 observations of the market value in year one of the IPO. While results differ from the panel results, we find evidence that the interaction of *Failure (Incumbents)* and *Radical Innovation* holds in the first year. However, we do not find the interaction with *Commercialization Partnerships* and *Radical Innovation* to be statistically significant. One reason could be that at IPO, firms are just starting their development and *Commercialization Partnerships* start at a later stage. We also note that using only 144 observations *Radical Innovation* while negative just fails to be marginally significant ($p<0.13$), when only testing its direct effect.

Finally, while we consider it beneficial to consider mechanism of action and origin of material together in defining radicalness, we also tested defining radicalness by either the mechanism of action or the origin of material separately.[56] The results are shown in model R11 through R14. Mode R11 and R13 show that both operationalization of radicalness have a negative effect on market value but only the origin of material is significant. However, when examining the moderations (R12 and R13), we observe that both operationalization show quite similar effects.

In unreported results, we also operationalized *Innovation Radicalness* using a 4 year history of drugs in development by the incumbent firms and not only the current year. Defining *Innovation Radicalness* this way does not change the results but rules out that we consider a technology as radical, which was discarded by incumbents years ago.

[56] The two alternative variables are correlated at 0.44.

DISCUSSION

Pursuing radical innovation, i.e., innovation which substantially differs from that of established industry players, has been suggested to lead to the "attacker's" advantage, which has been demonstrated in many settings (Christensen & Rosenbloom, 1995; Foster, 1986). However, pursuing radical innovations may also lead to severe challenges stemming from both legitimacy and resources constraints, in particular, when incumbents retain critical downstream complementary assets. The performance outcomes for startups pursuing radical innovations in such settings are the focus of this paper.

Startups operating in such an environment face a dilemma. On the one hand, startups have the ability to push technological change forward and pursue technological innovations, with elements of knowledge untested by established industry players. On the other hand, pursuing such radical innovations may adversely affect their ability to be visible and to attract resources from established firms. Indeed, we find a severe performance penalty in the form of lower market valuations for startups pursuing radical product innovations in the bio-pharmaceutical industry, an industry where established firms retain control of critical downstream complementary assets (Rothaermel, 2001). The study hence expands our understanding of the strategic balances of how being different or the same compared to other industry players may affect firm performance (Deephouse, 1999).

In a second step, our study more fully takes into account the unique dependencies between startup and established firms (Salancik & Pfeffer, 1978) to identify the conditions under which pursuing radical innovations may allow startup firms to benefit. Motivated by previous research, we take into account partnering as a fundamentally

important commercialization strategy for startup firms (Aggarwal & Hsu, 2009). While prior studies have outlined the importance of partnering for startup firms per se (e.g. Baum et al., 2000a), we demonstrate that benefits from such partnerships are particularly accrued by firms pursuing radical product innovations, as they disproportionally benefit from the legitimacy and resources accessed through such partnerships. Interestingly, the results found in a US setting are opposite to findings in emerging markets, in which a product innovation strategy had weaker performance when combined with strategic partnering in product development (Li & Atuahene-Gima, 2001). We hence extend our overall understanding on startups cooperative commercialization strategies (Aggarwal & Hsu, 2009) and their role when developing and commercializing radical innovations.

To our knowledge, our study is also the first to consider failure by incumbent firms as an important environmental factor influencing the relationship between radical product innovations and startup performance. While scholars previously considered failure by other players in the industry as a source of vicarious learning (Argote & Miron-Spektor, 2011; Madsen & Desai, 2010), we demonstrate that benefits from failure may be accrued by those startups that pursue more radical solutions. We hence extend prior research that has outlined the fundamental role of failure by other firms in organizational learning (Kim et al., 2009; Kim & Miner, 2007), but has not explicitly taken into account how established firm failure affects startup firms. The mechanism outlined in this paper builds upon organizational learning, as we posit that failure by established firms challenges the industry conventions as to what technological solutions are considered feasible and alters which solutions are ultimately considered to be legitimate or illegitimate.

Finally, the paper reveals the importance of using a dynamic lens on radical innovation, which changes over time as both startups and established firms modify their product development portfolio. We hence extend the literature on what constitutes radical innovation (Dahlin & Behrens, 2005) and provide an alternative way through which it can be measured in the bio-pharmaceutical space.

The study has a number of limitations, which should provide ample opportunities for future research. First, it was conducted in the context of a single industry and single country and the generalizability of our findings and their boundary conditions would need to be validated through explorations in other empirical contexts. In both Europe and Asia, biotechnology firms proliferated in the 1990s as well, and including them in the analysis may reveal further insights into the relationship between radical innovations and startup market performance. We opted to include only startups from one jurisdiction to ensure that our results are not sensitive to the regulatory, accounting and reporting rules, which may be idiosyncratic to domestic stock markets. The study could also be replicated in other industry settings in which established firms maintain complementary assets. In the telecommunication industry, for example, wireless telephony was certainly a source of radical innovation but the established firms have survived retaining ownership of key complementary assets (Hill & Rothaermel, 2003). Another extension of the study would be to examine distinct radical innovations which also have the potential to be disruptive, i.e., requiring a change in the incumbent's business model (Burgelman, 1985; Christensen, 2006; Christensen & Raynor, 2003). For example, while chemical-based solutions and many biologic-based solutions (e.g., Monoclonal Antibodies) in the bio-pharmaceutical space sustain the existing business model of incumbent firms

(Rothaermel, 2001) (i.e., prescribed as a long term treatment often administered at home resulting in yearly treatment costs for patients and insurers), newer technologies like gene therapy are considered more disruptive (one-off treatment administered by the physicians (e.g. Wilson, 2012)). Hence, the traditional revenue model based on regular prescriptions is not applicable. Given that we do not capture disruptiveness in our study, it would be interesting to further examine the performance implications for startups that engage in the pursuit of such disruptive technologies.

Second, we are unable to draw inferences regarding final commercialization outcomes such as product sales or firms' market share in our analysis as product approvals are rare in the bio-pharmaceutical industry and many of the firms never reach final product sales on the market. Hence, we observed radicalness based on intermediate stages by comparing product development initiatives of startups and incumbent firms. At the same time, using product in development captures startup activity at a more advanced stage of the startups development as it can take up to ten years until research is translated into a commercialized product. In a similar vein, we so far have not considered if capturing radicalness at the product development stage differs from patent-based measures, which are common when examining innovations by startups (e.g. Sørensen & Stuart, 2000). Examining analysts' reports, however, suggests that the market valuation of listed startup firms predominantly depends on the products in development (the pipeline) and not on the volume of patents generated by the startups. For example, radicalness in patenting per se may not drive market value as the time to develop and commercialize an invention is very long in the industry. This is reflected by the fact that

only late stage products in development (and not early stage products or patents) have an actual effect on the market value of the startups in the panel model.

Finally, while we identify the positive moderation from incumbent failure for startups pursuing radical innovations, we do not directly observe the theorized mechanism. While some studies show that established firm failure may open such firms up to novel types of technological solutions (chapter 2), scholars using qualitative methods could build on our findings to shed light on how startups pursuing radical innovations indeed benefit from incumbent firm failure and the role of legitimacy and resource availability driving this effect.

CONCLUSION

The study explores how pursuing radical innovations shapes market values and hence performance expectations for young startup firms. It departs from the typical emphasis on the advantages of startups "attacking" established firms and considers a setting in which established firms maintain control of critical downstream complementary assets. By examining product innovation of the startup relative to established firms, we show that pursuing radical innovations may have adverse performance implications in the form of market valuations. We also demonstrate the contingent roles of commercialization partnerships and failures of established firms in shaping the relationship of radical product innovation and market value. The findings argue for considering closely the dependencies of startups and established firms to understand when startups pursuing radical innovation can create value.

CHAPTER 4: NO STRINGS ATTACHED: EXAMINING THE RELATIONSHIP BETWEEN LOOSELY COUPLED RESEARCH PARTNERSHIPS AND INNOVATIVE PERFORMANCE

(A research repaper based on this chapter is developed mutually with Felipe Monteiro and Denise Dunlap.)

Faced with a rapidly changing technological environment, firms are increasingly required to combine knowledge from a range of disciplines which no single firm is likely to possess (Steensma & Corley, 2000). As a result, inter-firm research partnerships (i.e., partnerships to discover new innovative solutions) have grown substantially in both number and importance in the last decade (Hagedoorn, 2002; Kale & Singh, 2009; Rothaermel & Deeds, 2004). The intent behind these exploration types of partnerships (Koza & Lewin, 1998) is to accelerate the yield from research assets by reducing innovation cycle times and gaining access to valuable new elements of knowledge (Laursen et al., 2010; Leone & Reichstein, 2012; Rosenkopf & Almeida, 2003).

While research partnerships in general have been increasing, in this paper, we focus on those partnerships in which there is a low level of mutual commitment and interdependence between partners, as exemplified by research contracts or licensing agreements These types of research partnerships, which we call loosely coupled (Orton & Weick, 1990; Steensma & Corley, 2000; Thompson, 1967), often involve one firm paying to have access to specific knowledge from another firm and to reuse such knowledge created by the research partner (Murray & O'Mahony, 2007). Despite their importance and prevalence, loosely coupled partnerships are in sharp contrast with tightly coupled partnerships (Steensma & Corley, 2000), which rely on the reciprocal exchange of knowledge (Eisenhardt & Schoonhoven, 1996), high levels of commitment among the

partners and the generation of partnership-specific assets (e.g., joint product development agreements or equity joint ventures) (Sampson, 2007).

Previous studies have consistently shown the benefits of tightly coupled partnerships based on the fact that innovation more often than not requires the reciprocal exchange and recombination of knowledge from the cooperating parts (Dyer & Singh, 1998; Mowery et al., 1996). In a related vein, it has also been suggested that simply "handing off" research from one partner to another may not be enough to allow the in-sourcing firm to innovate (Eisenhardt & Schoonhoven, 1996).[57] Given that loosely coupled research partnerships (e.g., licensing deals and research contracts) typically lack those strong reciprocal interdependencies and do not rely on mutual knowledge exchange, it should not be entirely surprising that existing empirical evidence indicates a weak relationship between loosely coupled research partnerships and a firm's ability to develop innovations new to their industry (Fey & Birkinshaw, 2005; Keil et al., 2008; Luo, 2008; Mowery et al., 1996).

It is striking, then, that loosely coupled partnerships are increasingly prevalent in many industries, as exemplified by the widespread use and rapid growth of research contracts and licensing deals at very early stages of the innovation cycle in the pharmaceutical industry (Nicholls-Nixon & Woo, 2003; Rothaermel & Hess, 2007). Intrigued by the mismatch between previous findings pointing to the limited potential of loosely coupled partnerships to generate innovations on the one hand, and their prevalence in many industries on the other, we examine in this paper whether, why and

[57] This argument is also consistent with the findings in the network literature which show that despite the importance of weak ties for the *identification* of new ideas (Granovetter, 1985), strong ties are essential to the transformation of those ideas into actual innovations (Hansen, 1999)

when loosely coupled research partnerships may increase a firm's innovative performance.[58]

It is important to note that our main goal is not to challenge the findings of previous studies that showed the benefits of tightly coupled partnerships. Instead, the crux of our paper is to focus exclusively on loosely coupled partnerships and reveal the conditions under which they are more likely to spur the in-sourcing firm's innovation performance. Researchers have already suggested that the benefits of loosely coupled partnerships may stem from the in-sourcing firm's ability to add knowledge variety while, at the same time, allowing it to remain flexible in a rapidly changing technological environment (Danneels, 2003; Leone & Reichstein, 2012; Steensma & Corley, 2000). Yet innovation often requires firms to not only access a variety of diverse knowledge provided by external partners but also to experiment and recombine knowledge in novel ways (Levitt & March, 1988), and the length of innovation cycle requires the continued allocation of organizational resources, be they financial or managerial, towards research projects (Adner & Levinthal, 2008; Cyert & March, 1963).

Therefore, while loosely coupled partnerships add variety to the in-sourcing firm's knowledge base and this, per se, is important to innovation, their lack of a reciprocal knowledge exchange may not induce the experimentation necessary to allow that firm to fully benefit from the in-sourced knowledge. Moreover, while loosely coupled partnerships are a flexible mode of in-sourcing external knowledge, resources gained from them are also withdrawn more easily; therefore, ultimately, they may lack

[58] As we will detail in the methods section below, our operationalization of innovative performance is the introduction of solutions which are new to the market. This measure is in line with Teece's (1986) view that the innovator should be the firm that is first to introduce a solution to the market.

the continued resources necessary to positively affect the in-sourcing firm's innovative performance (Luo, 2008; Steensma & Corley, 2000). It is hence the purpose of this paper to go beyond the mere direct effect of loosely coupled partnerships on innovation performance by examining the conditions under which such partnerships are more likely to be fully leveraged to benefit the in-sourcing firm.

We argue that the innovation benefits accruing from research partnerships depend on both the external knowledge being in-sourced and the in-sourcing firm's internal context. More precisely, we suggest that, as a baseline model, loosely coupled partnerships are beneficial to a firm's innovative peformance. We argue, however, that those innovation benefits are more likely to transpire when certain internal firm factors are present. Namely, we hypothesize that the in-sourcing firm's experimental orientation (i.e., a firm's propensity to experiment internally with projects with elements of knowledge novel to the firm) (Ahuja & Morris Lampert, 2001) and its availability of financial and managerial resources (Cyert & March, 1963) positively moderate the impact of loosely coupled partnerships on the in-sourcing firm's innovative performance.

We test our hypothesis in the global pharmaceutical industry, using a panel dataset covering the world's largest (Top 50) global pharmaceutical firms between 1998 and 2007 and spanning 454 firm-year observations. In the pharmaceutical industry, the discovery of new solutions is pivotal for firm success (Roberts, 1999) and both types of research partnerships (i.e., tightly and loosely coupled) are widespread. We assess the effect of those loosely coupled research on innovative performance by examining the number of new products in development a focal firm is able to add to its innovation pipeline (Hess & Rothaermel, 2011).

As we discuss in detail below, our results suggest only a weak direct effect of loosely coupled partnerships on a firm's innovative peformance. More interestingly, though, we also show if the in-sourcing has an experimental orientation, it can work as a catalyst for using and experimenting with external knowledge accessed through the loosely coupled partnerships. In a similar vein, we show the importance of having the managerial and financial resources to fully benefit from loosely coupled partnerships. Our results account for unobserved heterogeneity across firms and over time, and are robust to a number of alternative econometric specifications and operationalization of key variables.

Taken together, our results indicate that while the mere existence of loosely coupled partnerships may not be enough for a firm to become more innovative, under certain conditions, those same loosely coupled partnerships are able to lead to the innovation outcomes (in our case, new product candidates representing solutions new to the in-sourcing firm's industry) typically only attributed, in previous studies, to tightly coupled partnerships (Laursen et al., 2010; Leone & Reichstein, 2012). The paper hence contributes to the growing literature on the role of loosely coupled partnerships and emphasizes their role in innovation attempts that goes beyond the exploitation of existing knowledge. The rest of the paper is organized as follows. The theoretical background and hypotheses are presented in the next section. A section on our methods follows. We subsequently present regression results, various robustness checks and post-hoc analyses. Contributions and implications are discussed in the concluding section.

THEORY AND HYPOTHESES

Accessing knowledge through research partnerships

Firms can access external knowledge through research partnerships in various ways. A common distinction that we adopt in this paper is based on the level of interorganizational dependence and the level of joint commitment among research partners (Gulati & Singh, 1998; Koza & Lewin, 1998). Tightly coupled partnerships are characterized by strong interdependencies in which firms rely on the reciprocal exchange of knowledge (Ahuja, 2000; Dyer & Singh, 1998; Gulati & Singh, 1998). This is exemplified by joint ventures, wherein partners commit resources and equity to form a completely new organizational entity, or by research alliances in which partners share scientific personnel, engineers and management or share resources for joint research (Kale & Singh, 2009; Mowery et al., 1996). Conversely, loosely coupled partnerships represent forms of accessing knowledge that predominantly rely on the sequential interdependence among the partners (Gulati & Singh, 1998; Luo, 2008). As much as in extreme cases, loosely coupled partnerships may be limited to an exchange of knowledge for money as exemplified by a pure in-licensing contract, where one firm will use the knowledge of another firm with limited further interaction (Anand & Khanna, 2000; Murray & O'Mahony, 2007), in most cases, the loosely coupled partnership involve an on-going relationship between research partners. Other examples include research contracts through which firms define their research needs ex ante (Mowery et al., 1996).[59] The defining characteristic of those research partnerships is the lack of mutual

[59] Although firms may engage in other formal transactions to gain access to external knowledge (e.g., corporate venture capital investments), tightly and loosely coupled research partnerships represent the vast majority of knowledge-access transactions (Dushnitsky & Lavie, 2010)

collaboration and of a bi-directional exchange of knowledge. In a loosely coupled partnership, one partner can be clearly identified as the firm receiving knowledge (i.e., the in-sourcing firm) from the other partner, which typically obtains some sort of financial compensation.

Loosely coupled partnerships and innovative performance

Loosely coupled research partnerships are believed to add variety to a firm's knowledge repertoire, which is conducive to innovation. Yet, surprisingly little research has empirically investigated the impact of this type of research partnership on the in-sourcing firm's innovative performance.

We posit that loose coupling has desirable benefits for an in-sourcing partner to the extent that they provide immediate access to specialized knowledge from external partners. Engaging in loosely coupled research partnerships allows firms to effectively divide work in research to leverage the specialization of research partners (Arora & Gambardella, 1994a). Mowery et al. (1996), for example, confirm that loosely coupled partnerships are an important way for firms to benefit from specialization of external partners. Engaging in such partnerships adds variety to a firm's repertoire of knowledge, which is important to finding new innovative solutions (Laursen et al., 2010). They also provide a firm with flexibility in their research projects as those partnerships are quickly initiated and require lower set-up costs (i.e., loosely coupled partnerships tend to not generate costly and partner-specific resources and routines) (Zollo, Reuer, & Singh, 2002). This allows firms to move quickly once new technologies emerge and to abandon those rendered obsolete (Luo, 2008; Steensma & Corley, 2000). Consequently, many

researchers have considered loosely coupled partnerships as valuable options in environments characterized by high technological uncertainty and change, where, for every successful innovation, many failures are likely to occur (Folta, 1998). Recently, researchers have started to examine in more detail the role of loosely coupled partnerships (e.g., by examining licensing contracts) on innovative performance and have found that licensing-in technologies accelerate the introduction of new inventions (Leone & Reichstein, 2012) and allow firms to subsequently search for and add more knowledge variety (Laursen et al., 2010). Given that firms require a large pool of potential solutions at their disposal and the flexibility to react to emerging technological trends, we suggest that loosely coupled research partnerships should positively affect a firm's innovative performance. More formally, we hypothesize that:

> *Hypothesis 1: Loosely coupled research partnerships increase the in-sourcing firm's innovative performance.*

High level of experimentation, financial and organizational resources: the fertile ground for loosely coupled partnerships to flourish

If, on one hand, loosely coupled partnerships provide a flexible way for the in-sourcing firm to add specialized knowledge to its repertoire, on the other, the nature of those partnerships may make their innovation benefits contingent on the presence of certain firm level characteristics. Namely, we argue that firms accessing external knowledge through loosely coupled partnerships may accumulate sufficient distinct elements of highly specialized knowledge, yet may still not experience an increase in their innovative performance unless they are able to recombine this knowledge in novel

ways through experimentation and support the partnerships through both financial and managerial resources. More specifically, in the following sections, we examine how accessing knowledge through loosely coupled partnerships interacts with the in-sourcing firm's ability to recombine knowledge in novel ways (its "experimental orientation"), and how the availability of managerial resources and financial slack plays a critical role in allowing the in-sourcing firm to fully benefit from its loosely coupled partnerships.

Experimental Orientation: Firms differ in their willingness to take risks and experiment with new elements of knowledge. We suggest that a firm's high experimental orientation (i.e., a firm's willingness to pioneer novel solutions) (Ahuja & Morris Lampert, 2001; Miller, 1983) may serve as a catalyst for experimenting with knowledge accessed through loosely coupled research partnerships.

In contrast to tightly coupled partnerships, loosely coupled research partnerships have a clear delineation between sender and receiver, so the flow of knowledge is unilateral. While firms may add specialized new knowledge, the unilateral structure inhibits experimentation, which is best achieved through an iterative and reciprocal exchange of knowledge (Eisenhardt & Schoonhoven, 1996; Galunic & Rodan, 1998). Innovation requires firms to challenge their existing paradigms, which results in firms redefining their heuristics as to how solutions and problems are interconnected (Lei et al., 1996). This is best achieved through repeated communication and joint management with a partner (Dyer & Singh, 1998), which are seldom present in loosely coupled research partnerships. The problem is exacerbated as the in-sourcing party in loosely coupled research partnerships may need to define the content of the knowledge exchange ex ante.

Given that potential ways of recombining and using knowledge are only revealed over time, loosely coupled partnerships may lack the experimentation necessary to develop with truly new solutions.

Previous research has shown that some firms are more willing than others to experiment and take risks in strategic actions related to market entry or product innovation (Miller, 1983; Roberts, 1999). With respect to innovation, researchers have suggested that firms may either take a more incremental approach to innovation or become a pioneer in offering new solutions as they challenge current industry assumptions (Ahuja & Morris Lampert, 2001). Following this idea, an experimental orientation reflects a firm's willingness to engage in projects where expected returns are not foreseeable (Miller, 1983).[60] This includes but is not limited to top managers' preferences to engage in risky projects but also is reflected in a firm's incentive and reward structures (Henderson & Cockburn, 1994).[61] An experimental orientation is not static but develops over time as firms adjust their communication channels, control systems and culture to the level of experimentation that they consider appropriate to current challenges (Tushman & Anderson, 1986).

Extant research highlights the technological benefits of experimenting with new knowledge. Ahuja and Lampert (2001), for example, identify that firms that generate knowledge without relying on prior elements of knowledge (pioneering technologies) are better positioned to generate innovative solutions. Following these arguments, we believe

[60] The notion that some firms may be more experimental than others is related to the seminal work of March (1991). March highlighted that some firms more than others emphasize experimental learning by trying out new ways of solving problems.

[61] Experimental orientation through risk taking may be considered as part of a firm's overall entrepreneurial orientation, which entails other dimensions such as proactiveness or competitive aggressiveness (Dess, Lumpkin, & Covin, 1997).

firms with a strong experimental orientation are more likely to benefit from their loosely coupled research partnerships since they are skilled at not only handling greater knowledge variety but, at the same time, are able to induce the experimentation required to effectively use this variety for innovation to occur.

First, although the exchange of knowledge between the partners is predominantly unidirectional, firms with a stronger experimental orientation will be better equipped to subsequently draw upon new external knowledge and recombine it in novel ways. Having an experimental orientation hence facilitates firms in complementing their internal knowledge with external knowledge (Cassiman & Veugelers, 2006) accessed through loosely coupled research partnerships. In such cases, knowledge recombination occurs independently of the reciprocal and frequent interactions among research partners.

Second, firms with a strong experimental orientation may also provide incentive structures to draw upon knowledge which is not immediately related to the scientists' current projects and activities. This is more likely to encourage scientists to leverage a broader variety of knowledge (Itami & Roehl, 1991), which again would make loosely coupled partnerships more effective. We suggest that firms with an experimental orientation may accrue stronger benefits from loosely coupled partnerships. More formally, we propose:

> *Hypothesis 2: The in-sourcing firm's level of experimental orientation positively moderates the effect of loosely coupled research partnerships on the in-sourcing firm's innovative performance.*

Organizational resources: Generally, firms can only sponsor a limited number of unique problems and solutions simultaneously (Cyert & March, 1963). This requires that they make tradeoffs in allocating resources, be they financial or managerial, among

multiple options (Hitt, Hoskisson, Johnson, & Moesel, 1996; Voss, Sirdeshmukh, & Voss, 2008). As a result, loosely coupled partnerships are most effective when organizational resources are available.

Extant research indicates that organizational resources impose important boundary conditions (Penrose, 1959) that affect a firm's ability to absorb and use external knowledge (Ahuja & Morris Lampert, 2001; Ocasio, 1997). These constraints are particularly salient for loosely coupled partnerships. Unlike tightly coupled research partnerships that quite often have a greater number of dedicated scientific and managerial personnel, loosely coupled research partnerships are characterized by lower levels of such commitment (Zollo et al., 2002). They are also often endowed with fewer overall organizational resources in the first place, which is evidenced by lower governance and administration costs (Contractor, 1990). It is hence likely that such partnerships will lack dedicated managerial personnel who could act as "champions" to promote and defend the partnership and its associated knowledge when, for example, making budget decisions. Moreover, resources committed to such projects rely less on building partner-specific assets to support the innovation process in the long run (Steensma & Corley, 2000), which limits the commitment associated with such partnerships. The result is that organizational resources can be more easily withdrawn from loosely coupled partnerships, in particular in the presence of alternative paths to develop new innovative products (Adner & Levinthal, 2008; Osborn & Baughn, 1990; Sirmon, Gove, & Hitt, 2008).

We focus on two types of organizational resources: managerial, exemplified by managerial attention (Cyert & March, 1963; Ocasio, 1997; Penrose, 1959) and financial

resources, exemplified by liquid resources beyond what is needed to operate the firm in the short term, i.e., financial slack (Singh, 1986; Voss et al., 2008).

Both types of resources can act as catalysts, making loosely coupled partnerships more effective. Innovation is not a one-off event, but a long process that requires firms to continuously commit managerial resources to their research activities and provide access to decision-making across the organization (Dougherty & Hardy, 1996). Managerial resources such as managerial attention are not scale-free (Levinthal & Wu, 2010), meaning that firms can usually only attend to a few unique innovation problems. Extant research, for example, indicates that fast-growing firms in one period tend to experience slower growth in ensuing periods due to a lack of managerial resources (Penrose, 1959). In a similar vein, scope-increasing activities are likely to absorb managerial attention, leaving only limited managerial resources available for loosely coupled partnerships.

Conversely, in the presence of limited growth and few alternatives to which resources must be allocated, loosely coupled partnerships are more likely to receive the managerial attention necessary to convert their knowledge into new innovative products. In our empirical setting (pharmaceuticals), firms build large pipelines of product candidates to innovate. Following the idea of managerial resource constraints, an increase in the pipeline of products in development is likely to absorb mangerial resources. However, when growth is limited, managerial resources are more likely to be available so that loosely coupled partnerships will be more effective.

Financial resources are also likely to act as a catalyst for loosely coupled partnerships. Cyert and March (1963:189) highlight that financial slack provides a fundamental role in the innovation process as it "*provides a source of funds for*

innovations that would not be approved in the face of scarcity."[62] Financial slack indirectly supports the innovation process by influencing the decision context in which resource allocations for innovative projects are undertaken (Greve, 2003a; Nohria & Gulati, 1996). Namely, financial slack relaxes the internal monitoring and controls that are critical in a firm's decision-making environment (Bourgeois III, 1981). The idea is that slack provides a "cushion" in the event of failure, leading firms to monitor performance less strictly (Cyert & March, 1963:43). Researchers have suggested that slack is necessary to adapt to a changing technological landscape, so that existing resources can complement new innovation activities (Rothaermel, 2001). In a similar vein, researchers have identified that the extent of investible resources, i.e., resources available for firms to invest, imposes an important boundary condition for subsequent firm acquisition activities (Kaul, 2012).

We suggest that the innovation benefits of loosely coupled research partnerships are more likely to materialize in the presence of financial slack in the in-sourcing firm. Financial slack can provide the in-sourcing firm with the ability to resist short-term performance pressures, thus enabling it to continue to commit the necessary financial resources required from its loosely coupled research partnerships (Greve, 2003a). Prior research further indicates that slack encourages experimentation (Cyert & March, 1963), which we identified as being particularly important for loosely coupled partnerships. In the event that additional resources are required by other projects, financial slack can serve as a buffer. Thus, loosely coupled partnerships face lower risks that resources will be

[62] Although slack may have many different forms (Voss et al., 2008), researchers have predominantly focused on financial slack in the form of financial reserves as an important resource influencing innovation (Nohria & Gulati, 1996).

withdrawn or re-allocated elsewhere. It follows then that the existence of financial slack allows the in-sourcing firm to more fully leverage the knowledge accessed through loosely coupled research partnerships. Considering these two arguments (the availability of managerial resources and financial slack), we propose that:

> *Hypothesis 3: The in-sourcing firm's level of managerial resources positively moderates the effect of loosely coupled research partnerships on the in-sourcing firm's innovative performance.*
>
> *Hypothesis 4: The in-sourcing firm's level of financial slack positively moderates the effect of loosely coupled research partnerships on the in-sourcing firm's innovative performance.*

METHODS

Setting: Global pharmaceutical industry

We tested our hypothesis in the global pharmaceutical industry and examined innovative performance in terms of new drug development in a given firm's year. New drug development takes, on average, 7 to 11 years from original discovery to launch (Powell et al., 1996), and is a highly regulated process with clearly defined steps. We focused on the early stage of drug development, which begins with the discovery of the chemical compound (small molecule) or biologically based large molecules. Only 2.5% of all drug compounds become lead candidates to enter the preclinical stage, where they are tested with animals (Giovannetti & Morrison, 2000; Hess & Rothaermel, 2011). This innovation cycle allowed us to clearly distinguish between discovery (everything prior to preclinical trials) and development (preclinical and beyond).

Sample

We compiled a unique database, merging data from ReCap,[63] Pharmaprojects, Adis R&D Insights and Compustat to track firms' efforts to access external knowledge and drugs in development from a sample of established biotechnology and pharmaceutical firms. Pharmaprojects and Adis R&D Insights are databases tracking new drug development in the pharmaceutical industry and have been used in prior research studies (Adegbesan & Higgins, 2011; Hess & Rothaermel, 2011).

Our sample was based on a comprehensive list of publicly traded firms in the pharmaceutical industry. We opted to use 1997 as a starting point (1 year before our 10 year study period) and queried the Top 50 research active firms based on compounds in development in Pharmaprojects.[64] Limiting the sample to the leading firms ensured that we observed a large portion of loosely coupled partnerships in the industry and at the same time, facilitated the data collection process across multiple databases. This approach is consistent with prior research examining established firms management of technological change (Anand et al., 2010; Kaplan & Tripsas, 2008; Rothaermel, 2001). To be included in our sample, a firm had to have at least one compound launched as a new molecular entity (or biologic) drug in Pharmaprojects before. We did not capture those firms predominantly focused on formulation technologies or generics. Our study was interested in the effect of external research agreements and all Top 50 Bio-pharmaceutical engaged at least in one loosely coupled inter-organizational agreement in

[63] Recombinant Capital (ReCap), a proprietary database tracking the life science industry, is considered to be one of the most comprehensive publicly available data sources for the industry (Schilling, 2009).

[64] This includes firms that do not belong to the bio-pharmaceutical industry per SIC code but are considered to be among the Top 50 pharmaceutical firms worldwide according to Pharmaceutical Executive. We identified 4 horizontal mergers (e.g., Astra AB and Zeneca forming AstraZeneca) for which we combined the data of the two merging firms. To keep a sample of 50 we added 4 firms, until rank 54.

ReCap. For each firm, we constructed a detailed history of divisions and subsidiaries using the Directory of Corporate Affiliations, LexisNexis and corporate websites to ensure that we allocated each drug and collaboration to the right firm at the right time. The total sample consisted of 50 firms, which span 454 observations from 1998 to 2007.

Measures

Dependent Variable - Innovative performance:

New product development starts as a process of discovering new knowledge and the transformation of such knowledge in a final product (Madhavan & Grover, 1998). Given the length of the innovation cycle, we opted to examine an intermediate output of the product development process as a proxy for innovative performance. Namely, we examined new products in development as a dependent variable. New products in development represent a key stage in the innovation process as they reveal a firm's ability to recombine various types of knowledge and have been used in prior research to measure a firm's innovativeness (Hess & Rothaermel, 2011; Rothaermel & Deeds, 2004; Shan, Walker, & Kogut, 1994). Given that the ultimate goal of firms through loosely coupled partnerships is to find a potential product candidate, we considered this intermediate output as appropriate to capture if firms can ultimately benefit from loosely coupled partnerships.[65] Using Pharmaprojects, we counted the annual number of new products in preclinical trials (*Innovative performance*) that were introduced by the firm in a given year. We used the new chemical entity flag provided by Pharmaprojects to identify innovations new to an industry (i.e., the molecule or biologic that represents a new

[65] Counting the number of patents used as in prior studies may be misleading as firms through loosely coupled partnerships may actually access rights to use certain patents but not necessarily need to increase their patenting output themselves. Important insights gained from loosely coupled partnerships like validating biological targets and new mechanism of actions in the human body cannot be patented

solution to address a therapeutic need).[66] For each preclinical compound, we manually checked the date in Pharmaprojects to identify when the firm first put this compound in preclinical development. We used a second database (Adis R&D Insights) to verify or complement missing data for when a drug entered preclinical testing. We used the earliest reported date in cases when the databases differed. On average, firms introduce 5.4 new molecular entities (including chemical and biologics) into preclinical development each year.

Independent Variables

Loosely coupled research partnerships: We used ReCap to capture loosely coupled research partnerships. We only counted agreements that were signed at the earliest research stage. These agreements are flagged in Recap as "discovery" based on when the partnership was signed. At the discovery stage, firms have usually not yet found an actual compound to be used for further testing and quite often only have an idea of what mechanism in the body the potential discovery should target (Rydzewski, 2008). To ensure that we only captured agreements in which the research partners had the intention to generate new knowledge, we excluded any partnership that addressed reformulations of existing drugs or new combinations of existing substances.[67] We only considered partnerships for which we knew that knowledge or technology flows in the direction of the incumbent pharmaceutical firm. Recap indicates which firm in a partnership is the technology provider and which one is the client, allowing us to explicitly distinguish, which firm is the in-sourcing partner.

[66] We also counted biological drugs as new to the industry but excluded biosimilars and generic drugs.
[67] Results are robust keeping these agreements.

Following extant work on partnerships (Lavie, 2007; Stuart, 2000), we acknowledged that the effect of accessing external knowledge may not be instantaneous. Instead, loosely coupled research partnerships agreements may generate innovation benefits over time that can be captured only by tracking their effect over multiple years. The idea is that the stock of research agreements, even after the year they are announced, may contribute towards innovative performance. We used a four year stock of innovative partnerships, reflective of the project time common for early stage research initiatives (Rydzewski, 2008).[68] We followed common conventions when studying the effect of interorganizational agreements on performance (Lavie, 2007; Stuart, 2000) and tested both a depreciated and undepreciated stock of partnerships.[69] We reported the undepreciated four year stock in the results, which are almost identical to using a depreciated measure. More importantly, we operationalized *Loosely Coupled Research Partnerships* as the number of research agreements, which we could unambiguously classify as signed during the discovery stage in the last four years wherein the in-sourcing firm enters a research partnership in order to access knowledge from a partner in exchange for money. We defined loosely coupled partnerships in our sample as either in-licensing (Recap code L)[70] and research contracts (Recap code R) with the in-sourcing firm financing and paying royalties for research and technologies of a partner.[71] We

[68] Results are robust using 4 and 5 years respectively.

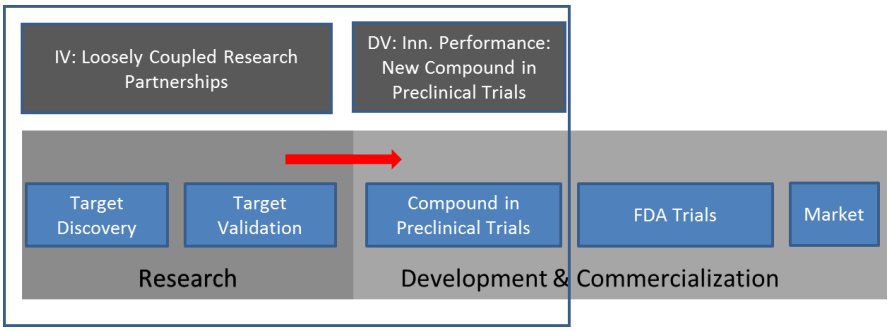
[69] Depreciation of the stock of bilateral partnerships reflects that recent sourcing activities might have a stronger effect than research agreements announced at an earlier point in time.

[70] 85% of all the research agreements had a licensing component.

[71] Some of those research partnerships were classified as "pure licensing," quite often involving a one-off purchase of knowledge (e.g., patent) by the in-sourcing firm. We believe these are extreme cases of a loosely coupled partnership (almost like an arm's length transaction) in which the classification as a "partnership" may be questioned. Therefore, as we report in our robustness checks, we ran our models excluding all those extremely loosely coupled partnerships. Our results remained qualitatively the same.

identified 770 such agreements initiated by the 50 sample firms between 1994 and 2006.[72] The baseline relationship between loosely coupled research partnerships and new compounds in development (H1) is shown in Figure 14, which situates the variable in the empirical context.

Figure 14: Chapter 4 – Baseline Model (H1) and Empirical Context



Moderators

Experimental Orientation: Following the literature on entrepreneurial orientation, we captured a firm's overall experimental orientation via their propensity to engage in risky innovative projects (Dess et al., 1997). This is similar to Bierly and Chakrabarti (1996), who differentiated between experimental vs. non experimental innovation in approved drugs. Firms in research have the option to develop drugs using elements of knowledge already implemented in prior innovation attempts by the firm. Two important elements of knowledge used in drug development are the mechanism of action and the origin of material, both of which are available from Pharmaprojects.

The origin of material gives a broad distinction if the drug development project is based on chemistry (small molecule), biology (e.g., a protein or viral vector) or if the compound is derived from a natural product. The mechanism of action classifies the pharmacological effect through which the drug may have an effect on the human body.

[72] Given the lag structure, we started our analysis in 1998 using partnership stock from 1994-1997.

For example, Cox-2 inhibitors (one of our mechanism of action categories) prevent the production of PHG (prostaglandin) from arachidonic acid, which causes inflammation.[73] We consider the origin of material, mechanism of action and indication as pockets of specialized knowledge which are embedded in a technology (Lane & Lubatkin, 1998), and then examined if projects initiated by the firm in the last four years are based on knowledge were novel (experimental) to the firm.

We counted all compounds in development of each focal firm as reported by Pharmaprojects. For each drug in development within the year's t-1 to t-4, we determined if the project was or was not experimental. For example, if a firm had 10 drugs reported in development during a three-year timeframe and 3 of them deployed either a new mechanism of action or origin of material to solve a given therapeutic problem, its level of *Experimental Orientation* would be 0.3. Higher values of this measure indicate a higher propensity to experiment with novel knowledge to the firm.

Financial slack: We proxied Financial slack by the current ratio of the firm in a given year, which is the ratio of its current assets divided by its current liabilities (Bourgeois III, 1981; Greve, 2003a; Singh, 1986). Firms with a low current ratio are resource-constrained as they have less free financial resources at hand.

Managerial resources: The availability of managerial resources such as managerial attention is difficult to observe as, unlike financial resources, they are not found on a firm's balance sheet. However, a good proxy for the availability of managerial resources (or the lack thereof) is the firm's ongoing product development activities: all

[73] We employed a consulting firm to assess which mechanism of action codes can be further aggregated. A pharmacology expert with 26 years in drug development and patented compounds and a biotechnology graduate student did the classification separately (resulting in 240 unique pharmacology codes in our sample).

else being equal, the more products in development, the less managerial resources are available to other projects. This resonates with a resource-based perspective in which firm growth in a previous period limits the growth of firms in subsequent years (Penrose, 1959). We constructed a variable called pipeline growth, which captured how the pipeline has gown or declined from year t-2 to t-1. We argue that a growing pipeline signals scarce managerial resources as the in-sourcing firm has many alternative development paths to pursue. Conversely, a decline in the pipeline is a good proxy for the availability of more managerial resources. We reverse coded the variable *Managerial Resources* as pipeline decline to indicate the availability of managerial resources.

Controls

We first controlled for the effect of other in-sourcing activities. We controlled for the effect of *Tightly Coupled Research Partnerships*, defined as the number of research agreements in which a firm engaged in the last three years wherein parties mutually shared knowledge and other resources. These arrangements are captured in Recap through the addition of distinct agreement types: CoL (Collaboration Agreement) and JVs (joint ventures).[74] We also added an indicator variable *Acquisition* to control for firms that engaged in a research-oriented acquisition in the prior year. Finally, we added *Exploitation* as the number of alliances formed to develop and commercialize existing compounds in the previous four years (these partnerships in-source "ready to use" compounds and are hence at a later stage of development).

[74] All results are robust when excluding joint ventures. We checked news articles associated with approximately 10% of all partnerships (available from Recap) it and found that the Recap classification was very much in line with the actual announcements.

Second, we controlled for various financial and performance measures that affect new product development. We included the variable return on assets (*RoA),* which captures the firm's performance. Other financial controls included *Total Assets* as a proxy for the firm's size and *R&D intensity* (R&D divided by Total Sales), which proxies the emphasis firms places on research in general. Finally, we captured internal research by adding the number of *Patents (logged)* a firm applied for in a given year as an important input for product development (Murray, 2002).

Empirical Specification

All variables were lagged by one year; for example, we predicted new products in development in year t by the financial controls from year t-1. The variables spanning multiple years (e.g., loosely coupled partnerships and experimentation) include the years t-4to t-1. Our dependent variable takes only positive integer values, so it is recommended to use a count model. The negative binomial model is appropriate as it relaxes the assumption of having a mean equal to the standard deviation. We reported both a fixed effect and random effect negative binomial model but the Hausman (1978) test indicated that a fixed effect model would be more appropriate. The fixed effect model controls for time invariant unobserved firm heterogeneity. Given that firm fixed effects may not be robust in this estimation (Allison & Waterman, 2002), we also report a random effects model and a fixed-effects Poisson quasi maximum likelihood estimator, which is robust when using firm fixed effects (Cameron & Trivedi, 2009).

RESULTS

Table 12 depicts the descriptive statistics and the bivariate correlation matrix. The summary statistics indicated that our sample firms are large incumbent players in the

industry (US$ 12 billion in assets on average). The firms were quite active with external partners with an average four year stock of 5.2 loosely coupled research partnerships. Table 12 shows that loosely and tightly coupled partnerships are both correlated with firm size *(Total Assets)*.[75]

[75] Multicollinearity is not a concern as the mean VIF for the final models was below 2.4 and individual VIFs were below 4.6, all well below the recommended cut-off levels. We centered all variables before interacting them (Cohen et al., 2003).

Table 12: Chapter 4 - Correlation & Summary Statistics

		1	2	3	4	5	6	7	8	9	10	11	12
1	Innovative Performance	1.00											
2	Exploitation	0.56	1.00										
3	Acquisition	0.17	0.24	1.00									
4	R&D Intensity	-0.11	-0.13	0.01	1.00								
5	Tightly Coupled Partnerships	0.62	0.68	0.29	-0.03	1.00							
6	Patents (log)	0.52	0.50	0.16	-0.20	0.46	1.00						
7	RoA	0.31	0.26	0.08	-0.54	0.28	0.32	1.00					
8	Total Assets (BNs)	0.63	0.58	0.26	-0.13	0.70	0.54	0.20	1.00				
9	Managerial Resources	0.01	0.01	-0.17	-0.19	-0.05	-0.01	0.03	-0.04	1.00			
10	Financial Slack	-0.34	-0.29	-0.16	0.38	-0.31	-0.36	-0.31	-0.35	-0.02	1.00		
11	Experimental Orientation	-0.25	-0.25	-0.10	0.11	-0.22	-0.20	-0.24	-0.27	-0.08	0.06	1.00	
12	Loosely Coupled Partnerships	0.58	0.59	0.22	-0.06	0.65	0.51	0.31	0.59	0.03	-0.28	-0.24	1.00
	Mean	5.41	5.75	0.45	0.21	5.02	4.35	0.15	12.73	2.42	2.60	0.51	5.22
	Standard Deviation	6.99	5.71	0.50	0.30	6.03	1.20	0.11	18.05	0.37	1.38	0.18	6.69
	Minimum Value	0	0	0.00	0.00	0.00	0.00	-0.10	0.23	0.00	0.68	0.00	0
	Maximum Value	47	35	1.00	2.79	38.00	6.89	0.41	123.68	3.00	6.12	1.00	34

n=454

Table 13: Chapter 4 – Results - Negative Binomial - DV: New product development

	(1) FE	(2) FE	(3) RE	(4) FE
Firm Effects	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y
Exploitation (4y)	-0.017+ (0.010)	-0.018+ (0.010)	-0.015+ (0.009)	-0.016 (0.010)
Acquisition (4y)	-0.014 (0.017)	-0.010 (0.017)	-0.007 (0.015)	-0.011 (0.017)
R&D Intensity (t-1)	-0.365 (0.270)	-0.365 (0.269)	-0.082 (0.233)	-0.378 (0.271)
Tightly Coupled Partnerships (4y)	0.034*** (0.009)	0.033*** (0.009)	0.036*** (0.008)	0.027** (0.009)
Patents (4y)	0.195* (0.098)	0.196* (0.099)	0.373*** (0.065)	0.194* (0.098)
RoA (t-1)	0.259 (0.571)	0.213 (0.574)	0.497 (0.541)	0.219 (0.576)
Total Assets (t-1)	-0.388 (2.571)	-0.867 (2.645)	-0.094 (2.431)	0.040 (2.656)
Experimental Orientation (4y)	0.523+ (0.299)	0.565+ (0.304)	0.179 (0.290)	0.512+ (0.299)
Managerial Resources (t-1)	-0.034 (0.116)	-0.029 (0.117)	0.080 (0.116)	-0.042 (0.116)
Financial Slack (t-1)	-0.087+ (0.048)	-0.085+ (0.048)	-0.085* (0.043)	-0.080+ (0.047)
Loosely Coupled Partnerships (4y)		0.006 (0.007)	0.014* (0.007)	0.002 (0.008)
Loosely Coupled X Experimental Orientation				0.118** (0.042)
Loosely Coupled X Managerial Resources				
Loosely Coupled X Financial Slack				
Constant	0.751 (0.626)	0.717 (0.627)	-0.518 (0.418)	0.762 (0.621)
Log Likelihood	-823.23	-822.88	-1042.15	-819.04
N	454	454	454	454

+ p<.10, * p<.05, ** p<.01, *** p<.001

Table 13 (continued): Chapter 4 – Results - Negative Binomial - DV: New product development

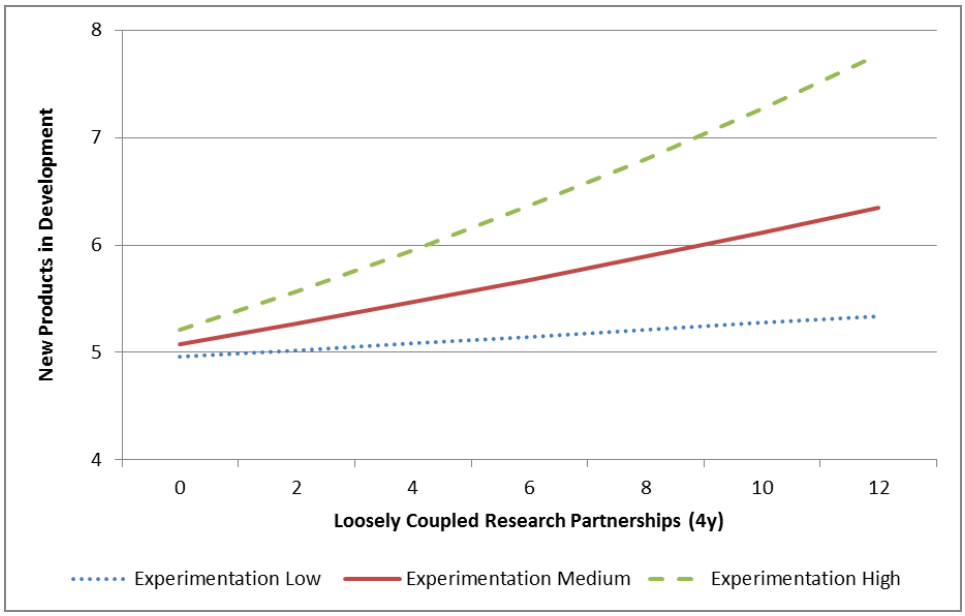
	(5) FE	(6) FE	(7) FE	(8) RE
Firm Effects	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y
Exploitation (4y)	-0.021* (0.010)	-0.013 (0.010)	-0.013 (0.010)	-0.009 (0.009)
Acquisition (4y)	-0.014 (0.017)	-0.019 (0.017)	-0.022 (0.017)	-0.018 (0.015)
R&D Intensity (t-1)	-0.437 (0.272)	-0.309 (0.270)	-0.398 (0.275)	-0.188 (0.237)
Tightly Coupled Partnerships (4y)	0.037*** (0.009)	0.030*** (0.009)	0.028** (0.009)	0.029*** (0.009)
Patents (4y)	0.204* (0.099)	0.195* (0.097)	0.200* (0.097)	0.337*** (0.063)
RoA (t-1)	0.153 (0.571)	0.304 (0.569)	0.255 (0.568)	0.560 (0.530)
Total Assets (t-1)	-0.203 (2.566)	-0.298 (2.621)	0.887 (2.548)	2.181 (2.350)
Experimental Orientation (4y)	0.553+ (0.302)	0.561+ (0.305)	0.486 (0.299)	0.057 (0.283)
Managerial Resources (t-1)	-0.102 (0.110)	-0.022 (0.117)	-0.105 (0.110)	-0.041 (0.110)
Financial Slack (t-1)	-0.077 (0.047)	-0.072 (0.048)	-0.061 (0.047)	-0.063 (0.042)
Loosely Coupled Partnerships (4y)	0.005 (0.007)	0.009 (0.007)	0.004 (0.007)	0.011 (0.007)
Loosely Coupled X Experimental Orientation			0.119** (0.042)	0.135*** (0.037)
Loosely Coupled X Managerial Resources	0.032* (0.013)		0.033* (0.013)	0.033** (0.013)
Loosely Coupled X Financial Slack		0.024** (0.009)	0.024** (0.009)	0.024** (0.008)
Constant	0.760 (0.627)	0.751 (0.615)	0.843 (0.612)	-0.135 (0.401)
Log Likelihood	-819.53	-819.39	-812.28	-1027.65
N	454	454	454	454

+ p<.10, * p<.05, ** p<.01, *** p<.001

Table 13 depicts the results for all hypotheses. Model 1 only shows the control variables. *Tightly Coupled Partnerships* and *Patents* are strong predictors for new products in development. In Models 2 and 3, we added the stock of loosely coupled research partnerships. We only found a significant positive effect using a random effects model (Model 3) while in the fixed effects model (Model 2), the coefficient, while positive, did not reach acceptable statistical significance levels. Overall, these results provide only weak support for Hypothesis 1.

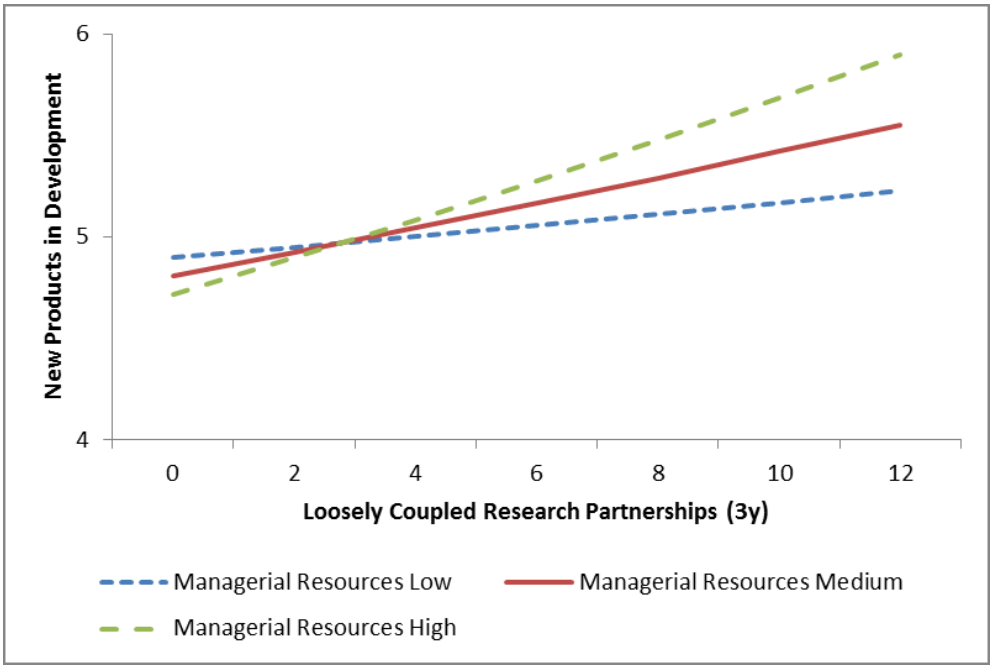
In Model 4, we added the first interaction: experimental orientation with loosely coupled partnerships. The results support Hypothesis 2. The interaction effect is best demonstrated graphically, which we show in Figure 15. At high levels (75th percentile) of *Experimental Orientation*, firms benefit much more from loosely coupled partnerships than at lower levels (25th percentile).

Figure 15: Chapter 4 - Moderation Loosely Coupled Partnersh. and Experiment. Orientation



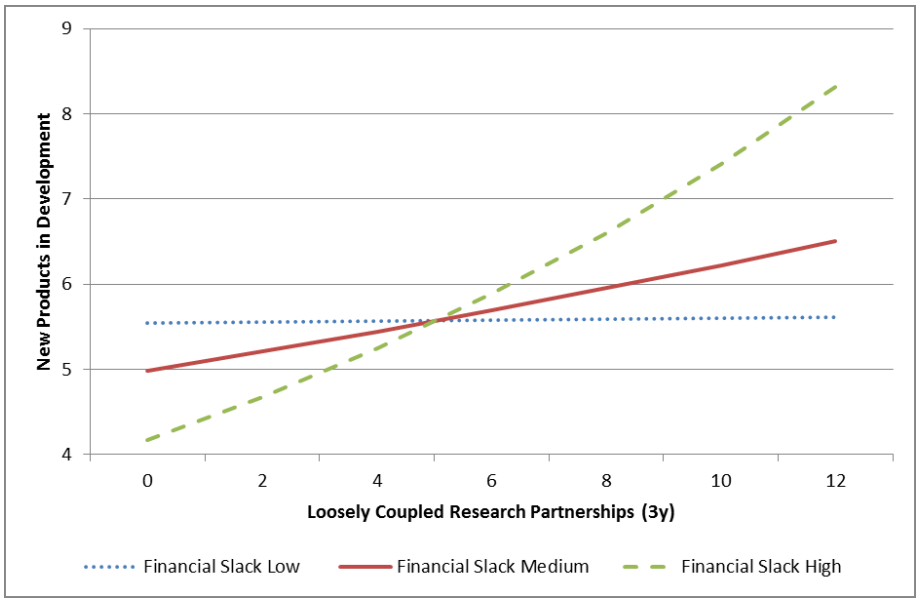
In Model 5, we entered the interaction of *Loosely Coupled Partnerships* and *Managerial Resources* (proxied by percentage decline in the number of drug development projects the firm has to attend to). As expected, the interaction was positive, indicating that the decline in the pipeline may free up managerial resources, thus allowing firms to benefit from *Loosely Coupled Partnerships*. The result is shown graphically in Figure 16 plotting *Managerial Resources* at 25th, 50th and 75th percentile.

Figure 16: Chapter 4 - Moderation Loosely Coupled Partnerships and Managerial Resources



Finally, Model 6 shows the interaction of loosely coupled partnerships and *Financial Slack* (current ratio). The results confirmed Hypothesis 4: the availability of financial resources allows firms to more effectively benefit from *Loosely Coupled Research Partnerships*. We demonstrate the effect graphically, plotting *Financial Slack* at the 25th, 50th and 75th percentile (Figure 17).

Figure 17: Chapter 4 - Moderation Loosely Coupled Partnerships and Financial Slack



To further examine the interaction effect, we reported marginal effects in Table 14 and compared marginal effects when the values of the three moderators are at the 25th percentile, the median and at the 75th percentile[76]. Testing the difference among coefficients of the 25th and 75th percentile derived from STATA's margins command, we found that the effect of loosely coupled partnerships is significantly stronger at higher levels of all moderators.

Table 14: Chapter 4 – Marginal Effects

STATA – Margins: Effects of Loosely Coupled Partnerships at different levels of moderators y	y=Experimental Orientation	y=Managerial Resources	y=Financial Slack
When y is at the25th percentile	0.008 (0.007)	0.005 (0.006)	0.007 (0.006)
When y is at the median	0.023** (0.008)	0.009 (0.006)	0.023* (0.009)
When y is at the75th percentile	0.038** (0.011)	0.017* (0.007)	0.046** (0.017)
Changes in the marginal effect (from 25th to 75th percentile)	0.03** chi2= 9.05	0.12* chi2= 6.00	0.39** chi2= 6.94

[76] Very similar results are obtained by using mean and a standard deviation above the mean values.

Model 7 shows the full model with all interactions, which remain supported; results are also similar in a random effects model in Model 8. Overall, these results confirmed our contention that firm context in the form of experimental orientation, financial slack and managerial resources substantially positively affect a firm's ability to convert loosely coupled research partnerships into innovations.

Robustness Tests

We conducted several robustness tests (Table 15). First, we used a fixed-effects Poisson quasi maximum likelihood model as the negative binomial fixed effect model has been criticized as not providing true fixed effects (Allison & Waterman, 2002). Results are in line with our other specifications. We further used alternative operationalization to proxy financial slack and managerial resources. For financial slack, we used working capital over sales as alternative (Bourgeois III, 1981; Singh, 1986) and found results similar to those reported for Hypothesis 3 (Model 11). For *Managerial Resources.* we used the number of *Therapeutic Areas* (Model 12) and number of Modes (acquisition, tight, loose partnering) pursued by the in-sourcing firm in t-1 to proxy a constraint on managerial resources (Model 13). As Models 12 and 13 indicate, our results show a sensitivity of loosely coupled partnerships to a lack of managerial resources. In order to demonstrate that the moderations are particularly important for loosely coupled partnerships, we ran the same analysis interacting *Tightly Coupled Partnerships* (Model 14) and found no significant effect except for *Experimental Orientation*, which is marginally significant. Finally, we examined whether our results would be robust if we excluded the most extreme cases of loosely coupled partnerships (i.e., pure licensing agreements). Our results were robust (Model 15).

Table 15: Chapter 4 - Robustness Tests - Negative Binomial FE

DV: New products in development	(M9) QML Poisson FE	(M10) FE Loosely Coup. >0	(M11) Financial Slack: WC/Sales
Firm and Year Fixed Effects	Y	Y	Y
Exploitation (4y)	-0.013+	-0.016	-0.016
	(0.007)	(0.010)	(0.010)
Acquisition (4y)	-0.023	-0.026	-0.015
	(0.015)	(0.017)	(0.017)
Tightly Coupled Partnerships (4y)	0.027***	0.030***	0.031***
	(0.006)	(0.009)	(0.009)
Patents (4y)	0.175	0.176	0.151
	(0.133)	(0.107)	(0.103)
Experimental Orientation (4y)	0.649*	0.691*	0.502+
	(0.299)	(0.342)	(0.303)
Managerial Resources (t-1)	-0.138	0.010	-0.098
	(0.103)	(0.134)	(0.116)
Financial Slack (t-1)	-0.014	-0.043	0.103
	(0.050)	(0.052)	(0.082)
Loosely Coupled Partnerships (4y)	0.003	0.004	0.018+
	(0.006)	(0.008)	(0.009)
Loosely Coupled X Experimental Orientation	0.087*	0.096*	
	(0.041)	(0.045)	
Loosely Coupled X Managerial Resources	0.037***	0.024+	
	(0.007)	(0.014)	
Loosely Coupled X Financial Slack	0.022**	0.021*	0.031*
	(0.008)	(0.009)	(0.016)
Therapeutic Areas (t-1)			
Loosely Coupled X Therapeutic Areas			
Alternative Modes (t-1)			
Loosely Coupled X Alternative Modes			
Tightly Coupled X Experimental Orientation			
Tightly Coupled X Managerial Resources			
Tightly Coupled X Financial Slack			
Constant		0.980	1.009
		(0.685)	(0.669)
Log Likelihood	-858.11	-704.49	-831.73
N	454	375	454

+ p<.10, * p<.05, ** p<.01, *** p<.001, Not shown but included in the models: Total Assets, Return on Assets and R&D Intensity

Table 15 (continued): Chapter 4 - Robustness Tests - Negative Binomial FE

DV: New products in development	(M12) Managerial Resources Alt. 1	(M13) Managerial Resources Alt 2	(M14) Tightly Coupled Interac.	(M15) Loosely C. (no pure licensing)
Firm and Year Fixed Effects	Y	Y	Y	Y
Exploitation (4y)	-0.017+	-0.016	-0.009	-0.013
	(0.009)	(0.010)	(0.011)	(0.010)
Acquisition (4y)	-0.017	-0.018	-0.011	-0.029+
	(0.017)	(0.018)	(0.019)	(0.017)
Tightly Coupled Partnerships (4y)	0.033***	0.031***	0.028*	0.032***
	(0.009)	(0.009)	(0.013)	(0.009)
Patents (4y)	0.185+	0.170+	0.206*	0.195*
	(0.098)	(0.099)	(0.101)	(0.097)
Experimental Orientation (4y)	0.597+	0.602*	0.564+	0.424
	(0.306)	(0.302)	(0.305)	(0.299)
Managerial Resources (t-1)	0.038	0.032	0.001	-0.084
	(0.127)	(0.120)	(0.121)	(0.109)
Financial Slack (t-1)	-0.067	-0.080+	-0.079+	-0.072
	(0.048)	(0.047)	(0.048)	(0.047)
Loosely Coupled Partnerships (4y)	0.047**	0.038**	0.007	0.001
	(0.018)	(0.014)	(0.007)	(0.007)
Loosely Coupled X Experimental Orientation				0.170*
				(0.075)
Loosely Coupled X Managerial Resources				0.053*
				(0.023)
Loosely Coupled X Financial Slack				0.034*
				(0.014)
Therapeutic Areas (t-1)	0.035+			
	(0.021)			
Loosely Coupled X Therapeutic Areas	-0.005*			
	(0.002)			
Alternative Modes (t-1)		0.153*		
		(0.063)		
Loosely Coupled X Alternative Modes		-0.020**		
		(0.007)		
Tightly Coupled X Experimental Orientation			0.094+	
			(0.055)	
Tightly Coupled X Managerial Resources			-0.008	
			(0.018)	
Tightly Coupled X Financial Slack			0.014	
			(0.009)	
Constant	0.636	0.752	0.617	0.890
	(0.613)	(0.631)	(0.640)	(0.613)
Log Likelihood	-819.47	-817.79	-819.73	-815.23
N	454	454	454	454

+ p<.10, * p<.05, ** p<.01, *** p<.001, Not shown but included in the models: Total Assets, Return on Assets and R&D Intensity

Endogeneity

An important concern in our study is that the decision to engage in loosely coupled partnerships may be endogenous. To address this issue, we further examined the data to determine if some firms systematically do not engage in loosely coupled partnerships. In our sample, all firms engaged in at least 1 loosely coupled partnership between 1994 and 2006 (the timeframe in which the independent variable is measured). Hence, there was no evidence that some firms avoid loosely coupled partnerships altogether. This said, in order to further address endogeneity concerns, we conducted the following robustness tests.

First, we limited our sample to firm years in which we observed a stock of loosely coupled partnerships (Model 10). This reduced our sample to 377 firm-year observations. We then replicated our analysis; the results found similar support compared to the full sample.

Second, we examined if the identified relationships hold only for specific types of firms. We split the sample by the size of firms and examined differences between larger and smaller incumbents in our sample. The results (available upon request) are very much in line with the results for the full sample. These robustness tests, along with using firm fixed effects, gave us increased confidence that our results were not driven by the selection of loosely coupled partnerships by specific types of firms.

DISCUSSION

Determining how future goods and services are discovered, developed and commercialized represents a fundamental question in strategy and innovation management research (Ahuja & Morris Lampert, 2001). Our study attempts to illuminate how firms manage this process when they opt to access external knowledge via loosely coupled partnerships. The study lies at the heart of two core organizational processes: interorganizational partnerships and new product development, both of which have a profound impact on a firm's ability to build value-creating strategies.

We find that accessing external knowledge via loosely coupled partnerships matters for innovative performance, but the innovation benefits of such partnerships reach their full potential only in specific firm contexts. Namely, we identify the in-sourcing firm's experimental orientation, its availability of financial slack and managerial resources as three key moderators that allow it to reap the innovation benefits of loosely coupled research partnerships.

Our study makes three main contributions. First, we highlight that scholars may need to distinguish between tightly and loosely coupled research partnerships when examining their effect on innovative performance in general. In the pharmaceutical space, previous studies (Hess & Rothaermel, 2011; Nicholls-Nixon & Woo, 2003) have found surprisingly little evidence of a direct relationship between in-sourcing external knowledge through partnering and generating new product development candidates,

which may stem from collapsing both tight and loose research partnerships into one single category.[77]

Second, we reveal that although the effect of loosely coupled research partnerships on the in-sourcing firm's innovative performance does not seem to be statistically strong, when we look at its interaction with the firm's experimental orientation as well as with its availability of financial and managerial resources, the results are strong and robust to several different specifications. While extant research has tended to focus on the benefits of tightly coupled partnerships, we unveil in this paper the conditions under which another category of partnerships (i.e., loosely coupled) may provide a focal in-sourcing firm with significant innovation benefits. Previous studies have already suggested that loosely coupled partnerships may be ideal in settings of rapid environmental change as they allow firms to effectively exploit the division of labor and gain access to specialized knowledge. Our results highlight that all these potential advantages of loosely coupled partnerships are much more likely to be manifested in terms of innovation benefits in the presence of a strong experimental orientation, financial slack and managerial resources in the in-sourcing firm.

Finally, we also contribute to the literature on financial slack. While the direct effect of slack on innovation continues to be subject to debate (Nohria & Gulati, 1996), our study reveals that financial slack may be an important contingency for firms to benefit from loosely coupled partnerships.

In its current form, this study has several limitations. First, the pharmaceutical industry is very distinctive as there is a clear delineation between discovery and

[77] For example, Rothaermel and Hess (2011) find no direct effect from upstream (i.e., discovery) partnerships on new product development in a similar context.

development. For instance, once in development, a compound usually undergoes only marginal alterations. This may not be true for other industries. A second concern is that the dependent variable (i.e., new preclinical compounds in development) only captures new product announcements that are disclosed by the firm. Although the pharmaceutical industry is regulated in the clinical trials, this does not guarantee that each compound is disclosed early in the preclinical trials. We tried to mitigate this risk by completing Pharmaprojects information with ADIS Insights to have two separate databases to identify when a compound was first visible. If some firms tend to underreport more than others, we hope to have remedied this by using fixed effects.

Given the firm-level analysis of our study, future research may examine how the firm-level factors (experimentation, financial slack and managerial resources) indeed influence individual loosely coupled research partnerships at the project level. Moreover, the analysis could be extended to partnership agreements beyond the discovery stage and closer to commercialization.

Overall, our paper demonstrates that loosely coupled partnerships can also be important vehicles to allow firms to devise solutions new to an industry. This should be an important reminder for managers and researchers alike that firms may achieve innovations through multiple paths and distinct external knowledge sourcing strategies.

CHAPTER 5: CONCLUSION AND OUTLOOK

We're at a tipping point. We've come to the point where internal discovery can no longer sustain companies of our size. And I'll say that across the field. We have to get better at leveraging the external environment but in a very serious way. … I do believe that there's disruptive innovation out there and we just have to learn to be externally focused instead of contemplating our own (Merck Senior Executive – World Wide Licensing, 2011)

Contributions

This dissertation makes both theoretical and empirical contributions to understanding the unique relationships of established and startup firms in environments characterized by rapid technological change. An overview of the hypothesized relationships and the dissertation results is shown in Table 16. Next, I discuss the most important findings of the dissertation followed by an exposition on some of the dissertation's most important limitations and potential avenues for future research.

All essays of this dissertation have in common that they address challenges associated with exploration, i.e., *the conscious effort to move away from current organizational routines and knowledge bases* (Katila & Ahuja, 2002:1184; March, 1991) in innovation and problem solving. Chapter 1 observes exploration directly in the form of the technological opportunities pursued by established firms. While on one hand, established firms pursue external partnerships to access exploratory knowledge from startups (see the introductory quote of this chapter), I find that established firms may "overlook" highly novel and early stage technological opportunities in partnership formation. As such, forming exploratory type partnerships may be challenging for firms.. Similarly, in chapter 3, I observe exploration of startup firms relative to the established industry players. I find that pursuing radical innovations (innovations which differ from those of established firms) is associated with severe market value penalties for startups.

This suggests substantial difficulties for startup firms to position themselves in a very exploratory position versus established industry players. Finally, chapter 4 highlights the challenges of established firms to effectively use external knowledge sourced into the firms through loosely coupled partnerships with the intention to explore and innovate.

Table 16: Summary of hypotheses and empirical results

Ch.	Hyp.	Dependent Variable	Independent Variable	Hyp. Effect	Supported?
2	1	Partnership Formation	Novelty Partnering Opportunity	-	Yes
2	2	Partnership Formation	Distance to Commercialization of Opportunity	-	Yes
2	3a	Partnership Formation	Interaction: Novelty Partnering Opportunity x Prior Failures	+	Yes
2	3b	Partnership Formation	Novelty Partnering Opportunity x Prior Successes	-	No
2	4a	Partnership Formation	Distance to Commercialization x Prior Failures	-	Partially
2	4b	Partnership Formation	Distance to Commercialization x Prior Successes	+	Yes
3	1	Market Value Startup	Radicalness of Innovation	-	Yes
3	2	Market Value Startup	Radicalness of Innovation x Formation of Commercialization Partnerships	+	Yes
3	3	Market Value Startup	Radicalness of Innovation x Failure Incumbent Firms	+	Yes
3	4	Market Value Startup	Interaction: Radicalness of Innovation x Maturity of Innovation	+	No
4	1	New Products in Development	Loosely Coupled Partnerships	+	No
4	2	New Products in Development	Interaction: Loosely Coupled Partnerships x Experimentation	+	Yes
4	3	New Products in Development	Interaction: Loosely Coupled Partnerships x Financial Slack	+	Yes
4	4	New Products in Development	Interaction: Loosely Coupled Partnerships x Managerial Resources	+	Yes

This illustrates that merely adding and accessing external knowledge may not be enough for firms to innovate, as the exploration of new knowledge may require both adding new knowledge and recombining knowledge in new ways (Fleming & Sorenson,

2004). Overall, the dissertation outlines various severe challenges related to exploration, even in environments where a division of innovative labor between established and startup firms has emerged (Arora & Gambardella, 1994a)

Importantly, all dissertation essays contribute to our understanding about the conditions under which challenges related to exploration hold or do not hold. To that end I extend studies examining a firm's organizational context and, in particular, internal R&D as boundary conditions to recognize and use external knowledge (Cohen & Levinthal, 1990; Jansen et al., 2005; Lewin, Massini, & Peeters, 2011; Volberda, Foss, & Lyles, 2010). For example, chapters 2 reveals how all experience is not created equal and that prior failures and successes in R&D differently shape "spatial" and "temporal" myopia in the formation of partnerships. I find that while prior failures lead firms to become more open to novel ways of solving problems, they, at the same time, push firms to seek partnering opportunities which promise immediate payoffs. These findings resolve existing tensions in the literature as to whether prior failures lead to a problemistic type search, which is often characterized as local and reactive (Cyert & March, 1963; Staw et al., 1981) or if failures can lead to search which is more experimental and risk-seeking (Greve, 2011; Madsen & Desai, 2010). In a related vein, I find that startups pursuing radical innovations may benefit from failures of established firms (chapter 3), which supports the idea that failures make novel types of solutions more attractive and trigger a reallocation of resources towards such initiatives.

Quite differently, I find that prior successes may enable firms to take a long term perspective, allowing them to consider partnering opportunities with more distant payoffs (chapter 2). This resonates with Cyert and March's (1992:189) suggestion that "success

tends to breed slack" which acts as a buffer for "risky" decisions, ultimately allowing firms to be more lenient in allocating resources to early stage partnering opportunities. On the other hand, it challenges ideas that success may ultimately harm subsequent innovation attempts as it traps organizations into existing knowledge bases and routines (Audia et al., 2000). In chapter 4, I observe financial slack as a proxy for success and reveal that slack may be an important condition to effectively utilizing knowledge gained from loosely coupled partnerships. All these findings argue for the value of integrating perspectives on myopia and local search with studies examining experiences of failures and successes as well as organizational slack (Greve, 2011; Laursen, 2012).

All three essays also contribute to the understanding of partnerships between startups and established firms. While the formation of partnerships is studied as an outcome in chapter 2, chapters 3 and 4 consider partnerships as important inputs to create value for firms. For example, chapter 4 illuminates the unique properties of loosely coupled partnerships, which represent an exchange of knowledge absent strong collaboration and organizational support (Steensma & Corley, 2000). I find that benefits from such partnerships do not necessarily stem from the sourcing relationship per se, but are closely linked to the in-sourcing firm's experimental orientation to pursue risky projects and the availability of financial and managerial resources. Finally, chapter 3 demonstrates that partnering can be an important moderator, shaping the legitimacy and resources available for startup firms. I identify that, beyond direct benefits, partnerships seem to be particularly important for startups pursuing radical innovations. Interestingly, this essay also reveals that even in the absence of partnerships, the relationship between startups and established firms remains important. Namely, failures in established firms'

R&D attempts may benefit those startups that pursue product innovations which depart from the industry's existing recipes for problem-solving. Table 17 provides a summary of key insights from each chapter of this dissertation and outlines the key arguments made.

Table 17: Dissertation Highlights

	Chapter 2	**Chapter 3**	**Chapter 4**
Outcome Studied	Established Firm's Partnership Formation	Startup's Market Value	Established Firm's New Products in Development
Innovation Process	Established firms selecting among a range of partnering opportunities from startups.	Startup firms' pursuit of product innovations relative to industry incumbents.	Innovation benefits accrued from loosely coupled research partnerships.
Exploration Challenge	Established firms face challenges in pursuing partnering opportunities with novel technological solutions and with payoffs in the distant future.	Startup firms face challenges when pursuing radical innovations, i.e., innovations which differ from those sought by established placers.	Engaging with external partners through loosely coupled partnerships may add to the firm's variety of knowledge but such knowledge may not be effectively used to boost innovative performance.
Theorized Mechanisms	Firms prefer established means-end relation-ships in problem-solving (spatial myopia) and prefer exploiting existing commercialization routines (temporal myopia).	Pursuing radical innovations leads to a lack of legitimacy and resources for startups, adversely affecting market valuations.	Innovation not only requires elements of external knowledge, but also experimentation and supporting resources, which loosely coupled partnerships lack.
Identified Boundary Conditions	Prior Failure and Success shape myopic tendencies: Spatial Myopia: Prior Failures challenges existing means-end relations, while prior successes may reinforce them. Temporal Myopia: Prior Failures reinforce temporal myopia, while prior successes allow firms to more readily consider partnering opportunities at an early stage of development.	Legitimacy and resources provided through: Formation of commercialization partnerships (validate technology and provide resources to commercialize) Established firms failures in R&D: Relative legitimacy of radical solutions increases. Resource re-allocation of established firms signals resource availability for startups with radical innovations Maturing innovations: Increases viability of radical innovations. Possible resource independence from established firms.	Necessary to look within the firm to observe when firms benefit from external knowledge sourced-in through loosely coupled partnerships: Experimental Orientation: Induces recombination and experimentation Abundant Managerial and Financial Resources: Support innovation initiatives, which lack managerial and financial resources in the first place.
Main Contributions	"Temporal" and "spatial" myopia salient in the formation of partnerships between established firms and startups. Prior failures and successes have a different effect on the two types of myopia. Failures open firms to partnering opportunities with novel elements of knowledge. Prior successes open firms to solutions that are distant from commercialization.	In an environment wherein established firms retain complementary assets, pursuing radical innovations is associated with market value penalties. Forming commercialization partnerships and failure in R&D initiatives by established firms provide both legitimacy and resources to startups pursuing radical innovation, hence mitigating market value penalties.	Innovation benefits may not stem from sourcing external knowledge per se. Benefits contingent on the in-sourcing firm's experimental orientation to pursue risky projects and the availability of financial and managerial resources.

The dissertation also makes important methodical contributions. Focusing on innovation associated with compounds in development in all essays allows me to capture information in the innovation process that cannot be derived from patent-based studies. For example, I am able to unambiguously identify if a technology (i.e., a compound) was available for partnering or not (chapter 2) while, for patents, it is often not clear which patents are already licensed to other parties and hence not available. Patents also do not allow us to capture the "time to commercialization" dimension of exploration, which is important to understanding organizational decision-making (chapter 2 and chapter 3). Compounds can be unambiguously characterized as being very early or late in the innovation process, which is not possible through the mere observation of patents. Moreover, compounds are at the nexus of research and commercialization and hence represent an important area in which managerial decisions (e.g., the allocation of resources) are made. It is here where challenges to exploration may materialize as managers need to make compensatory tradeoffs among various investment alternatives (Adner & Levinthal, 2008; Klingebiel & Rammer, 2013). A final methodological contribution lies in the idea of expanding our toolset to measure radical innovations (chapter 3), which follows the fact that prior studies have examined radical innovations, not as an ex post, but as a dynamic measure defined through the overlap in innovation activities by startups and established firms (Dahlin & Behrens, 2005).

Limitations & Extensions

This dissertation is not without limitations, which should provide ample opportunities for future research. I will focus on the two most important ones as I addressed limitations separately in each dissertation chapter.

First, I have analyzed a single industry, which poses concerns as results may not be generalizable. In particular, I have purposefully chosen an industry in which established firms are known to remain in possession of complementary assets. I have not, however, contrasted my observations to an industry in which this may not be the case.

Second, the dissertation currently solely considers partnering as an important strategic tool deployed by established firms and startup firms in their innovation activities. However, firms possess a broad variety of tools to tap into external knowledge, including acquisitions or CVC investments (Keil et al., 2008; Nicholls-Nixon & Woo, 2003), which in this dissertation only serve as controls. The dissertation hence only captures a subset of actions at the disposal of firms. The inclusion of alternative modes like acquisitions would, hence, provide an interesting area for future research.

My goal when generating my dissertation data was to build the most comprehensive dataset linking both external activities (from ReCap) and product development (from Pharmaprojects). Linking external agreements and product development data allows me to more readily compare internal R&D (in product development) as well as external R&D. Hence, I have the unique opportunity to study internal and external R&D not only by counting activities but by explicating the direction firms take (exploration and exploitation).

This dataset will cover a variety of external agreements including alliances, licensing, equity investments and acquisitions, which allows me to a) gain a better understanding what types of technological solutions are actually sourced by established firm or available by startups and b) track the outcomes related to the external R&D activities of both startups and established firms. As an example, I could compare what

type of compounds is sourced through acquisitions and which ones through partnerships. At the same time, I could track the outcomes related to the in-sourced technologies (compounds) and examine how they progress through the development stages.

Increasingly, the direction of the sourcing relationship between established and startup firms is also reversed as more and more established firms not only are opening up to external knowledge but also opening up to smaller firms using their external knowledge (Rivette & Kline, 2000). As an example, Merck and Pfizer both have initiated dedicated organizational units responsible for identifying internal and unused technological opportunities to either spin-off or sell to other firms. Understanding what technologies are selected by established firms, which are let go and identifying the partners which attract such assets expands our current understanding of the division of labor between established and startup firms. At the same time, studying such relationships, in which knowledge flows from the established to the startup firm, may expand our understanding of organizational search as well as exploration and exploitation.

Another extension of this dissertation is to examine in greater detail how firms source external knowledge and how this knowledge ultimately is productively used. This dissertation illuminated the importance of understanding the organizational context into which external knowledge is added for the purpose of innovation. Despite incumbents' investing in the new technology, subsequent innovation and commercialization attempts may not materialize, as demonstrated in chapter 4. A rich set of literature highlights that beyond investments into new technologies per se, capabilities, routines, managerial cognition and resource dependencies need to be accounted for to understand firm's

actions in environments characterized by rapid technological change (Christensen & Bower, 1996; Gilbert, 2005; Leonard-Barton, 1992; Tripsas & Gavetti, 2000). Data from this dissertation allows me to take a closer look at what happens within organizations with external knowledge. One extension would be to note that not all technological change is the same as some changes have the potential to disrupt the way incumbents firms would need to conduct their business (Burgelman, 1985; Christensen, 2006; Christensen & Raynor, 2003; Tripsas & Gavetti, 2000). For example, in 1990s, gene therapy emerged as a revolutionary therapeutic approach based on genetic engineering to treat diseases (Sosa, 2011). A gene therapy treatment is not taken in the form of a pill at home but in the hospital, administered by a doctor via small intramuscular injections. Most importantly, gene therapy treatments tend to be one-off, which means that the current revenue model based on regular prescriptions would not be applicable (Wilson, 2012). It is hence interesting to observe how such technologies are effectively used once technological knowledge is added into the firm. Accordingly, I have started a project with Professor Kapoor to investigate if the impact of upstream R&D investments on incumbents' downstream commercialization is shaped by whether the emerging technology is sustaining (i.e., is consistent with) or disruptive to the incumbent's business model (Burgelman, 1985; Christensen, 2006; Christensen & Raynor, 2003). We hope to explicate how the different modes of adaptive responses (partnering, acquisitions, internal R&D) may differently impact commercialization attempts across sustaining and disruptive technologies.

Another extension is to shift attention from exploration activities to exploitation. Throughout the dissertation, I claim the need for exploration, in particular when focusing

on the established firms (chapter 2 and chapter 4). However, examining the young startups' industry players (chapter 3) reveals that it may be equally important to understand how such startups can more readily exploit their technologies and transition towards more predictable types of organizations. While I have attempted to keep startups theoretically distinct from established firms within an industry, over time, startups may themselves become established industry players as they have commercial success (i.e., a product on the market). For example, in the late 1990's, Amgen, Genentech and Chiron were considered to be established firms with billions of revenues but were startups in the mid-1980s. Recently, companies I have treated as startups in the 1990s (e.g., Gilead Sciences or Vertex Pharmaceuticals) made the transition to becoming important industry players. An extension of this dissertation would be to examine what these firms did to become more "exploitative." Given the findings of this dissertation, my expectation is that partnerships with established firms to build commercialization competencies played a fundamental role in this transition for these startup firms. Examining this phenomenon would be also highly interesting from the perspective of the established firms, which on the one hand gain access to technologies from the startups but, at the same time, may give rise to their next competitor.

Conclusion

Overall, understanding how established and startup firms innovate is fundamentally important. I believe there is still a great deal to learn about how firms explore new ways of solving problems, search beyond their boundaries for new external technological solutions, and use partnering as an important tool to innovate and adapt to technological change. The current changes in the pharmaceutical industry (e.g., a breakup

of Abbott and the potential breakup of Pfizer (Herper, 2011)), combined with the explosion in scientific knowledge, suggest that environmental turbulence will increase in the next years, making the industry a highly interesting setting in which to study innovation and the role of partnerships between established and startup firms.

APPENDIX

Appendix 1: Chapter 1 - Examples of Partnerships in Recap

Example: Recap	Supporting Press Release:
Joint Collaborations	***Asklepios Bio and Bayer (Value Chain Activity - Research):*** Triangle-based Asklepios Biopharmaceutical Inc., a private development-stage biotechnology company and California-based Bayer HealthCare, LLC, Biological Products Division have entered into an early-stage research and collaboration agreement to evaluate gene therapy for the treatment of hemophilia B. Pending positive results of a feasibility study, this collaboration could lead to a joint development and commercialization agreement between Bayer Biological Products Division and Asklepios for the novel gene therapy treatment for hemophilia B (www.bayerbiologicals.com). ***KAI Pharmaceuticals and Daiichi Sankyo (Value Chain Activity - Phase 2):*** Sankyo has entered into an agreement with USA-based KAI Pharmaceuticals for the joint development and commercialization of KAI-9803. The partnerships will have an initial focus on cardiovascular disease. The novel delta protein kinase C inhibitor is a first-in-class agent and is currently in a Phase I clinical trial to assess safety.
Partnerships with less reciprocity among the partners	***Valentis and Wyeth (Value Chain Activity - Research):*** Valentis, Inc. announced that it has granted a non-exclusive license of the Company's GeneSwitch(TM) gene regulation technology to Wyeth-Ayerst Laboratories, the pharmaceutical division of American Home Products Corporation. The GeneSwitch(TM) system allows researchers to control the level and duration of selected genes in transgenic animals and cell cultures, aiding in the identification and characterization of a gene's function. ***Acacia Biosciences and Bristol-Myers-Squibb (Value Chain Activity - Research):*** Bristol-Myers Squibb Company and Acacia Biosciences, Inc., today announced an agreement in which Bristol-Myers Squibb will license the use of Acacia's proprietary Genome Reporter Matrix(TM) (GRM) to profile pharmaceutical compounds. ***Pherin Pharmaceuticals and Organon (Value Chain Activity - Phase I):*** Pherin Pharmaceuticals has signed an agreement with Organon, an Akzo Nobel subsidiary, for the development and marketing of drugs based on Pherin's compound PH80 which mimic pheromones.

Appendix 2: Chapter 2 - Measure Novelty Example (simplified)

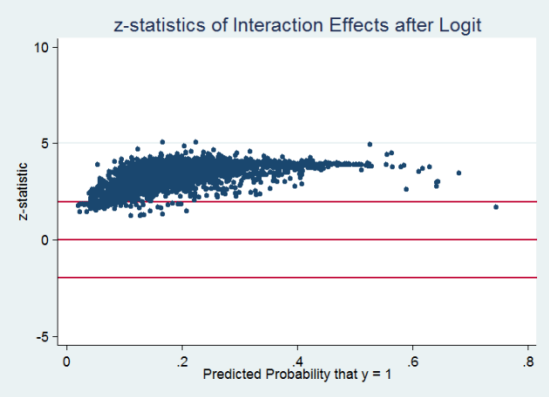
Startup: ZymoGenetics 2000: 2 available compounds for partnering	Established Firm: Merck & Co (1997-2000)	Novelty score	Average *Novelty* Score
Compound 1: Atacicept Broad Therapy: Immunological	Merck Experience in Immunological:	2	(Startup-Established Firm Year Level) (2+1)/2=1.5
Mechanism: B-cell activating factor inhibitor	Mechanism of Action: New to Merck (1)		
Origin of Material: Biological-Protein, recombinant	Origin of Material: New to Merck (1)		
Compound 2: denenicokin Broad Therapy: Cancer	Merck Experience in Cancer:	1	
Mechanism: Interleukin 21 agonist	Origin of Material: New to Merck (1)		
Origin of Material: Biological-Protein, recombinant	Origin of Material: Known to Merck (0)		

Appendix 3: Chapter 2 – Measure Success, Failure

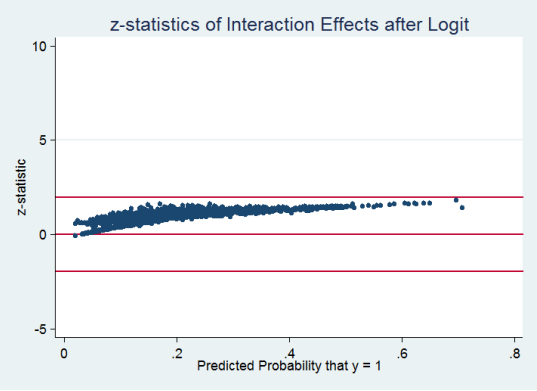
Partnering Opportunity: *Startup:* ZymoGenetics in year t-1 *Compound*: Atacicept	Established Firm: Merck & Co
Broad Therapy: Immunological	Moderator: *Prior Successes:* Count Number of Approved Drugs by Merck in Co. in broad Therapy Area Immunological between t-4 to t-1
Broad Therapy: Immunological	Moderator: *Prior Failures*: Count Number of Failed Drugs (PII/PIII) by Merck in Co. in Therapy Area Immunological between t-4 to t-1

Appendix 4: Chapter 2 – Inteff – z-statistics

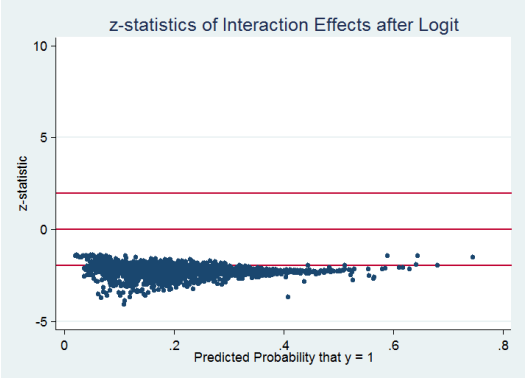
Moderation Novelty and Prior Failures (+ supported):



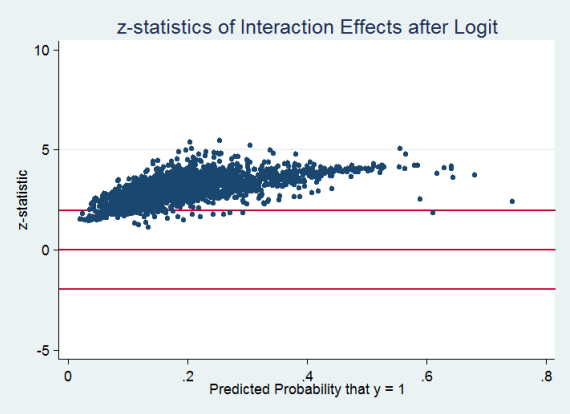
Moderation Novelty and Prior Successes (- not supported):



Moderation Distance to Commercialization and Prior Failures (- some support)



Moderation Distance to Commercialization and Prior Successes (+ supported)



Appendix 5: Chapter 3 - Measure - Innovation Radicalness (Simplified Example)

Startup in year 2001:	Pfizer -2001 (active in cancer)	Merck- 2001 (active in cancer)	Independent Variable
Cancer Compound 1: OoM: Chemical MoA: Phosphodiesterase (PDE) inhibitor	Score: 0 (OoM and MoA both also in development by Pfizer in Cancer)	0	Average: 0/2=0
Cancer Compound 2: OoM: Biological-Viral Vector MoA: Protein synthesis inhibitor	Score 2 (neither OoM nor MoA pursued by Pfizer in Cancer)	2	Average: 4/2=2
			Innovation Radicalness startup level (average): (0+2)/2 = 1

OoM-Origin of Material, MoA-Mechanism of Action

Appendix 6: Chapter 3 - Measure - Failure & Success Incumbents

Startup active in year 2001 in:	Pfizer -2001	Merck- 2001	Moderating Variables/Controls
Therapy Area 1: Cancer	Number of Failures (Phase III discontinuation): 1 Number of Successes (Drug Approved): 1	Number of Failures: 2 Number of Successes: 1	*Failure Incumbents* (Pfizer: 1+0, Merck: 2+0): 3 *Success Incumbents* (Pfizer: 1+1, Merck: 1+1): 4
Therapy Area 2: Cardiovascular	Number of Failures: 0 Number of Successes: 1	Number of Failures: 0 Number of Successes: 1	

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