ABSTRACT

Title of dissertation: RECONFIGURATION STRATEGIES, ENTREPRENEURIAL ENTRY AND INCUBATION OF NASCENT INDUSTRIES: THREE ESSAYS

Mahka Moeen, Doctor of Philosophy, 2013

Directed by: Professor Rajshree Agarwal
Department of Management and Organization

The first essay of my dissertation focuses on the incubation stage – the period between introduction of a technological change and its first commercialization – of an industry, which is an understudied phenomenon. It examines firms' technological investments in a nascent industry in anticipation of commercialization, and contributes novel insights to the classic industry evolution literature that conceptualizes industry formation from the first instance of product. Using the agricultural biotechnology industry as the empirical context, this essay documents not only the extent to which firms undertake technological investments in anticipation of entry, but also the heterogeneity in types of entrants and their modes of value capture. I thus shed light on the intertwined processes of economic value capture at the firm-level and ecosystem development at the industry-level that underpin incubation of nascent industries.

The second essay examines the capability antecedents of a firm market entry into a nascent industry. A firm's technical capabilities and complementary assets, at time of

entry, have been consistently noted as key determinants of the likelihood of entry. Drawing on the premise that firms make deliberate decisions regarding technological investments well before they enter nascent markets, I make a distinction between a firm's pre-entry and pre-investment capabilities and study the type of pre-investment capabilities that are related to the likelihood of firm entry. I suggest that a firm's pre-investment reconfiguration experiences are the critical capability: these experiences shape the firm's development of pre-entry technical capabilities and complementary assets, which in turn affect the likelihood of entry. I find empirical support for the mediating role of pre-entry capabilities to the relationship between pre-investment experiences and the likelihood of entry in the context of the population of firms that conducted R&D investments in agricultural biotechnology between 1980 and 2010.

The third essay studies the reconfiguration strategies pursued by firms in anticipation of entry into a nascent industry. Whether entry to a nascent industry is undertaken by de novo startups, diversifying firms from related industries or industry incumbents from the obsolescing industry, a critical strategic action for firms is to achieve the required configuration of capabilities for operations in the new industry. The choice, timing, and sequence of these capability reconfiguration mechanisms may, however, differ across different types of firms. I provide theoretical propositions that link firm types to the underlying sources of heterogeneity and suggest how this heterogeneity leads to differential paths undertaken by de novo startups, diversifying firms and industry incumbents while reconfiguring themselves in anticipation of entry into a nascent industry. Implications of the model are discussed using three firm case studies from the agricultural biotechnology industry.

RECONFIGURATION STRATEGIES, ENTREPRENEURIAL ENTRY AND INCUBATION OF NASCENT INDUSTRIES: THREE ESSAYS

By

Mahka Moeen

Dissertation submitted to the faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
Of requirement for the degree of
Doctor of Philosophy
2013

Dissertation Committee:

Professor Rajshree Agarwal, Chair
Professor David Kirsch
Professor Joseph Mahoney
Professor Rachelle Sampson
Professor David Sicilia
Professor David Waguespack

Acknowledgements

The completion of this dissertation is indebted to the exemplar scholars in the fields of strategic management, entrepreneurship and economics, whose works have inspired my research ideas and with whom I have been engaged in a virtual conversation. In this sense, the bibliography of this manuscript best represents the name of people without whom writing this dissertation would not be possible. That being said, as a student of strategic management, I very well know that market imperfections do play a role, knowledge transfer and integration does not occur automatically, and the path dependence of events may have had a substantial impact on the journey that I pursued during my doctoral program. Accordingly, the continuous support of my dissertation committee members, faculty of the universities of Maryland and Illinois, my family and friends has been critical. I thank all of you.

From supporting my admission to PhD program to reading this final draft of my dissertation, Rajshree has been *always* there. I am thankful for all she has done for me so far and all she will be doing in the future. Being her student has been such a privilege at multiple dimensions that no single instance of interaction with her could be emphasized. Throughout my doctoral studies, I have been so fortunate to have Joe as my other mentor. From the first year philosophy of science seminar to my dissertation research, I have benefited so much from his insights and knowledge. Many thanks go to Rachelle, Dave Waguespack and David Sicilia for their valuable feedback and suggestions for development of my dissertation. Also, hours of conversations with David Kirsch, Deepak and Glenn have extensively shaped my research interests and academic personality. Academic guidance of Anil, Anju, Brent, Doug, Hadi, Janet, Raj, and Waverly has been extraordinary. Thank you all.

The decision to enter a doctoral program as well as my post-entry survival has been greatly impacted by the unconditional support of Soroush and my mom. Melika's smile has kept me going in many instances. Bahar, Sepideh and Khale Tara made my transition to US easier and made me feel like home. I also want to thank my father, Fariba joon, Sania, and Mr. Ghazi for their invaluable encouragements. I know the joy that they take in my accomplishments is the best gratitude.

I am also grateful to Afarin, Arezoo, Banafsheh, Golriz, Marleen, Mehdi, Seth, Shora, Shweta and Yasmin for their wonderful friendship; to Denisa, Lihong, Martin and Pao-Lien for setting outstanding examples of what a doctoral research should look like; to Annie, Brad, Bryan, Dan, Joshua, Malter, Min-Young, Qiang, Robert, Sai, and Vivian for being great colleagues; to Protiti for helping me with my teaching; to Natalya for her early work on the agbiotech project; and to Justina for being the best graduate coordinator.

Finally, I would like to thank the Ewing Marion Kauffman Foundation and the Strategy Research Foundation for their financial support. The content of this dissertation is solely my responsibility and does not represent the official views of these institutions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Entrepreneurial entry of firms to new industries and the concomitant change in the technological regime and competitive landscape of industries have been associated with creative destruction (Schumpeter, 1942). Much of the scholarly research in industry evolution and entrepreneurship has focused on the entry of entrepreneurial firms to new industries and performance implications of their entry vis-à-vis industry incumbents, defining a firm's entry to a new industry as the point when the firm first commercializes a product within the new industry (Helfat & Lieberman, 2002). Similarly, inception of an industry is conceptualized based on the first instance of product commercialization (Agarwal & Gort, 1996; Gort & Klepper, 1982). My dissertation is based on the premise that studying entrepreneurial entry of firms to a new industry by considering the first product commercialization may provide an incomplete picture of which firms choose to enter a new industry and how firms and industries co-evolve.

Indeed, technologies often undergo an *incubation* period, which I define as the period between the introduction of a discontinuous technological change and the first instance of product commercialization. During the incubation period, firms invest effort in transforming the invention to commercially valuable innovations. These efforts entail a reconfiguration of existing resource base and capability portfolio according to the requirements of the new industry. In the context of industry evolution, while scholars have documented existence of the incubation stage where firms make investments in exploring the new industry (Agarwal & Bayus, 2002; Golder, Shacham & Mitra, 2009), there is little work examining how firms transform technological opportunities to economic value and further reconfigure their resources according to the requirements of an industry that has not been created yet. Further, although existing research has noted the existence of firms prior to their entry into a new industry and the differences in firms' pre-entry capabilities (Bayus & Agarwal, 2007; Helfat & Lieberman, 2002; Khessina & Carroll, 2008), researchers have largely abstracted away from examining firms' strategies during the incubation stage of the industry. This is an important unaddressed gap, since firm-level investments undertaken in anticipation of creation of a new industry have important ramifications not only for firm, but also for industry and its innovation ecosystem's evolution. Analysis of this critical period that may define subsequent firm's evolution in the nascent industry, thus, deserves greater attention.

The main focus of my dissertation is to contribute to a better understanding of firms' entrepreneurial entry to nascent industries. While the existing literature has considered a firm's product commercialization as the focal point of a firm's entry into a nascent industry, the three essays of my dissertation highlight the new theoretical and empirical insights that could be gained by analysis of the technological investments that firms undertake prior to their product commercialization within a nascent industry context. Specifically, the theme of my dissertation is to address the following questions by accounting for firms' technological investments in a nascent industry prior to product commercialization: What are the types of capabilities which enable entrepreneurial foray of firms to new industries? What are the breadth and depth of reconfiguration strategies that are undertaken in anticipation of creation of a nascent industry and a firm's subsequent entry to that industry? What are the firm-level and industry-level consequences of firms' investments in a nascent industry?

The empirical context of my dissertation is the agricultural biotechnology industry. Agricultural biotechnology is the use of modern biotechnology techniques to improve or modify plants with a particular focus on enhancing agricultural traits such as herbicide tolerance, pest resistance, and resistance to environmental stresses. Regulatory requirements in this industry require that firms seek permits from the USDA to conduct experiments with their transgenic crops outside the conditions of the laboratory. A firm's application for these permits indicates that it has devoted resources to conduct technological experiments related to the agricultural biotechnology industry. This unique characteristic enables a systematic analysis of firms' activities prior to product commercialization, and thus makes this industry an ideal context to study firm's pre-commercialization efforts.

Below, I elaborate on each of the essays. The first essay of my dissertation examines the incubation stage of industry evolution. While the classic industry evolution literature has provided important insights about evolution of industries (Agarwal & Gort, 1996; Gort & Klepper, 1982), a primary assumption in these models is that firm entry into an industry is analogous to its first instance of product commercialization (Agarwal, Echambadi & Sarkar, 2002). Therefore, there has been less research attention devoted to studying the implications of firm activities that occur prior to product commercialization, or activities that do not result in product commercialization. To address this research gap, I focus on the technological investments that firms undertake prior to entry into an industry, and study the intertwined processes of firm-level economic value capture and industry-level ecosystem formation which underpin incubation of nascent industries.

Within the context of the agricultural biotechnology industry, I document critical patterns related to firms' technological investments. First, I show the investment life cycle for the agricultural biotechnology industry indicating that initial investments by firms in the technological opportunities related to this industry precedes product commercialization by 18 years. Second, I show that when firms' investments in a technology is considered, the magnitude of investment life cycle is much larger than what is typically observed in the classic industry evolution life cycle based on product commercialization patterns. Not only are there many more investing firms relative to commercializing firms, but also heterogeneity in the type of investing firms increases. In particular, 85.5 percent of investing firms did not commercialized any product in the nascent industry, and while the population of investing firms comprised of startup firms, agriculture incumbents, and diversifying entrant from related industries such chemical, product commercialization was disproportionately pursued by diversifying entrants. These important patterns highlight the contrasting inferences that may be made about evolution of industries based on investment patterns during incubation stage as opposed to solely post-commercialization patterns.

Furthermore, the substantial decline in the number and heterogeneity of commercializing firms relative to investing firms motivates a critical understudied aspect of incubation stage regarding the role and fate of the firms that do not engage in product commercialization. Do they represent failures? Or, do these firms nonetheless capture value in modes other than commercialization, and also help define subsequent industry evolution and formation of ecosystems? At the firm level of analysis, I show that firms may capture economic value from their investments as they license their technologies to third parties or as they get acquired. This heterogeneity in mode of value capture may indeed stem from the heterogeneity in firm capabilities. At the industry level of analysis, I show that as firms captured economic value through modes other than product commercialization, their capabilities were used and retained in the industry innovation ecosystem. In so doing, they contributed to the process of industry emergence via participation as support firms in the industry ecosystem.

The second essay focuses on the capability antecedents of a firm's entry into a nascent industry. In particular, it examines the pre-investment capabilities that impact the likelihood of a firm's market entry into a nascent industry. The existing literature highlights a firm's endowment of technical capabilities (Helfat & Raubitschek, 2000; Nerkar & Roberts, 2004) and complementary assets (Gans & Stern, 2003; Teece, 1986) as critical factors determining a firm's market entry into a nascent industry; however, these capability endowments are measured as the stock of a firm's capabilities before its product commercialization. An understudied question is how a firm's capability portfolio at the time of the initial technological investment in a nascent industry is related to its likelihood of entry. In order to address this question, I make a distinction between a firm's pre-investment and pre-entry capabilities – i.e., a firm's capability portfolio prior to its initial technological investment in the nascent industry and prior to its market entry, respectively.

Using the empirical context of agricultural biotechnology, the findings of this essay corroborate the well-established relationship that a firm's pre-entry stock of technical capabilities and complementary assets is related to the likelihood of entry into a nascent industry. However, it extends the existing literature by providing evidence that a firm's reconfiguration experiences prior to initial technological investment are the key pre-investment factors that are related to the likelihood of entry into a nascent industry. Prior reconfiguration experiences – i.e., a firm's experiences in modifying its capability portfolio prior to its investment in the focal industry – enable a firm's efforts in gaining access to the technical capabilities and complementary assets that have been suggested as crucial pre-entry capabilities. When the pre-investment reconfiguration experiences and the pre-entry stock of capabilities are considered jointly, a firm's pre-entry stock of technical capabilities and complementary assets is the dominant explaining factor of entry into a nascent industry; thus, it implies that pre-investment reconfiguration experiences affect the likelihood of entry via their influence on pre-entry technical capabilities and complementary assets. By explicitly theorizing a mediation model, I emphasize the endogeneity of capability development process and the role of deliberate reconfiguration efforts, rather than passive leveraging of existing resource endowments.

This essay contributes to the literature by providing novel insights about capability antecedents of a firm's entry into a nascent industry. I join the two literatures of industry evolution and firm evolution. In doing so, I draw attention to the endogenous sources of heterogeneity in pre-entry capabilities across firms. My hypotheses build on the literature regarding the role of a firm's pre-entry capabilities and extend it by accounting for the capability reconfiguration efforts that are undertaken by firms in anticipation of entry into a nascent industry. Rather than presuming firm's pre-entry capabilities as exogenous factors that are leveraged to the new industry context, I emphasize that pre-entry capabilities are indeed developed during incubation period.

In the third essay, I elaborate on the reconfiguration strategies that firms undertake in anticipation of entry into nascent industries. In particular, I focus on the extent to which incumbents of the obsolescing industry, de novo startups and diversifying firms differ in terms of the content, sequence and sources of capability reconfiguration strategies.

The propositions of this theory essay draw on the assumption that the objective of a firm's capability reconfiguration strategies is to narrow the capability gap that exists between its initial capabilities and the required configuration of technical capabilities and specialized complementary assets in a nascent industry. I suggest that capability reconfiguration efforts of firms take the two forms of capability extension and capability deepening (Karim & Mitchell, 2000). Due to the differential historical antecedents, incumbents of the obsolescing industry, de novo startups and diversifying firms differ in whether they pursue capability extension or capability deepening. Specifically, incumbents are more likely to engage in capability extension for achieving the required portfolio of technical capabilities, while startups and diversifying firms are more likely to engage in capability deepening for achieving the required portfolio of technical capabilities. For obtaining specialized complementary assets, incumbents are more likely to engage in capability deepening, while startups and diversifying firms are more likely to engage in capability extension.

In terms of the sequence of reconfiguration strategies, incumbents are likely to pursue extension of technical capabilities prior to deepening of specialized complementary assets. Diversifying entrants are likely to pursue deepening of technical capabilities concurrent with extension of specialized complementary assets. De novo entrants are likely to pursue deepening of technical capabilities prior to extension of specialized complementary assets. Similarly, these three types of firms differ in the extent to which they draw on internal versus external sources of capabilities.

This essay contributes to the strategic management literature by suggesting that although firms may be similar in the content of their capability reconfiguration strategies and their focus on achieving a similar configuration of capabilities, they are likely to pursue divergent processes in terms of the sequence of reconfiguration efforts and sources of capabilities. Specifically, while firms undertake different sequence of activities or draw on different sources of capabilities, they were all focused on attaining a similar configuration of technical capabilities and specialized complementary assets.

Together, the three essays shed light on an understudied phenomenon –incubation of an industry, with a focus on heterogeneity among firms, and their strategic reconfiguration efforts. Contrary to prior literature that has focused on stocks of endowments, my dissertation shows that firms actively engage in entrepreneurial reconfiguration of capabilities, and in doing so, impact the evolution of a nascent industry.

CHAPTER 2: ESSAY 1

MODES OF VALUE CAPTURE IN ECOSYSTEMS OF NASCENT INDUSTRIES: EVIDENCE FROM AGRICULTURAL BIOTECHNOLOGY[1]

The birth of new industries, due to entry of entrepreneurial firms and introduction of technology breakthroughs, has long been associated with creative destruction (Schumpeter, 1942). Industry evolution scholars typically study firm strategy and industry structure after commercialization of the first product[2] within the new industry (Agarwal, Sarkar & Echambadi, 2002; Gort & Klepper, 1982); hence, existing literature has provided important insights about the patterns of firm entry and exit in an industry (Gort & Klepper, 1982; Utterback & Suárez, 1993), the competitive dynamics between industry incumbents and new entrants (Henderson & Clark, 1990; Tripsas, 1997; Tushman & Anderson, 1986), and heterogeneity in firms' performance within new industries (Bayus & Agarwal, 2007; Helfat & Lieberman, 2002; Klepper & Simons, 2000) in the post-commercialization era. Left understudied, though, is the dynamics of evolution of firm and industry prior to the first instance of product commercialization.

Long before the first product is commercialized in the market, firms make investments in the technological opportunities related to a nascent industry. These firm-level investments in anticipation of creation of a new industry result in an industry-level *incubation* period, which we define as the period between the introduction of a discontinuous technological change and the first instance of product commercialization. This critical period

---

[1] This chapter is co-authored with Dr. Rajshree Agarwal.

[2] The use of the term 'product commercialization' in this essay also includes 'introduction of a new service' within the context of service industries.

may influence subsequent evolution of the nascent industry, but has largely been understudied. In particular, due to the focus on product commercialization as the focal point of a firm's entry to a nascent industry, most studies have abstracted away from analysis of a firm's technological investments prior to the instance of product commercialization as well as alternative modes of economic value capture within nascent industries.

The objective of this essay is to elaborate on the critical processes that underpin incubation of a nascent industry. We focus on the incubation period of the agricultural biotechnology industry and study the firm-level and industry-level consequences of technological investments that are undertaken by firms during this period. At the firm-level of analysis, we examine the alternative modes of value capture from investments in technological opportunities during the incubation period and link the heterogeneity in the type of investing firms to their mode of value capture. At the industry-level of analysis, we discuss the implications of firms' value capture through alternative modes for development of innovation ecosystems and the eventual incubation of a nascent industry. Analysis of firm-level and industry-level outcomes of firms' technological investments thus provides a holistic view of incubation of nascent industries.

We rely on rich data that look at the population of firms that were involved in research experiments related to agricultural biotechnology during 1980-2010. Agricultural biotechnology is the use of modern biotechnology techniques to improve or modify plants with a particular focus on enhancing agricultural traits such as herbicide tolerance, pest resistance, and resistance to environmental stresses. The agricultural biotechnology is an appropriate context to examine these questions for a number of reasons. Because of the regulatory requirements in this industry, firms are required to seek permits from the USDA to conduct experiments with their transgenic crops outside the conditions of the laboratory. This unique characteristic enables a systematic analysis of firms' activities prior to their product commercialization and during the incubation period.

The detailed analysis of incubation of agricultural biotechnology leads to identification of critical patterns regarding incubation of nascent industries. First, we document the duration and patterns of firm activity during incubation period of this industry. These findings show that the incubation period lasted for 18 years, and that technological investments occurred at a larger scale (6.8 times) compared to product commercialization. Second, at the firm level of analysis, we show that firms may capture economic value from their investments as they license their technologies to third parties or as they get acquired. This heterogeneity in mode of value capture may indeed stem from the heterogeneity in firm capabilities. Third, at the industry level of analysis, we show that as firms captured economic value through modes other than product commercialization, their capabilities were used and retained in the industry innovation ecosystem. Thus, they contributed to the process of industry emergence via participation in the industry ecosystem.

These findings provide novel insights to the research literatures in entrepreneurship, industry evolution and strategic management in a number of ways. First, to the industry evolution literature, we highlight the importance of the incubation period. Because the classic industry evolution marks the inception of a new industry as the time of first product commercialization within the nascent industry, firms' technological investments during the incubation period is systematically excluded from these studies, and this essay underscores the importance of firms' activities during the incubation period for a better understanding of factors underpinning subsequent evolution of industries. Second, by examining alternative modes of value capture, we reconcile literature in entrepreneurship that treats acquisitions as successful exits with literature in industry evolution that treats lack of product commercialization as failure, and show that even if an entrepreneurial firm may no longer exist, value creation may continue and value capture might have already occurred. Third, we contribute to innovation and entrepreneurship literature by elaborating on how nascent industries are created when firms capture economic value through modes other than product commercialization, and in turn contribute to the development of an innovation ecosystem.

This essay proceeds as follows. We begin with a brief review of the literature regarding evolution of new industries and propose a model for incubation of nascent industries. This review is followed by a detailed description of the industry context of this essay: agricultural biotechnology. In doing so, we discuss the implications of the advent of agricultural biotechnology for firm-level economic value capture and industry-level ecosystem development.

THEORETICAL FRAMEWORK

Literature Review: Evolution of Nascent Industries

An extensive body of research literature in evolutionary economics (Gort & Klepper, 1982; Nelson & Winter, 1982), organizational ecology (Hannan & Freeman, 1977) and technology management (Abernathy & Utterback, 1978; Tushman & Anderson, 1986) has focused on studying evolution of industries. Two focal aspects of the evolutionary trajectories of industries in these literature streams relate to the patterns of firm entry and exit and the demography of industry entrants (Agarwal & Tripsas, 2008). Models of industry life cycle typically examine patterns of firm entry and exit within an industry subsequent to the first instance of product commercialization (Agarwal, Sarkar & Echambadi, 2002). The generic industry life cycle model illustrates an early period of small number of firms, followed by a rapid increase in firms during the growth stage, a sharp exit during the shakeout stage and an eventual mature stage characterized by a stable number of firms with low levels of entry and exit (Gort & Klepper, 1982). Discontinuous transformations and technological shocks may render the industry obsolete, and the new industry born from such radical innovations follows similar patterns as well (Tushman & Anderson, 1986). These empirical regularities have been consistently documented across a variety of industry contexts.

The literature has also highlighted the heterogeneity in the demography of firms: de novo startups, diversifying firms from related industries and industry incumbents from the obsolescing industry vie for success after they enter the focal industry context (Helfat & Lieberman, 2002). The rates of entry and the relative advantage of these firms differ across industries and over time. In particular, there is variance across industries regarding what types of firms enter early and/or subsequently dominate the industry. For example, Internet-related industries in the mid-1990s (Goldfarb, Kirsch & Miller, 2007) or the personal computer industry (Bayus & Agarwal, 2007) primarily arose due to entry of de novo firms, whereas industries such as automobiles (Carroll, Bigelow, Siedel & Tsai, 1996) and television receivers (Klepper & Simons, 2000) represented early entry by diversifying firms. Still other industries, such as telecommunications (Chen, Williams & Agarwal, 2012), represented an even mix of de novo, diversifying, and incumbent firms.

Different explanations have been suggested for the observed patterns in the evolution of industries. While scholars of evolutionary economics focus on the information sources and the accumulated stock of knowledge as key factors determining firm entry into new industries (Gort & Klepper, 1982; Nelson & Winter, 1982), the focus of organizational ecology literature has been predominantly on the density of firms within an industry and its implications for forces of legitimization and resource scarcity (Carroll & Hannan, 1989; Hannan & Freeman, 1977). Moreover, technology management perspective attributes patterns of industry evolution to the underlying technological changes so that firm entry and exit are often influenced by the technology cycles (Abernathy & Utterback, 1978; Tushman & Anderson, 1986).

Although these streams of literature have provided important empirical and theoretical advances regarding the evolution of industries, a relatively unaddressed research area relates to the incubation period of an industry. A primary assumption in these models is that firm entry into an industry is analogous to its product commercialization. Accordingly, models of industry life cycle typically mark the inception of an industry as the first instance of product commercialization within that industry. Therefore, activities that occur prior to the first instance of product commercialization at the industry-level have been largely understudied. Although the existence of the incubation period has been documented in a handful of studies (Agarwal & Bayus, 2002; Golder, Shacham & Mitra, 2009), there has been less scholarly attention devoted to study heterogeneity in investing firms in a new technology and its implications for competitive dynamics of an evolving industry (Forbes & Kirsch, 2011). This is an important gap, since activities undertaken by firms prior to commercialization may have defining implications for subsequent evolution of the industry, and the relative advantage across heterogeneous firms.

Another implication of considering a firm's first instance of product commercialization as the point of firm entry into an industry is that these models typically do not account for the firm-level activities that occur prior to the first instance of product commercialization or firm-level activities that do not lead to product commercialization. Firms may initiate their technological investments in exploring the new industry and transforming entrepreneurial opportunities into commercially valuable products well before their market entry into an industry. These technological investments by entrepreneurial firms may result in product commercialization, in which case the commercial activities of these firms inform the functional models of industry evolution (Agarwal & Gort, 1996; Gort & Klepper, 1982). However, if the technological investments by these firms do not lead to product commercialization within the focal industry context, these firms are typically excluded from models of the classic industry evolution literature. Thus, the role and fate of these *excluded* firms are left unstudied. Do they merely represent failed experiments? Or, do these firms nonetheless capture value in modes other than commercialization, and also help define subsequent industry evolution and formation of ecosystems? Addressing these questions is important from both industry and firm perspectives.

Incubation of Nascent Industries: A Proposed Model

In studying the incubation of nascent industries, we abstract away from the key assumption in the industry evolution literature that a firm's point of entry into a nascent industry is the time of the first product commercialization, and instead focus on the firms' pre-commercialization technological investments in a nascent industry. Figure 1-1 illustrates the building blocks of a model that describes some of the processes underpinning the incubation of nascent industries. In our model, introduction of a technological change triggers firms to make technological investments that represent efforts in transforming technological opportunities in a nascent industry to a product with commercial value. The inception of the industry occurs when at least one firm's technological investment results in product commercialization.

[Figure 1-1 about here]

The investing firms are, however, heterogeneous in terms of their backgrounds. Conforming to the industry evolution literature, the three types of firms that may invest in a new industry are de novo firms, diversifying firms and industry incumbents of the prior industry regime. The firm-level heterogeneity across investing firms implies that firms may differ in terms of their capability endowments (Helfat & Lieberman, 2002; Klepper & Simons, 2000; Mitchell, 1989), incentives (Arrow, 1962; Henderson, 1993), and cognition of the technological landscape (Benner & Tripsas, 2012; Kaplan, 2008). Not only do these sources of heterogeneity indicate differences in the initial position of firms, but they also suggest different paths pursued by firms in anticipation of entry into a nascent industry. Thus, it is likely that different types of firms achieve different outcomes following their technological investment.

Given that introduction of a commercial product indicates a firm's entry into an industry as well as the inception of the new industry, one outcome of interest for investing firms is product commercialization. Firms that engage in commercialization constitute the core firms within an industry, and capture economic value from selling products. However, even though a firm's initial technological investment in a nascent industry may indicate that its managers perceive a strategic fit between a firm's characteristics and the requirements of the nascent industry, it is likely that they pursue modes of value capture other than product commercialization. These alternative modes include licensing of technologies or exiting through acquisition. In doing so, they too play a critical role in the incubation of nascent industries. Finally, firms may terminate technological investment prior to realization of any of the above modes of value capture, and thus may be considered *failures* because of their inability to capture any direct economic value.

We link heterogeneity in the types of investing firms to the firm-level consequences of technological investment by examining modes of economic value capture and the industry-level consequences of technological investment by examining development of ecosystems within an industry. Firm-level value capture occurs as firms engage in product commercialization, licensing of their technologies or exit through acquisition. Therefore, even though some firms may not commercialize a product, they may still capture economic value through these alternative modes. These modes of value capture have a one-to-one correspondence with a firm's role within the innovation ecosystem of an industry. Firms that engage in product commercialization are the core firms in the ecosystem, whereas firms that engage in alternative modes of value capture serve as support roles in the ecosystem providing complementary capabilities to the commercializing firms. Moreover, firms that terminate their technological investment may provide knowledge spillovers that are beneficial to other investing firms.

The two intertwined processes of economic value capture at the firm-level and ecosystem development at the industry-level underpin the incubation of a nascent industry. The heterogeneity in these outcomes is driven by the heterogeneity in the types of investing firms. Different investing firms may leverage heterogeneous bundles of capabilities to the new industry. As some of the investing firms configure the required capability portfolio for product commercialization, capabilities available in the ecosystem enable their technology sourcing. Thus, the capabilities provided by non-commercializing firms become crucial for product commercialization by other firms. Further, the prospect of value capture through alternative modes provides adequate incentives for firms to initiate technological investments. Drawing on this model, we next discuss the incubation of agricultural biotechnology industry.

INDUSTRY CONTEXT: AGRICULTURAL BIOTECHNOLOGY

Agricultural biotechnology is the use of modern biotechnology techniques such as molecular biology to improve or modify the characteristics of plants and achieve enhanced agricultural traits such as herbicide tolerance, pest resistance, and resistance to environmental stresses[3]. The revenue potential of genetic modification in the agriculture industry arises due to increased agricultural productivity and reduction in farming costs. Thus, famers are willing to pay a price premium for a transgenic seed with a potential to reduce their costs and enhance agricultural productivity. For instance, farmers may apply less pesticide on a pest-resistant transgenic crop because the external protein that has been genetically embedded within the crop is itself harmful to pests and may replicate the function of pesticides.

[3] The science of plant biotechnology, i.e., genetic modification of plants, has applications broader than enhanced agricultural productivity traits. Genetic modification of plants may be of interest to the food industry (foods with enhanced nutritional characteristics or better flavor or appearance), to the pharmaceutical industry (plant-based drugs), to the energy industry (crops for bio-based fuel production) and to the bioremediation industry. Although all of these applications rely on the general science of plant biotechnology, the commercial industry with which they are associated are distinct from each other. This essay only focuses on the implications of plant biotechnology sciences for crop production and agricultural productivity.

Incubation and Evolution of Agricultural Biotechnology

The agricultural biotechnology industry builds on the applications of technological advancements in modern biotechnology for plant sciences. The first viability of genetic modification of plants was shown in 1977 when a research group at the University of Ghent in Belgium identified a gene transfer technique using Agrobacterium tumefaciens. This was followed by another major technological event in 1983 when three independent research groups, from Washington University in St. Louis, University of Ghent, and Monsanto, respectively, presented their research findings on the first transgenic plants – i.e., antibiotic resistant tobacco and petunias. In the aftermath of these technological achievements, firms with diverse capabilities made technological investments in the new technology and experimented with transforming this technological opportunity to a product with commercial value. The incubation period continued through 1995, at which time the first commercial product in the agricultural biotechnology – herbicide-tolerant cotton – was introduced, followed by introduction of herbicide-tolerant soybeans and pest-resistant cotton. Table 1-1 provides a timeline of notable events during the incubation stage and further evolution of the agricultural biotechnology industry.

[Table 1-1 about here]

The fact that it took 18 years since the technological breakthrough in 1977 until the first instance of product commercialization and inception of this industry in 1995 highlights that new industries are not automatically created based on a single technological event. Rather, entrepreneurial actions of firms and individuals are required for a technology with a potential economic value to be transformed into an innovative output and create a nascent industry. Further empirical evidence is consistent with this observation. Across 30 new industries studied by Agarwal and Bayus (2002), the incubation period lasted on average about 28 years.[4] In addition, Golder, Shacham and Mitra (2009) have documented the average duration of the incubation period across 29 radical innovations as 26 years.[5] Similar accounts of incubation of new industries have been recorded for the VCR industry (Rosenbloom & Cusumano, 1987), cochlear implants industry (Garud & Rappa, 1994) and wireless communication industry (Levinthal, 1998). Even for a fully developed product, accounts of 32 consumer durable product markets indicate an average time period of eight years before the product is commercialized on the market (Kohli, Lehmann & Pae, 1999). Overall, these trends suggest the importance of close examination of firm activities during the incubation period.

Shifting Landscape in the Conventional Agriculture Industry

The advent of the agricultural biotechnology was a major technological shock to the conventional agriculture industry. Historically, conventional agriculture firms used plant breeding techniques, including hybridization, to develop elite varieties of crops. Conventional plant breeders select superior varieties based on characteristics such as faster growth, higher yields, better taste, improved pest and disease resistance, and better fit to the agro-climatic condition of each geographic region. The selected varieties are then cross-bred to create new and improved varieties of crops. This process is repeated over years to obtain a good line of crop. Conventional agriculture firms derived economic value from selling these

---

[4] This information is calculated by the authors based on Table 2 of Agarwal & Bayus (2002). We consider the incubation period as the time period between the first invention year until the first commercialization year.

[5] The authors calculated this information based on Table 6 of the Golder et al. (2009), and consider the incubation period as the time period between the first concept year until the micro-commercialization year.

elite varieties of crops to farmers. However, introduction of modern biotechnology techniques transformed the underlying capabilities for operation in the crop production industry extensively. The major change was that agricultural biotechnology enabled achieving improved varieties that were not possible through breeding of the same or very closely related varieties. For instance, new external genes from other organisms may be inserted into a plant. Alternately, plants may be modified by removing or switching off their existing genes. Further, modern biotechnology techniques such as marker-assisted breeding have made major changes in conventional plant breeding by accelerating the selection process.

From the farmers' perspectives, the introduction of transgenic crop varieties in addition to conventional varieties has changed the face of the U.S. agriculture industry. In 2011, 69 million hectares of transgenic crops were planted in the United States. The USDA estimates the adoption rate for major transgenic crops in the United States as 91 percent for soybean, 88 percent for cotton, 85 percent for corn, 95 percent for sugar beet, and 85 percent for canola (James, 2011). Figure 1-2 shows the percentage of land cultivated by transgenic crops in the United States in each year, which conforms to the sales take-off patterns depicted in industry evolution studies (Agarwal & Bayus, 2002).

[Figure 1-2 about here]

For the incumbent agriculture firms, technological advancement in agricultural biotechnology was considered a major technological change. Their familiarity with plant breeding capabilities was no longer the key capability for operation in the industry. Nonetheless, the stock of accumulated knowledge and intellectual property embodied in the conventional varieties (i.e., germplasm) offered by conventional agriculture firms retained value as complementary assets to genetic modification moving forward. Hence, not only was the conventional crop varieties displaced by the transgenic varieties at the product market level, but also conventional agriculture firms' model of business operation was displaced with the model according to the requirements of biotechnology regime.

Entrepreneurial Entry into Agricultural Biotechnology

The technological opportunities related to agricultural biotechnology invited firms from diverse backgrounds to invest in the new technology and explore ways to transform the technological opportunity to commercial value. Figure 1-3 shows the *technological investment* and *product commercialization* patterns related to agricultural biotechnology. The gray bars show the number of firms that are involved in technological investments related to agricultural biotechnology at each year; and the black bars show the number of firms that commercialized a product within the agricultural biotechnology industry.

[Figure 1-3 about here]

In our research design, firms are assumed to be involved in technological investment in agricultural biotechnology if they applied for permits to conduct experiments with their transgenic crops outside the conditions of laboratory. Firms are required to seek release permits from APHIS (Animal and Plant Health Inspection Services) within the USDA for these experiments (§7 CFR 340), based on which a comprehensive list of investing firms in agricultural biotechnology can be compiled. A firm's application for these permits indicates that it has devoted resources to conduct technological experiments related to the agricultural biotechnology industry. In order to analyze firms' technological investments in agricultural biotechnology, we focus on private firms' experiments in product categories corresponding to SIC industry groups of 011 and 013 within the major group of agricultural production crops, which include corn, cotton, potatoes, soybeans, squash, sugar beets, canola, and alfalfa. Although application for a release permit indicates a firm's involvements in experiments with transgenic crops and provides a consistent proxy to create the sample of investing firms, the actual investment in agricultural biotechnology may have started before the application date for a release permit. Using firm's SEC filings, annual reports and LexisNexis press releases, we identify the first mention of a firm's involvement in agricultural biotechnology in the form of establishing a new research division, engaging in research and development alliances, or acquiring relevant businesses. The final list of investing firms includes 69 firms that were involved in experimental field trials in the U.S. agricultural biotechnology during 1980-2010.

In order to compile the list of commercialized agricultural biotechnology traits, we track all the genetic transformation events that have been cleared for commercial release based on the federal government regulatory requirements (§7 CFR 340) overseen by USDA and EPA. Approval of a petition for non-regulated status indicates that a particular genetic transformation could be legally commercialized in the United States. We further confirm the instance of commercialization using the firm's SEC filings, annual reports, company websites and LexisNexis. The commercialization data show that 14 firms have been involved in selling agricultural biotechnology traits to farmers or in licensing these traits to seed distributors. Ten of these firms have commercialized products based on their own technological investments in the agricultural biotechnology, and four firms have commercialized products due to acquisition of another firm with an already commercialized product.

Comparison of technological investment and product commercialization patterns in Figure 1-3 shows that both charts seem to conform to the classic depiction of firm entry and exit over the industry life cycle (Gort & Klepper, 1982; Utterback & Suárez, 1993); however, the magnitude of the two charts show that more firms entered the industry as measured by technological investments in agricultural biotechnology, rather than as measured by commercialization of agricultural biotechnology traits. Indeed, only 14.5 percent of investing firms eventually commercialized a product. Such a substantial difference in the number of firms that made technological investments versus commercialized products forms an empirical puzzle regarding the fate of 85.5 percent of firms that invested resources toward the technology, but had no product commercialization. Does lack of product commercialization indicate that these firms were unable to capture economic value from their investments, and that they should be deemed failures? Or, did they capture value, and continue to be active even though they did not commercialize a product? What were the consequences of their lack of product commercialization for the industry incubation?

Although current literature has reported the survival rate of industry entrants after their product commercialization (Bayus & Agarwal, 2007; Carroll et al., 1996; Klepper & Simons, 2000; Mitchell, 1991), there has been less focus on the market entry rate of investing firms – an exception is the study of automobile industry by Carroll & Hannan (2000) in which 11% of pre-producers have commercialized their products. This is despite the budding research interest in studying the pre-production activity of firms (Carroll & Hannan, 2000; Carroll & Khessina, 2005; Jovanovic, 2004; Lomi, Larsen & Wezel, 2010) or their technological entry – as opposed to market entry – to a field (Malerba & Orsenigo, 1999).

Heterogeneity in Investing Firms Types

Another observation regarding the incubation period is the heterogeneity in the type of investing firms compared to commercializing firms. The three types of firms that conducted investment in agricultural biotechnology included de novo startups, incumbent agriculture firms, and diversifying firms from related industries, particularly chemical. In our data coding, firms are considered *de novo entrants* or startups if the firm was not in existence prior to its first investment in the agricultural biotechnology industry; agriculture *incumbents* if the firm was previously engaged in conventional agriculture businesses that used plant breeding and hybridization with the standard industry classification (SIC) code 01; and *diversifying entrants* if the firm had prior experience in related pharmaceutical (SIC 283) or agricultural chemical (SIC 287) industries.

Among 69 investing firms, 18 firms (26 percent) are agricultural biotechnology startup, 33 firms (48 percent) are conventional agriculture incumbents, and 18 firms (26 percent) are diversifying entrants from the chemical industry. The importance of the heterogeneity in the type of investing firms becomes salient when we look at the same distribution for firms with a commercialized product. Among 10 firms with a commercialized product, 1 firm (10 percent) is agricultural biotechnology startup, 2 firms (20 percent) are conventional agriculture incumbents, and 7 firms (70 percent) are diversifying entrants. Not only is the investing firms population much larger in number, but also investing firms are more diverse in terms of their background.

The type of firms that comprise a nascent industry and the conditions under which a particular type of firm tend to arise are important understudied questions for understanding incubation of nascent industries (Forbes & Kirsch, 2011). Inferences about the composition of firms in an industry are typically made using the population of firms with commercialized products within that industry. Records of product commercialization suggest that the agricultural biotechnology industry is predominantly composed of diversifying entrants with chemical background. Analysis of firms' technological investments, though, provides a different picture. While diversifying entrants comprise 70 percent of commercializing firms, they are only 26 percent of investing firms. More importantly, all three types of firms are engaged in technological investments in roughly equal numbers. Thus, the composition of this industry based on product commercialization may seem more homogenous relative to the composition of industry based on technology investments.

This is a particularly important issue when viewed in the light of modes of value capture within a nascent industry. If there are systematic differences between firms that may lead to product commercialization by only one firm type, it is imperative to understand those. Therefore, focusing on investing firms as opposed to solely commercializing firms would address an understudied research issue as it relates to firm-level economic value capture and industry-level ecosystem development. The next two sections examine the systematic differences across the three types of investing firms in a nascent industry – i.e., de novo entrants, diversifying entrants and prior technology regime incumbents – in terms of mode of economic value capture and the consequences for incubation of industries.

HETEROGENEITY OF FIRMS AND MODE OF VALUE CAPTURE

In this section, we elaborate on the firm-level consequences of technological investments in a nascent industry. Although product commercialization has been emphasized as the chief mode of economic value capture within the industry evolution literature, a parallel literature in technology entrepreneurship has identified alternative modes of value capture such as participation in the market for technology (Arora, Fosfuri & Gambardella, 2001; Gans & Stern, 2003). Investing firms may possess technologies or capabilities that are of interest to other firms. Even if a firm does not commercialize a product and does not capture economic value through direct sales of products to customers, its capabilities may be a source of economic value in two ways: the first mode is technology licensing so that another firm gets access to the intellectual property rights associated with a technology in exchange for an agreed form of payment. The second mode operates through acquisitions of firms so that the acquiring firms get access to a firm's intellectual properties and benefit from its capabilities.

Alternative Modes of Value Capture

We explore the extent to which firms engage in alternative modes of value capture by tracking their histories through various sources. Investing firms are considered to capture value through *acquisition* if their whole firm or their agricultural biotechnology unit is acquired by a third party, and it is indicated in the acquisition deal that the agricultural biotechnology capabilities of a acquired firm was of the acquiring firm's interest. Investing firms are considered to capture value through a *licensing agreement* if they have formed a non-equity or equity-based alliance for exchange or licensing of their agricultural biotechnology intellectual property or knowledge. Investing firms are considered to have *terminated investment* if they experienced bankruptcy or ceased all their agricultural biotechnology activity prior to any form of the above-mentioned value capture.

Among 69 investing firms, 10 firms (14.5 percent) have commercialized a product, 22 firms (32 percent) were acquired, 6 firms (8.7 percent) were involved in technology licensing as their primary mode of value capture, 17 firms (24.5 percent) terminated their investments in agricultural biotechnology, and 14 firms (20.3 percent) are active investing firms as in 2011. Since technology licensing is not mutually exclusive from the other modes of value capture, we make a distinction between firms whose primary mode of value capture was technology licensing (six firms as mentioned above), those with technology licensing in parallel to product commercialization, and those with technology licensing prior to being acquired. These results suggest that a success rate of 14.5 percent based on commercialization outcomes becomes a 55.2 percent success rate given alternative modes of value capture.

In order to address the question regarding the potential systematic differences across firms that engaged in different modes of value capture, we link firm types to their mode of value capture. Table 1-2 shows the summary statistics of heterogeneity in mode of value capture based on firm type. Summary statistics in table 1-2 show that diversifying firms are present in larger numbers among firms that have commercialized a product. Moreover, startups and incumbents are present in larger numbers among acquired firms. Startups are also active in technology licensing.

[Table 1-2 about here]

In order to further explore the relationship between heterogeneity in firm type and mode of value capture, we use a competing risk event history model (Fine & Gray, 1999) to estimate the sub-hazard ratio that a firm engages in different modes of value capture such as product commercialization and getting acquired. We use the competing risk estimation technique because it accounts for the possibility of termination of a firm’s investment in agricultural biotechnology and for right censorship in the data. Due to the small number of firms with technology licensing as their primary mode of value capture, we do not include technology licensing as a competing event in the estimation model. Moreover, technology licensing does not eliminate a firm from the risk set of experiencing other modes of value capture and thus it is incompatible with the econometric assumptions of a competing risk event history model. Table 1-3 shows the empirical results. Model 1 shows that hazard of product commercialization for diversifying entrants is greater relative to startups, whereas the hazard of product commercialization for agriculture incumbents is not statistically different from startups and diversifying entrants. Model 2 shows that the hazard of getting acquired for both startups and agriculture incumbents is greater relative to diversifying entrants; however, the hazard of getting acquired for startups is not statistically different from agriculture incumbents. Model 3 shows that the hazard of ceasing investment is greater for diversifying entrants relative to both startups and agriculture incumbents; however, the hazard of investment termination is not statistically different between startups and agriculture incumbents.

[Table 1-3 about here]

The models in Table 1-3 also account for alternative mechanisms suggested in the industry ecology and early mover (dis)advantage literatures. The density of firms at each year may influence firm performance in a nascent industry (Carroll & Hannan, 1989) because density of firms may shape forces related to industry legitimization from both supply and demand sides. Alternatively, it may influence the level of competition over industry resources. Table 1-3 includes the linear and quadratic terms for the number of investing firms at the year of the focal firm's investment in agricultural biotechnology. Empirical results show that they do not have a statistically significant relationship with sub-hazard ratio of any of the events. With regard to the timing of entry (Lieberman & Montgomery, 1988), we include the year of investment in the model. Earlier investment in agricultural biotechnology increases the hazard of getting acquired for the firm. Accordingly, the relation between firm type and mode of value capture is above and beyond the explanations of early mover advantage and organizational ecology.

These empirical findings show how heterogeneity in mode of value capture is related to firm type. Specifically, diversifying firms are more likely to commercialize products, while conventional agriculture firms and startups are more likely to get acquired.

Diversifying Entrants and Product Commercialization

Product commercialization within a new industry is the dominant mode of economic value capture according to the industry evolution literature. The empirical results show that diversifying entrants are more likely to commercialize a product within the context of agricultural biotechnology. Within the context of agricultural biotechnology, diversifying firms mainly entered from related industries such as chemical industry. While they lacked plant breeding capabilities prior to their investments, many of them were engaged in production of agriculture-related products such as pesticides and herbicides. Additionally, key motivating factors led to their investment in agricultural biotechnology as a potential high value-added business, given some demand and supply related disruptions in their focal industry. Chemical companies, for instance, experienced a substantial increase in prices of oil, an important input for their operations, following the first and second oil shock in 1973 and 1979. Also, chemistry knowledge had been stagnant since the 1960s and thus chemical firms were looking for a valuable diversification strategy (Chandler, 2005; Lieberman, 1990). Finally, chemical companies had related capabilities in plant sciences due to their involvement in agricultural chemical production. These general plant sciences capability and agricultural chemical production imply that managers benefited from the right information corridor to recognize the opportunities related to agricultural biotechnology.

Although a thorough examination of the factors that lead to product commercialization is beyond the scope of this essay, a preliminary comparison across the three types of investing firms suggest that diversifying firms' capability portfolios enabled their product commercialization. Each type of firm had capabilities that were relevant to agricultural biotechnology, and thus created value. However, the different types of firms also represent different bundles of capabilities within the firm boundary, and thus have implications for the type of value that they could capture. Incumbent firm advantage is typically related to the complementary assets that may continue to retain value (Mitchell, 1989; Rothaermel, 2001; Tripsas, 1997), since the discontinuous technology often renders their core technological capabilities obsolete. To the extent that these firms face organizational inertia (Hannan & Freeman, 1984; Tripsas & Gavetti, 2000) and lack transformational experience (King & Tucci, 2002), they have a limited ability to reconfigure the capabilities required for product commercialization, and thus are less likely to commercialize a product. Startups have core technical capabilities that are relevant to the nascent industry, but lack the necessary complementary assets. Moreover, product commercialization in nascent industries typically requires significant investments in reconfiguration of firm capabilities, and startups have neither the scale nor the experience necessary to undertake this task. Thus, similar to incumbents, these firms are less likely to commercialize a product.

On the other hand, diversifying firms are more likely to be a composite bundle of related technological capabilities, complementary assets and reconfiguration experience. For instance, diversifying firms in the context of agricultural biotechnology came from pharmaceutical and chemical industries, and thus they could draw on the related technological capabilities and R&D expertise. Most important, they benefitted from prior reconfiguration experiences because most of the diversifying firms were in multiple industry value chains, and had past experiences in both alliance and acquisition management. Since all three of these capabilities are important components for entry into a nascent industry, it is likely that they engage in product commercialization.

De Novo Entrants in the Market for Technology

De novo startups are created for the context of the new industry; therefore, their technical capabilities are presumably a better fit for the requirements of the nascent industry (Agarwal, Echambadi, Franco & Sarkar, 2004; Khessina & Carroll, 2008; Klepper & Sleeper, 2005). Although technical capabilities of de novo firms are critical for developing new products, they typically lack complementary assets. Scholars have noted that when complementary assets are important, technology startups may be more advantaged in the market for technology, rather than the market for products (Gans & Stern, 2003; Teece, 1986). Accordingly, participation in the market for technology in either form of technology licensing or technological acquisition is the most common outcome for startups. While the industry evolution literature views lack of product commercialization as failure, entrepreneurship scholars consider acquisition as an important mode of value capture for successful startups (Arora & Nandkumar, 2011; Lowe & Ziedonis, 2006) and a desirable outcome for venture capital firms (Gompers, 1995). Indeed, among exit strategies of startup firms, acquisitions often surpass initial public offerings strategy (Arikan, 2003; Brau, Francis & Kohers, 2003).

In the context of agricultural biotechnology, startup firms largely had technical capabilities in the area of plant biotechnology, and many of them were university research spinoffs. For example, Mycogen – a startup formed in 1982 by a biochemist from Stanford University – discovered several toxins that can be encapsulated in transgenic plants and make them resistant to pests. Another example is Mendel Biotechnology – a startup formed in 1997 – which discovered genetic traits to enhance drought tolerance of soybeans and corn. These technical capabilities under control of startup firms were critical components of the new product development process. Therefore, startup firms with access to these technical capabilities were likely to be acquired. In particular, Arora and Nandkumar (2011) suggested that if the acquisition deal value exceeds that of all rounds of venture capital investment in a startup firm, the acquisition could be categorized as a successful mode of value capture. Among seven de novo startups that were acquired in the context of agricultural biotechnology, five startups received venture capital investments. The dollar value of some acquisitions are undisclosed. But, for the remaining firms, the dollar value of acquisitions exceeded venture capital investment in all but one case. As an illustration, Athenix Corporation was acquired by Bayer CropScience in a deal that exceeded its venture capital investment by eight times. Table 1-4 provides additional details.

[Table 1-4 about here]

Value Capture by Incumbents through Leveraging Complementary Assets

Existing research shows that industry incumbents, owners of complementary assets, may capture some of the economic benefits of a technology breakthrough despite their lack of technical capabilities if they could imitate an innovative product due to weak intellectual property regimes (Gans & Stern, 2003; Teece, 1986), if isolating mechanism related to complementary assets provide incumbents with the time and resource luxury to adjust to the new technology regime at a later time (Tripsas, 1997), or if they are able to integrate into technology development and collaboration with owners of technical capabilities (Rothaermel, 2001). Under these conditions, an industry incumbent typically survives the consequences of a technological change and continues to operate as a firm in the new industry regime.

Drawing on the insights from agricultural biotechnology, we underscore another mechanism through which complementary assets of industry incumbents may prove beneficial at the face of a technological change. When complementary assets preserve their value within the new technology regime, new entrants to an industry face limitations in in-house development of complementary assets, and if industry incumbents cannot gain access to the technical capabilities of the new industry regime, it is likely that incumbent firms get acquired. In other words, instead of industry incumbents bringing the technological capabilities of new entrants in-house, they were entrants that could internalize the complementary assets of industry incumbents. Accordingly, rather than facing failure through dissolution, the assets embodied in the incumbents could be leveraged by other firms through post-acquisition integration (Fortune & Mitchell, 2012). This situation may resemble the phenomenon of creative destruction (Schumpeter, 1942), where industry incumbents are replaced by new entrants; however, the fundamental difference between this context and the generic depiction of creative destruction is that the firm-level displacement of incumbents by new entrants is accompanied by economic value capture by industry incumbents and retention of their capabilities within the ecosystem of the nascent industry. This is the phenomenon that occurred within the context of agricultural biotechnology.

In the context of agricultural biotechnology, complementary assets of conventional agriculture incumbents enabled lucrative exit of firms through being acquired. In the aftermath of the agricultural biotechnology breakthrough, the necessary knowledge to perform genetic modification was in the realm of biotechnology and proved inaccessible to conventional plant breeders. Nonetheless, elite varieties of crops that were developed under the conventional agriculture regime were still required as a platform for genetic modification and thus served as critical complementary assets. Importantly, it was infeasible for new entrants to pursue in-house development of these complementary assets due to time compression diseconomies (Dierickx & Cool, 1989) and intellectual property protection provided by the Plant Protection Varieties Act. Hence, even though conventional agriculture firms did not commercialize a product in the new industry regime, their stocks of complementary assets enabled them to capture economic value from their investments in agricultural biotechnology. These complementary assets were indeed so valuable and limited in supply that acquiring firms engaged in preemptive activities to lock-out their competitors from gaining access to them. These preemptive behaviors and excessive bargaining raised the dollar value of acquisitions, increasing the extent to which industry incumbents could reap economic benefits within the new industry regime.

For instance, Holden’s Foundation Seeds, a corn breeder that initiated its investments in the agricultural biotechnology in 1991, was acquired in 1997 for 1.02 billion dollars. The motive of the acquisition was gaining access to the elite varieties of corn under control of Holden's Foundation Seeds. Due to being private firms, financial accounts of conventional agriculture firms' productivity are not available to compare the pre- and post-acquisition value of these companies. However, several historical accounts of these acquisitions indicate that acquisition deal dollar values were more than what would have been expected prior to agricultural biotechnology and thus could be considered lucrative value capture outcome. In the case of Holden's acquisition, it was considered "a big seed deal whose price raises eyebrows" (New York Times, 1997) or "a substantial but justifiable premium to reflect the strategic importance of the deal" (Financial Times, 1997).

DEVELOPMENT OF INNOVATION ECOSYSTEMS

In this section, we elaborate on the industry-level consequences of firm technological investments in a nascent industry and the extent to which these activities contribute to industry incubation. Although the classic model of industry evolution maintains that producer firms with a commercialized product comprise an industry, accounts of incubation of nascent industries indicate that many more firms are involved in technological investment within a nascent industry. Given that many investing firms do not commercialize a product and are not considered core firms within the industry, it is essential to understand their potential role.

Existing literature holds that there may be positive ramifications associated with failure and exit of firms from the industry landscape. The excess entry that precedes firm failure in an industry may influence the strategic choices of investing firms so that they engage in more innovation and enhance their capabilities. Thus, the population of commercializing firms in an industry becomes a stronger population after exit of other firms (Knott & Posen, 2005). In addition, the technical expertise and resources of firms that exit the industry may benefit other firms in the form of knowledge spillovers (Hoetker & Agarwal, 2007). Although these mechanisms may play an important role in reducing the negative consequences of firm failure for the population of surviving firm and in turn advance incubation of a nascent industry, these are unintentional outcomes of firm failure and the economic benefits are reaped by the surviving firms. We suggest that the positive implications of firms' technological investments despite lack of product commercialization extend beyond the unintentional knowledge spillovers (Hoetker & Agarwal, 2007) or competition effects (Knott & Posen, 2005). Rather, firms may contribute directly to the incubation of an industry by deliberate participation in the innovation ecosystem.

Accounts of nascent industries and technologies underscore the need for firms to embed themselves within an innovation ecosystem, often marshaling resources and capabilities from the existing institutional infrastructure (Adner, 2006; Adner & Kapoor, 2010; Hargadon & Douglas, 2001). For example, successful commercialization of electric lighting required Edison to undertake significant investments and efforts to embed the incandescent bulb in an ecosystem that included suppliers, complementors, investors and lead users, while simultaneously ironing out critical technological issues surrounding the feasibility of electric lighting (Hargadon & Douglas, 2001). Similarly, product commercialization within the context of agricultural biotechnology required gaining access to critical sources of technical capabilities and complementary assets that reside in the innovation ecosystem.

We suggest that the flipside of firm-level economic value capture by firms is their contribution to incubation of a nascent industry in the form of support roles in innovation ecosystems. When participating in the market for technology, a firm provides its technology and capabilities to a third party that serves as a conduit for bringing the technology into the product market (Gans & Stern, 2003). Alternatively, acquired firms in technological acquisition provide necessary technical capabilities (Ahuja & Katila, 2001; Chadhuri & Tabrizi, 1999) and human capital (Paruchuri, Nerkar & Hambrick, 2006; Puranam & Srikanth, 2007) to their acquiring firms. Moreover, acquisitions of complementary assets may enable post-acquisition redeployment of key assets in a way that facilitates product commercialization (Karim & Mitchell, 2004).

Within the context of agricultural biotechnology, the primary mode of value capture for 40.7 percent of investing firms was technology licensing or acquisitions. As these investing firms captured economic value through different modes, they also participated in formation of an innovation ecosystem of an industry. Although diversifying firms are considered the focal entrant to the agricultural biotechnology industry, startups and conventional agriculture firms also contributed critical resources and capabilities to the emerging industry. Product commercialization by diversifying firms occurs as a result of firms' internal capability development as well as integration of complementary assets of industry incumbents and technological capabilities of startup firms. In other words, product commercialization by these firms is enabled through development of an innovation ecosystem. Not only does this innovation ecosystem development enable product commercialization, but it also provides the opportunity for economic value capture for startups and conventional agriculture incumbents. Indeed, internal capability development of diversifying entrants may not have been as effective without their external capability sourcing efforts.

Taken together, even if technological investments of firms do not lead to product commercialization, the alternative modes through which they capture economic value imply that they directly contribute to the incubation of an industry through participation in the innovation ecosystem.

DISCUSSION AND CONCLUSIONS

This essay examines the incubation stage of an industry life cycle, which is an important but overlooked phenomenon in the strategic management and industry evolution literature. Accounting for firms' investments in a new technology prior to their product commercialization enables us to examine important aspects of incubation of a nascent industry including heterogeneity in firm type, heterogeneity in mode of value capture and development of innovation ecosystem. Below, we summarize some of the noteworthy contributions.

To the industry evolution literature, we present firms' investment life cycle for the agricultural biotechnology industry. In doing so, we document an industry-level incubation stage that lasted for 18 years. Despite the prevalence of incubation stage across various industries, strategic management scholars have largely abstracted away from studying this timeline. Another important observation regarding the investment life cycle is its similarity to the commercialization life cycle in terms of patterns and slope despite the difference in the scales of the two charts. Nonetheless, this study is a single-industry analysis; thus, results should be generalized with caution. Although this essay is a primary attempt in reporting some trends, it helps in identifying some important future research questions. Future research embarking on multiple-industry data may identify additional stylized facts and evolutionary patterns related to incubation stage at the industry-level of analysis.

We also show the heterogeneity in the type of investing firms in a nascent industry. All three types of firms, namely, startups, diversifying firms, and conventional agriculture incumbents, are present in relatively equal numbers as investing firms. However, diversifying entrants are dominant in product commercialization. Thus, contrasting inferences about demography/composition of firms in an industry may be made based on investment patterns as opposed to commercialization patterns. This empirical finding underscores the future research opportunities that reside in analysis of firm's investment patterns.

Moreover, we discuss different modes of value capture by heterogeneous investing firms. Commercialization of a product and survival despite technological change has been portrayed as the desired outcome for firms. This essay documents that product commercialization is not the only mode of value capture for investing firms. Some of the investing firms captured value when licensing their technologies or exit through acquisition. The firm-level value capture is indeed accompanied by contribution to the development of innovation ecosystems, and thus indicates that firm-level survival may not necessarily be the sole desirable outcome for firms at the face of a technological change.

We further study how the heterogeneity in firm type − incumbent, startup, or diversifying firms − influence the mode of value capture. We find that diversifying entrants are more likely to engage in product commercialization in the context of agricultural biotechnology, whereas technology licensing and exit through acquisition are the dominant modes of value capture for startups and incumbents. With regard to diversifying firm, our results underscore the importance of strategic renewal and corporate entrepreneurship of established firms for creation of new industries (Agarwal & Helfat, 2009). Although startups do play a critical role in providing some technological capabilities in the overall ecosystem of firms, the main innovative activity takes place within diversifying entrants; therefore, analysis of the entrepreneurial actions of established firm and their strategic renewal efforts may provide valuable insights about incubation of nascent industries.

With regard to startups' mode of value capture, the entrepreneurship field has identified both acquisitions and alliances as important strategic levers for entrepreneurial firms. This is despite the presumption in the industry evolution literature that considers lack of product commercialization as failure. We show that even if an entrepreneurial firm may no longer exist, value creation may continue and value capture might have already occurred. From the perspective of an investing firm, it is important to consider the prospects of economic value capture from a new technology. Similarly, firms may use market for technology as a comparable alternative to product commercialization (Gans & Stern, 2003).

This essay also contributes to the literature about role of complementary assets during times of technological change. Existing literature notes that owners of complementary assets may survive the gales of creative destruction and retain their market share in the new technology regime in spite of their technologically inferior products (Rothaermel, 2001; Tripsas, 1997). We show that valuable complementary assets may lead to acquisitions of owners of complementary assets. Incumbent firms, owning key complementary assets, do not survive as a firm, but they are acquired. Their displacement by new entrants is indeed accompanied by their firm-level value capture as well as redeployment of their key assets within the ecosystem of the nascent industry.

Another contribution is to the literature stream of the fate of firm's capabilities in a system. This is in line with prior literature that highlights how capabilities of out of business firms continue to exist in the industry (Fortune & Mitchell, 2012; Hoetker & Agarwal, 2007).

An important empirical observation with regard to agricultural biotechnology industry is that 14.5 percent of investing firms eventually commercialized a product. When accounting for firms that join an innovation ecosystem, a survival rate of 14.5 percent which is observed in the chart comparing investing firms and firms that have commercialized a product, will actually turn out to be a 55.2 percent survival rate in terms of the number of firms. The implication is that even though the original owner of those capabilities no longer exists at the firm level or could not commercialize a product, the capabilities continue to live and be used by others. Therefore, by focusing on value capture of all types and not limited to product commercialization, we show how resources and capabilities of firms may remain in the industry ecosystem and in turn contribute to the incubation of an industry.

The first essay of my dissertation underscores the importance of studying firm's investments in a nascent industry prior to product commercialization. Analyses of firm's technological investments enabled us to provide evidence of heterogeneity in firm types and modes of value capture during the incubation stage of industry life cycle. The implications of these findings might have been very different if the sole focus of analysis had been on firms' product commercialization. This essay, thus, identifies a prominent avenue for future research that accounts for firms' pre-commercialization investment in a nascent industry.

Figure 1-1: Overview of the Proposed Model

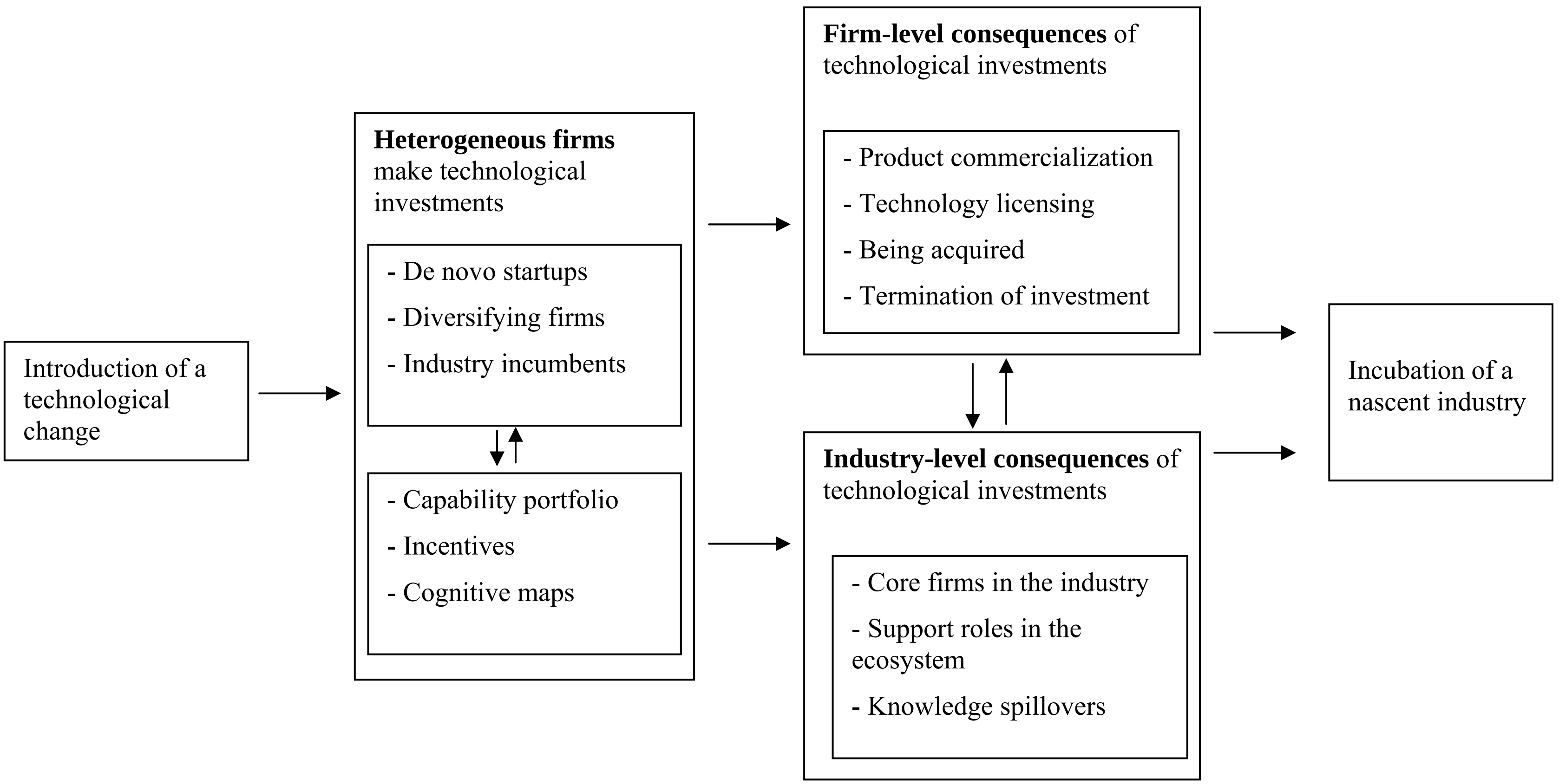
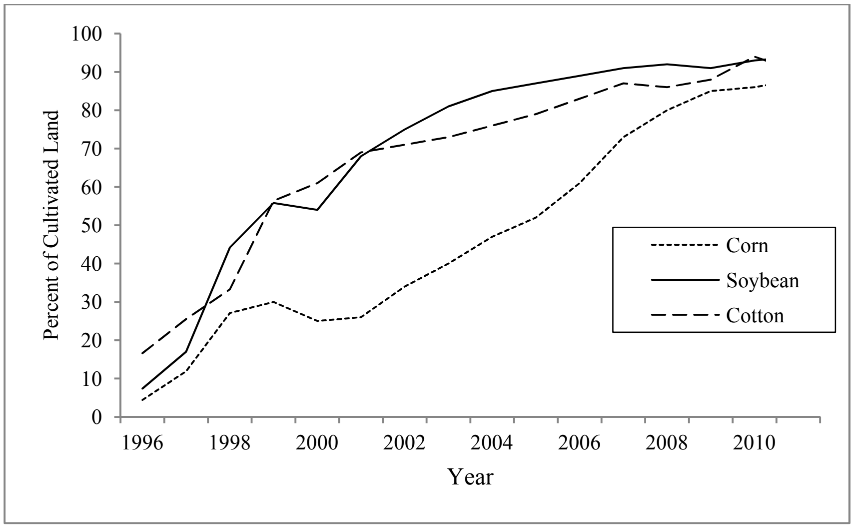


Figure 1-2: Adoption of Transgenic Crops in U.S.



Source: USDA, 2011

Figure 1-3: Agricultural Biotechnology Industry Evolution

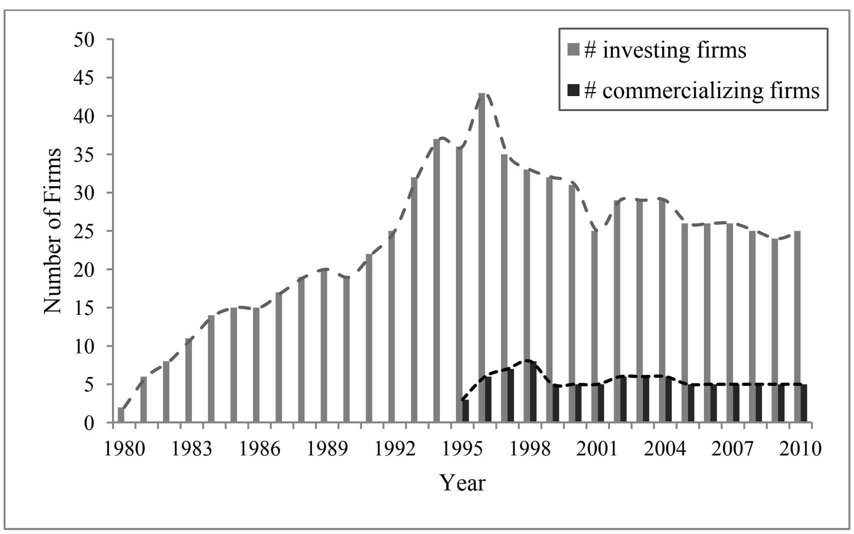


Table 1-1: Timeline of Notable Events in the Agricultural Biotechnology Industry

Prior to Agricultural Biotechnology	
1865	Gregor Mendel's experiments with pea plants
1901	A Japanese bacteriologist isolated Bacillus thuringiensis from infected silkworms.
1907	USDA plant pathologists discovered Agrobacterium tumefaciens – a rod-shaped soil bacterium that infects plant cells and causes crown gall disease.
1924	The first hybrid corn seed is commercialized.
1970	The U.S. Plant Protection Variety Act is enacted, providing breeders up to 25 years of exclusive marketing rights over new, distinct, uniform and stable sexually reproduced plant varieties.
Incubation of Agricultural Biotechnology Industry	
1977	Van Montagu and Schell of the University of Ghent discovered a gene transfer mechanism via the soil bacterium Agrobacterium tumefaciens.
1980	The Supreme Court ruled that biological organisms are eligible for utility patent protection in the 'Diamond vs. Chakrabarty' case.
1983	Viability of genetic modification of plants was shown due to identification of a marker gene.
1986	The coordinated framework for regulation of biotechnology is devised by the federal government.
1987	The first gene gun, an alternative to the use of plasmids and viruses to deliver genetic information into cells, was developed by John Sanford.
Agricultural Biotechnology Era	
1995	Calgene introduced the first herbicide-tolerant cotton.
1996	Monsanto introduced a variety of transgenic crops, including herbicide-tolerant Roundup Ready Soybeans and insect-resistant Bollgard cotton.
1998	Monsanto acquired Calgene.
1998	Dow Chemical acquired Mycogen.
1999	DuPont acquired Pioneer Hi-Bred Company.
2000	Syngenta was established following the merger of AstraZeneca (a merger of Astra and Zeneca) and Novartis agricultural biotechnology businesses (a merger of Ciba-Geigy and Sandoz).

Table 1-2: Summary Statistics, # Investing Firms

(Percentage in parentheses)

Investing Firm Type	**Mode of Value Capture**					**Total**
	Product Commercialization	Exit through Acquisition	Technology Licensing	Termination of Investment	Censored/ Active in 2011	
Diversifying Entrant	7 (10.1 %)	3 (4.3 %)	1 (1.45 %)	7 (10.1 %)	0 (. %)	18 (26 %)
Incumbent	2 (2.9 %)	12 (17.6 %)	0 (. %)	8 (11.5 %)	11 (16 %)	33 (48 %)
De Novo Startup	1 (1.45 %)	7 (10.1 %)	5 (7.25 %)	2 (2.9 %)	3 (4.3 %)	18 (26 %)
Total	10 (14.5 %)	22 (32 %)	6 (8.7 %)	17 (24.5 %)	14 (20.3 %)	69

Table 1-3: The Effect of Firm Types on Mode of Value Capture

Sub-hazard Ratio	(1) Product Commercialization	(2) Exit through Acquisition	(3) Exit/ Termination of Investment
Startup =1	0.165**	6.284***	0.100***
	(0.136)	(3.760)	(0.087)
Incumbent =1	1.540	3.846**	0.205***
	(1.967)	(2.387)	(0.107)
Investment Year	1.103	0.780**	1.067
	(0.084)	(0.094)	(0.066)
# Investing Firms	0.937	1.215	0.978
	(0.076)	(0.148)	(0.102)
# Investing Firms, Squared	0.997	0.998	1.002
	(0.003)	(0.002)	(0.002)
Observations	69	69	69

Diversifying Entrants are the comparison group.
Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1-4: Comparison of a Firm's VC Investment and Acquisition Value

Startup Firm Name	Year of Acquisition	Acquisition Deal Value ($ Million)	Received Venture Capital Investment ($ Million)
Athenix Corporation	2009	400	52
Biotechnica	1994	undisclosed	14
Exseed Genetics	2000	undisclosed	not available
Mycogen	1998	Above 420	23
Plant Genetics Inc	1989	12	25
Plant Genetics System	1996	undisclosed	not available
Prodigene	2003	undisclosed	16

CHAPTER 3: ESSAY 2

PRE-ENTRY OR PRE-INVESTMENT CAPABILITIES?
THE ROLE OF CAPABILITY RECONFIGURATIONS FOR MARKET ENTRY INTO NASCENT INDUSTRIES

Entrepreneurial entry of firms into nascent industries and the ensuing change in the competitive landscape of industries have been a topic of extensive research across economics, strategy, and entrepreneurship literatures. In particular, scholars have focused on the capability antecedents of a firm's entry into a nascent industry, highlighting the effect of a firm's pre-entry capabilities on the likelihood of firm entry (Klepper & Simons, 2000; Mitchell, 1989). In most of these studies, entry of a firm into a new industry is defined by its first product commercialization within that industry (Helfat & Lieberman, 2002); likewise, the point of inception of a new industry is defined by the first industry-level product offering (Gort & Klepper, 1982). However, prior to the first instance of product commercialization, firms are typically involved in *technological investments* in order to transform technological opportunities to commercially valuable products. Similarly, industries often undergo an *incubation* period, defined as the period between the introduction of a discontinuous technological change and the first instance of product commercialization. Despite the importance of firm-level investments undertaken in anticipation of incubation of a new industry, the implications of these investments for entrepreneurial foray of firms are less examined. This is an important unaddressed gap because analysis of this period may provide important insights about the capability antecedents of firm entry into nascent industries.

Specifically, the question of how a firm's capability portfolio at the time of initial investment in a nascent industry influences a firm's market entry has been understudied. If a firm's technological investments in a new industry take place at a time prior to market entry, then there is a need to study how a firm's entry into a nascent industry depends on its capabilities at various points in time. Are the same types of capabilities that are critical at the time of market entry also the distinguishing factor when examined at the time of initial investment? If not, what are the pre-investment capabilities that may put firms in an advantageous position for entry into a nascent industry? These questions become more important given the possibility that a firm's investment efforts may entail a reconfiguration of the firm's existing resource base and capability portfolio according to the requirements of the new industry.

In this essay, I examine the pre-investment capabilities that are related to the likelihood of a firm's market entry into a nascent industry. Based on the premise that firms initiate their technological investments toward a nascent industry at a time before their first product commercialization, I make a distinction between a firm's *pre-entry* and *pre-investment* capabilities. By pre-investment capabilities, I refer to the capabilities that a firm possesses prior to its initial technological investment in the industry. I draw on the existing literature that has emphasized a firm's technical capabilities (Helfat & Raubitschek, 2000; Henderson & Cockburn, 1994) and complementary assets (Gans & Stern, 2003; Teece, 1986) as key drivers of entry into nascent industries. In this literature, the positive relationship between possession of these capabilities and the likelihood of entry into nascent industries has been examined based on the conceptualization of pre-entry capabilities as the stock of a firm's capabilities at the time of market entry (Helfat & Lieberman, 2002). My empirical findings corroborate these well-established relationships. However, I show that at the time of initial technological investment, a firm's *reconfiguration experiences* become the key pre-investment factor. Indeed, reconfiguration experiences – i.e., a firm's experiences in modifying its capability portfolio prior to its investment in the focal industry – enable a firm's efforts in gaining access to the technical capabilities and complementary assets that have been suggested as crucial pre-entry capabilities. By explicitly theorizing a mediating role for pre-entry technical capabilities and complementary assets, I show that pre-investment reconfiguration experiences affect the likelihood of entry through their influence on pre-entry technical capabilities and complementary assets.

The empirical context of this essay is the U.S. agricultural biotechnology industry. Agricultural biotechnology is the use of modern biotechnology techniques to improve or modify plants. The focus of these genetic modifications has typically been enhanced agricultural traits such as herbicide tolerance, pest resistance, and resistance to environmental stresses. I base my analysis on the population of firms that have made technological investments in agricultural biotechnology during 1980-2010. Firms are required to seek permits from the USDA to conduct experiments with their transgenic crops outside the conditions of the laboratory. Applying for these permits implies that a firm has devoted resources toward the agricultural biotechnology industry, and thus indicates a firm's technological investments in this field. This approach enables me to compile the comprehensive list of firms that are engaged in entrepreneurial activity in agricultural biotechnology prior to product commercialization. In addition, a firm's capability portfolio prior to initial investment and prior to market entry can be distinctly identified.

This essay contributes to the research literature in strategic management, industry evolution and entrepreneurship. To the strategic management literature, I underscore the time-varying nature of firm capabilities during the incubation period. By making a distinction between a firm's capabilities at the time of market entry and at the time of initial technological investment, I show that different factors explain the likelihood of a firm's entry at different times. While the stock of pre-entry technical capabilities and complementary assets is related to the likelihood of firm's entry into a nascent industry, at the time of investment, a firm does not necessarily need to possess the technical capabilities and complementary assets that are required for successful operation in the industry. Rather, it is important for a firm to be able to develop technical capabilities and complementary assets during the incubation period.

In addition, this essay draws attention to the endogenous sources of heterogeneity in pre-entry capabilities across firms (Mahoney & Pandian, 1992). My hypotheses build on the literature regarding the role of a firm's pre-entry capabilities (Bayus & Agarwal, 2007; Carroll, Bigelow, Siedel & Tsai, 1996; Helfat & Lieberman, 2002; Klepper & Simons, 2000; Mitchell, 1989) and extend it by accounting for the capability reconfiguration efforts that are undertaken by firms in anticipation of entry into a nascent industry. Rather than presuming a firm's pre-entry capabilities as exogenous factors that are leveraged to the new industry context, I highlight that pre-entry capabilities are indeed endogenously developed prior to entry. This heterogeneity in pre-entry capabilities is related to a firm's pre-investment reconfiguration experiences and potential superior dynamic capabilities (Teece, Pisano & Shuen, 1997; Winter, 2003).

To the entrepreneurship literature, this essay provides novel insights about the capability drivers of entrepreneurial entry of firms into nascent industries and its implications for new industry formation. Particularly, it emphasizes that a more complete understanding of the antecedents of a firm's entry into a nascent industry may be gained by analysis of the dynamics of the time period between a firm's initial technological investment and market entry. Given that potential entrants do not have the option to enter the industry through outright acquisition of industry incumbents, both the entrepreneurial entry of firms and the concomitant creation of the new industries, rely on the strategic investments of potential entrants prior to commercialization in an industry that is not yet in existence itself.

THEORETICAL BACKGROUND

I begin with a review of the existing literature regarding the role of a firm's pre-entry capabilities and its connections to the reconfiguration strategies literature, based on which I then develop a set of hypotheses relating a firm's pre-investment experiences to the likelihood of entry into nascent industries.

"Stocks" of Technical Capabilities and Complementary Assets

Drawing on the resource-based view of the firm (Penrose, 1959; Wernerfelt, 1984), existing literature in strategic management and entrepreneurship has noted that firms with capabilities relevant to the requirements of an industry are more likely to enter into those industries (Helfat & Lieberman, 2002). In particular, technical capabilities (Helfat & Raubitschek, 2000; Henderson & Cockburn, 1994) and complementary assets (Teece, 1986) of a firm have been consistently emphasized as two critical factors for successful commercial performance within nascent industries.[6] While access to technical capabilities enables a

[6] While this essay predominantly focuses on the capability drivers of firm entry, managerial cognition regarding new industries (Kaplan, 2008) are also important. Given the sample creation of this essay, cognition explanations are empirically addressed. In an ideal empirical design, a researcher would first see which firms decide to make the initial investment and then deal with capability drivers at the second stage.

firm's efforts in transforming technological opportunities to an innovative product, complementary assets are required for appropriating economic benefits from a new product.

Technical capabilities are a crucial source of competitive advantage within nascent industries. By technical capabilities, I refer to a firm's expertise in the technology or scientific disciplinary area of the nascent industry. Creation of new products typically requires leveraging a firm's stock of technical capabilities as well as effective recombination across different areas of technical expertise. Thus, access to the underlying technical capabilities of a nascent industry could form the foundation for development of new products (Helfat & Raubitschek, 2000) and subsequent market entry into a nascent industry.

Existing literature has noted that access to technical capabilities of the focal industry is positively associated with new product development (Danneels, 2002; Katila & Ahuja, 2002; King & Tucci, 2002; Leonard-Barton, 1992; Nerkar & Roberts, 2004), research productivity (Henderson & Cockburn, 1994) and intensity of R&D spending (Helfat, 1997). Pre-entry technical capabilities are also critical drivers of a firm's decision to enter a new industry across various groups of entrants to a new industry. For instance, diversifying entrants typically leverage technical capabilities from their prior operations in other industries (Bayus & Agarwal, 2007; Klepper & Simons, 2000), while de novo entrants typically draw on technical capabilities gained during previous employment experiences of their founding team (Agarwal, Echambadi, Franco & Sarkar, 2004; Klepper & Sleeper, 2005). Furthermore, similarities between a firm's stock of technical capabilities and the capability profile of other industries may be a source of related diversification (Chatterjee & Wernerfelt, 1991; Silverman, 1999). Drawing on this research stream:

Stylized Fact 1: The level of pre-entry technical capabilities is positively related to the likelihood of market entry into a nascent industry.

The second key factor for market entry into new industries is the extent to which a firm has access to complementary assets. Complementary assets refer to downstream market-related factors, such as manufacturing facilities, distribution channels, brand name, and complementary technologies, which facilitate product commercialization (Teece, 1986). Absent complementary assets, innovative products may not reach customers, or customers may not experience the full value of an innovative product; therefore, a firm lacking complementary assets may not fully capture the economic value that is created by its innovative product. Access to complementary assets is, thus, critical for commercialization of innovative products (Gans & Stern, 2003; Teece, 1986). Importance of complementary assets has been examined for operations across a variety of industries. For instance, sales and service relationships of firms in the medical diagnostic imaging industry (Mitchell, 1989), specialized manufacturing capabilities and proprietary font libraries in the typesetters industry (Tripsas, 1997), and distribution channels in the pharmaceutical industry (Rothaermel, 2001) have been identified as key complementary assets.

Complementary assets are so important that they may act as a shielding mechanism and enable industry incumbents to operate in a new technology regime that has rendered their R&D capabilities obsolete (Rothaermel, 2001; Tripsas, 1997). Moreover, diversification of firms into other industries may be attributed to the relatedness in complementary assets (Silverman, 1999). Possession of complementary assets may also shape the direction of a firm's innovative activities (Helfat, 1997; Nerkar & Roberts, 2004). Further, gaining access to complementary assets has been noted as one of the motives for alliance formation (Dushnitsky & Lenox, 2005; Gans, Hsu & Stern, 2002). Drawing on this research stream:

Stylized Fact 2: The level of pre-entry complementary assets is positively related to the likelihood of market entry into a nascent industry.

The above stylized facts highlight that firms are strongly influenced by their stock of capability endowments at the time of market entry, so that the nature and size of the capability gap determines the likelihood of a firm's product commercialization in the nascent industry. However, these studies typically do not adequately address the source of pre-entry capabilities. Do the stocks of technical capability and complementary asset represent capability endowments that are passively leveraged by firms to a new industry context? Do firms possess the required capabilities given their prior experience in other settings and do these pre-entry capabilities provide them "dominance by birthright"? Or, are the stocks of pre-entry capabilities endogenously developed by firms via active capability reconfiguration in anticipation of entry into a new industry? Additional insights in this regard may be gained through a dynamic view that takes into account the possibility of capability reconfigurations by firms during the incubation stage and examines the heterogeneity in firm capabilities at the time of initial investment.

Capability "Flows" and Reconfiguration Strategies

While the industry evolution and entrepreneurship literature has not explicitly examined firms' resource reconfiguration efforts, a parallel research literature in strategic management has focused on how firms engage in capability reconfiguration strategies in pursuit of strategic renewal (Agarwal & Helfat, 2009). Capability reconfiguration strategies refer to the strategies that are undertaken by firms to modify their resource base and capability portfolio (Karim & Mitchell, 2000) and may include addition, deletion or retention of capabilities. Capability reconfiguration efforts of firms may resemble flows of capability (Dierickx & Cool, 1986) and thus enable firms to achieve the required configuration of capabilities for operations in their focal industry.

In an effort to alter their capability portfolio, firms may add new capabilities by engaging in in-house research, employee recruitments (Song, Almeida & Wu, 2003), inter-firm alliances (Mowery, Oxley & Silverman, 1996; Rosenkopf & Almeida, 2003), collaborations with universities (Bercovitz & Feldman, 2007; Zucker, Darby & Armstrong, 2002), and acquisitions (Ahuja & Katila, 2001; Karim & Mitchell, 2000). Alternatively, they may delete capabilities by divestment out of existing businesses (Capron, Mitchell & Swaminathan, 2001). Moreover, firms typically select between alternative modes (Capron & Mitchell, 2009) and take advantage of potential complementarities across these modes of change (Cassiman & Veugelers, 2006; Karim & Mitchell, 2004) through concurrent or sequential use of these mechanisms. Once firms gain access to the different components of capabilities that reside within and across their boundary, they need to rearrange their capabilities to achieve the desired arrangement of capabilities. Redeployment of acquired assets (Capron, 1999; Capron, Dussuage & Mitchell, 1998) and integration across externally sourced capabilities and internal ones (Karim, 2006; Puranam, Singh & Chaudhuri, 2009) enable the firm in so doing. The combination of these efforts may then transform the capability portfolio of a firm. Drawing on this research stream:

Stylized Fact 3: Undertaking reconfiguration strategies through various mechanisms – e.g., acquisitions and alliances – is positively associated with changes in a firm's capability portfolio.

The question of how existing firms within existing industries reconfigure their capability portfolio – as in Stylized Fact 3 – has been the focus of several research studies; however, this research area has not explicitly looked at a firm's reconfiguration efforts prior to entry into a nascent industry. The incubation stage is characterized by high degree of environmental uncertainty, given that the industry is not yet in existence. The uncertainties relate not only to the prospects of the industry (whether and when the industry will be created), but also to required capabilities for the emerging industry (what and how resources need to be configured for potential success). When operating within the context of existing industries, firms may conduct some capability benchmarking in order to understand the nature of required technical capabilities and complementary assets (Camp, 1989; Teece et al., 1997); whereas the required capabilities for successful entry into a nascent industry may not be ex-ante known. Further, given the incubation stage of the industry, the potential pool of target firms for external sourcing of capabilities may not be well developed, or may not have capabilities that are already well configured for the focal industry (Jacobides & Winter, 2005).

This literature review indicates that a better understanding of capability antecedents of a firm's entry into nascent industries may be gained by combining insights from strategic renewal and capability reconfiguration literature into pre-entry experience literature. Specifically, in addressing the question of what pre-investment capabilities are associated with market entry of firms into a nascent industry, I draw on these two literatures. On the one hand, it is well-established in the literature that firms' stock of pre-entry technical capabilities and complementary assets are related to the likelihood of entry into a new industry while presuming these capability endowments to be exogenous to entry. On the other hand, multiple capability reconfiguration mechanisms through which firms may modify their capability portfolio have been identified; nonetheless, the interrelation between reconfiguration strategies in anticipation of entry to an industry and development of the required pre-entry capabilities is understudied. To develop hypotheses relating a firm's pre-investment capabilities to likelihood of market entry, I link the two literatures by examining a temporal relationship between a firm's capability reconfiguration efforts and possession of stocks of pre-entry technical capabilities and complementary assets.

HYPOTHESES DEVELOPMENT

I first examine the sources of a firm's pre-entry capabilities and identify a pre-investment factor that is related to development of technical capabilities and complementary assets. Firms may possess an initial level of relevant technical capability that enables their endeavors in building up additional technical capabilities (Cohen & Levinthal, 1990); however, given that this essay focuses on the incubation period of industry evolution, it is unlikely that a firm possesses the required levels of technical capabilities at the time of its initial investment. Hence, a firm needs to employ strategies that would enable getting access to the technical capabilities required for operations in the nascent industry. As indicated in Stylized Fact 3, undertaking capability reconfiguration strategies enables altering a firm's capability portfolio in the form of addition of technical capability. These reconfiguration strategies are not, however, without challenge.

Firms may have the option to develop these capabilities internally or draw on external sources of capabilities. Internal R&D in the new technical field may be fraught with technological uncertainties given that it is not yet clear whether the technological opportunities could be transformed to a commercial product. These technological uncertainties may make firms less likely to pursue irreversible commitment to a technological trajectory (Ghemawat, 1991) and thus require some level of experimentation. Drawing on the external sources of technical capability, such as university scientists and technology-focused startups, also poses challenges. Availability of external sources of technical capability is likely to be limited in the early stages of the industry, as all actors are still involved in advancing the scientific frontiers of a field. Even when external sources of technical capability are available, there may be a need for extensive reconfiguration efforts to gain access to those technical capabilities. Beside the information asymmetry between the firm and the owner of the technology, the overall value of new technologies is unknown in a nascent field. Further, a firm needs to benefit from some processes that facilitate technology transfer and knowledge integration within and across its boundaries. If technology sourcing occurs through licensing and alliances, firms need access to governance capabilities (Argyres & Zenger, 2013) to alleviate the transactional hazards associated with market mechanisms. If a firm pursues technological acquisitions, it faces challenges in assessing the value of firms. In addition, integration challenges need to be addressed extensively. The technical capabilities often reside within the human capital of a firm, which necessitates implementing mechanisms to ensure sustained post-acquisition research productivity of inventors (Kapoor & Lim, 2007; Paruchuri, Nerkar & Hambrick, 2006). Further, recombining different components of technical capability to achieve a firm-specific technology base may be needed.

Given the inherent challenges involved in gaining access to technical capabilities, the question is: What pre-investment factors enable a firm to undertake reconfiguration strategies that are required to add technical capabilities to its capability portfolio during the incubation stage? I suggest that a firm's prior reconfiguration experiences are crucial for a firm's development of new technical capabilities. By a firm's prior reconfiguration experiences, I refer to the extent to which a firm has pursued resource and capability reconfigurations prior to its investment in the focal industry and for the purpose of changing its resource base for operations in existing and non-related businesses to the focal industry. For example, for entry into the agricultural biotechnology industry, firms may benefit from prior experiences that they accumulated while reconfiguring their capabilities for market entry into other unrelated businesses.

The underlying rationale is that prior reconfiguration efforts may lead to tacit accumulation of experience and formal codification of processes required for navigating organizational change (Helfat & Peteraf, 2003; Zollo & Winter, 2002). Because firm-specific routines form and evolve in a path-dependent manner (Nelson & Winter, 1982), firms that have incrementally developed the necessary procedures for undertaking reconfiguration strategies may have an advantage in management of the different modes of change within the context of a nascent industry. These prior experiences may enable development of specific processes for identification of external sources of technology, assessment of the value of the technology, governing alliances (Kale, Dyer & Singh, 2002; Sampson, 2005; Zollo, Reuer & Singh, 2002), and effective integration of acquired capabilities (Zollo & Singh, 2004). Thus, it is more likely that a firm with prior experiences in reconfiguration can replicate the same processes to gain access to technical capabilities for its operations in a nascent industry. When developing technical capabilities for entry into a nascent industry, a firm's pre-investment reconfiguration experiences may enable undertaking the required reconfiguration strategies. Hence, it is more likely that firms with pre-investment reconfiguration experience develop pre-entry technical capabilities. Therefore, I suggest:

Hypothesis 1a: The level of pre-investment reconfiguration experience is positively related to the level of pre-entry technical capabilities.

A similar line of reasoning applies for the role of pre-investment reconfiguration experience in development of complementary assets. During the incubation period, the nature of complementary assets is typically unknown. Before firms design their business models and identify strategies for economic value capture, it is not ex-ante clear what types of resources and capabilities constitute the complementary assets within the nascent industry. At the later stages of industry evolution, early entrants to an industry have already experimented with different business models and have identified key complementary assets; therefore, late entrants could focus their efforts on gaining access to what has been established as key complementary assets within the industry. Moreover, a substantial part of economic value capture comes from access to specialized complementary assets for which there is dependence between the technology and the complementary assets. Although some industries solely rely on generic complementary assets that do not need to be tailored to a specific technology or product (Teece, 1986), the required complementary assets for operations in nascent technology-based industries are more likely to be of the former type. Because of the need for experimentation with alternative business models and value capture approaches, identifying the relevant portfolio of specialized complementary assets such as manufacturing, distribution, and logistics that are specific to a particular industry is likely to be more challenging than leveraging generic complementary assets such as financial capital.

Even after a firm has identified relevant types of complementary assets and seeks to get access to them, key questions relate to whether these complementary assets could be leveraged from other existing businesses of a firm (Mitchell, 1989), whether they could be built from scratch, or whether they could be sourced from external owners of complementary assets (Rothaermel, 2001). In either case, firms need to address challenges related to alleviation of transaction hazards as well as coordination of activities within and across its value chain. Prior reconfiguration experiences may enable undertaking these necessary activities through formation of governance capabilities (Argyres & Zenger, 2013) and integrative capabilities (Helfat & Raubitschek, 2000; Qian, Agarwal & Hoetker, 2012). Therefore, I suggest:

Hypothesis 1b: The level of pre-investment reconfiguration experience is positively related to the level of pre-entry complementary assets.

I next examine the focal question of this essay with regard to identifying the key pre-investment factor that is related to a firm's market entry. A critical consideration of a firm at the time of initial technological investment is whether it would develop technical capabilities and complementary assets by the time of market entry. Accounting for the importance of pre-entry technical capabilities for entry along with the importance of pre-investment reconfiguration experience in developing the pre-entry capabilities, I suggest that prior reconfiguration experiences become a critical pre-investment capability. Firms may not possess all the required technical capabilities and complementary assets at the time of investment; rather, investing firms may pursue strategies that enable development and acquisition of the required resources and capabilities during the incubation stage.

For instance, investing firms in the agricultural biotechnology industry were involved in an array of reconfiguration strategies including research agreements with university scientists, alliances with biotechnology startup firms, and acquisitions of seed producers. Earlier experiences of these firms in capability reconfiguration provided them with the necessary routines and procedures to undertake the extensive reconfiguration strategies in anticipation of entry into agricultural biotechnology. This implies that it is not the capability gap at the time of investment per se that is critical; rather, a firm's ability to fill the capability gap and to pursue deliberate reconfiguration strategies to modify a firm's resource base may also matter. Thus, likelihood of entry into a nascent industry through product commercialization may be related to the extent to which a firm can engage in capability reconfiguration strategies during the investment period, as opposed to the stock of capability endowments at the time of investment.

Additionally, prior experiences in reconfiguration imply that a firm has a history of organizational change. Entry into nascent industries is a major decision for a firm that requires commitment and participation of a firm management and employees. In the presence of organizational inertia, firms may become inflexible and resist major changes to their current activities (Hannan & Freeman, 1984). However, firms are less likely to build up inertia if they have previously undertaken necessary activities for change (Amburgey, Kelly & Barnett, 1993) or have pursued diversification into new industries (Chen, Williams & Agarwal, 2012). Thus, prior reconfiguration experiences may enhance entry into a nascent industry through its effect on overcoming inertial constraints within a firm. Hence, I suggest:

Hypothesis 2: The level of pre-investment reconfiguration experience is positively related to the likelihood of market entry into a nascent industry.

I next discuss how pre-investment and pre-entry factors, when considered jointly, influence the likelihood of market entry within a nascent industry. A theory of mediation maintains that the mechanism through which two variables are related is explained by inclusion of a third mediating variable, in a way that the observed relationship between two variables is representing an association between the independent variable and a mediating variable, which itself has an association with the dependent variable (MacKinnon, 2008). In the context of market entry into a nascent industry, the underlying reasoning for the importance of pre-investment reconfiguration experience draws on the proposition that pre-investment capabilities matter to the extent that they are responsible for accumulating technical capabilities and complementary assets. In other words, pre-investment experience in reconfiguration influences the likelihood of market entry into a nascent industry through its effect on development of the required pre-entry capabilities. Thus, I suggest a mediating role played by a firm's pre-entry technical capabilities and complementary assets, as follows:

Hypothesis 3a: The level of pre-entry technical capabilities mediates the relationship between the level of pre-investment reconfiguration experience and likelihood of market entry into a nascent industry, such that the effect of pre-investment reconfiguration experience is eclipsed given the presence of pre-entry technical capabilities.

Hypothesis 3b: The level of pre-entry complementary assets mediates the relationship between the level of pre-investment reconfiguration experience and likelihood of market entry into a nascent industry, such that the effect of pre-investment reconfiguration experience is eclipsed given the presence of pre-entry complementary assets.

Overall, these hypotheses explicate how pre-investment reconfiguration experiences become a key factor as firms contemplate their entry decision into a nascent industry.

DATA AND METHODS

Industry Context

I empirically test the developed hypotheses in the context of the agricultural biotechnology industry. The agricultural biotechnology is the use of modern biotechnology techniques to modify crops in ways that enhance agricultural productivity. The product in agricultural biotechnology industry is a genetically modified seed that is sold to farmers. Two important groups of products in this industry are crops that have been modified to show agricultural traits of herbicide tolerance – i.e., the ability of a crop to survive the application of an herbicide that would otherwise be expected to harm it – and pest resistance – i.e., the ability of a crop to produce a protein that is only toxic to pests. Other agronomic traits that have been genetically modified include efficiency in nitrogen use or better tolerance of environmental stress such as drought. The revenue potential in this industry arises due to farmers' willingness to pay a price premium for transgenic seeds with a potential to increase agronomic productivity and reduce farming costs.

The agricultural biotechnology industry builds on the applications of modern biotechnology for plant sciences. The first viability of genetic modification of plants was shown in 1977, when a research group from the University of Ghent in Belgium discovered a gene transfer mechanism in plants using Agrobacterium. This technological breakthrough laid the foundation for inception of the agricultural biotechnology industry and was followed by firms' and universities' efforts to achieve additional technological advancements. The year 1995 marked the inception of the agricultural biotechnology industry, when the first products of agricultural biotechnology – transgenic cotton and squash – were commercialized. Since 1995, additional transgenic crops such as corn, soybeans, papayas, sugar beets, and alfalfa have been introduced to the market.

During the incubation stage of this industry, firms with diverse capabilities made technological investments in agricultural biotechnology and experimented with transforming this technological opportunity to a product with commercial value. Three types of firms – namely, incumbent agricultural firms, de novo startups, and diversifying firms from related industries, particularly chemical – invested in agricultural biotechnology. All three types of firms had capabilities that were relevant in agricultural biotechnology. For the conventional agricultural firms, the advent of biotechnology was a discontinuous technological shock. Hitherto, they had relied on plant breeding capabilities, including hybridization, to introduce elite varieties of crops. These capabilities continued to be relevant; however, it is imperative to integrate plant breeding capabilities with modern biotechnology. The second group of firms, de novo startups, largely had agricultural biotechnology knowledge, and many of these were university research spinoffs. The final group of firms diversified from related industries, mainly with chemical backgrounds. Although they lacked agricultural biotechnology capabilities prior to their investments, many of them were engaged in agriculture-related products such as herbicides and pesticides.

Some characteristics of the agricultural biotechnology industry make it an ideal context to study the type of pre-investment capabilities that enable entry into a nascent industry. First, there has been a relatively long industry-level incubation stage (17 years) as well as a firm-level investment period (on average, 10 years). This incubation stage is long enough to provide firms with the possibility of altering their resource and capability portfolios; accordingly, the distinction between pre-entry and pre-investment capabilities of firms is meaningful. Second, the USDA requires firms to disclose and seek permits to conduct experiments with their transgenic crops outside the conditions of the laboratory. Thus, firms' disclosures of their research activities to the USDA enable me to base my empirical analyses on the population of firms active in agricultural biotechnology field releases. In addition, early indications of a firm's interest in devoting resources to agricultural biotechnology can be identified.

It should be noted that plant biotechnology – i.e., the science of genetic modification of plants – has additional applications in the pharmaceutical, bioremediation, and food industries. Since 1977, the possibility of developing transgenic plants that produce pharmaceuticals, eliminate toxic pollutants from the environment, or contain enhanced nutrients has been explored. However, most of these applications have not yet yielded to any commercial product, and do not target agricultural productivity. This essay only focuses on the applications of modern biotechnology for the agriculture industry.

Capability Requirements in Agricultural Biotechnology

In this section, I describe the technical capabilities and complementary assets that should be developed and reconfigured for entry into the agricultural biotechnology industry. I use the example of pest-resistant soybeans to elaborate. Pest-resistant soybeans are genetically modified to contain toxins that kill specific types of pests. In order to make soybeans resistant to pests, a firm needs to understand the genetic structure of soybeans, know the nature of external proteins and genes with desirable traits (harmful to pests) that could be added to soybeans, and find techniques to insert the external gene or protein into the genetic structure of soybeans. These are the technical capabilities in the realm of plant biotechnology. Using its plant biotechnology expertise and applying this process on any soybean crop, a firm is able to introduce pest-resistant soybeans. Although the pest-resistance trait of soybeans increases crop productivity by reducing pesticide application by farmers, pest resistance is only one among several traits of soybeans. In addition to pest resistance, farmers seek high-yielding soybeans that exhibit a good fit for the agro-climatic conditions of their geographic region. Thus, the pest-resistant soybean becomes valuable for farmers (and gains commercial value for firms), if the process of genetic modification is conducted on soybeans with an array of other traits. Over the years, conventional plant breeders – through the long-practiced process of crossing closely related crop varieties and selecting the ones with desired traits – have achieved high-quality varieties of soybeans that provide the other traits sought by farmers. These high-quality varieties are referred to as elite varieties or elite germplasm[7]. The elite varieties are used as a platform for genetic modification and have thus become critical downstream complementary assets.

In the general case, expertise in plant biotechnology – i.e., knowledge of gene sequences as well as methods of genetic transformation of plants – is considered the key technical capability, and access to elite varieties of crops – i.e., crop varieties that have been bred to show superior characteristics sought by farmers in each agro-climatic condition – is considered the key complementary asset. These are the two capabilities that firms need to possess for entry into the agricultural biotechnology industry.

[7] Plant germplasm is a living tissue from which new plants can be grown. This can be a seed, or it can be another plant part such as a leaf, a piece of pollen, or even a few cells that can be cultured into a whole plant. Plant germplasm contains the genetic information for the plant's hereditary makeup. [Source: The U.S. National Plant Germplasm System]

Data Description

I derive the sample from the comprehensive list of firms that have applied for a release permit of a transgenic crop during 1985-2010. United States laws require that all firms seek permits from the APHIS (Animal and Plant Health Inspection Services) within the USDA to conduct experiments with a regulated transgenic plant outside the constraints of physical confinement that are found in a laboratory. I consider a firm's application for a release permit as an indication of its technological investment in agricultural biotechnology. This approach in sample construction enables me to identify the population of firms that have made technological investments in agricultural biotechnology. Moreover, firms' technological investments are observed at the early stages, regardless of product commercialization.

During 1985 to 2010, 16,541 release permit requests were submitted to the USDA Biotechnology Regulatory Services. Among these, 3,255 requests (19 percent) were submitted by universities or not-for-profit research institutions, and 13,286 requests (81 percent) were submitted by private firms[8]. Given my focus on firms' investments in agricultural biotechnology, my sample only includes firms involved in experiments related to the agriculture industry, and excludes firms and experiments in other product categories.[9] The included product categories correspond to SIC industry groups of 011 and 013 within the

---

[8] The identities of the organizations applying for 82 requests are not clear based on USDA records either because they requested it to remain confidential (55 applications) or because an agricultural consulting firm (27 applications) applied for the release permits on behalf of the actual firms; accordingly, I exclude these permits (corresponds to 0.6 percent of all permits) from the sample.

[9] This criterion results in excluding 19% of all experiments. As noted earlier in this essay, the science of genetic modification of plants has additional applications other than plants with enhanced agricultural productivity such as development of transgenic plants that produce pharmaceuticals, eliminate toxic pollutants from the environment, or contain enhanced nutrients.

major group of agricultural production crops, and include corn, cotton, potatoes, soybeans, squash, sugar beets, canola, and alfalfa. Furthermore, I exclude the experiments that have been conducted under the control of university technology transfer offices from the current sample[10]. In case the release permit requests by the same parent firm are reported in the name of its different subsidiaries, I aggregate them across the various entities for a total count at the parent-firm level.

The final sample includes 69 firms that made technological investment toward agricultural biotechnology industry during 1980-2010. For these firms, the analysis is based on data compiled from various sources such as the USDA (U.S. Department of Agriculture), the EPA (Environmental Protection Agency), the SEC (Securities and Exchange Commission), the FDA (Food and Drug Administration), the USPTO (U.S. Patent Office), and the OECD (Organization for Economic Cooperation and Development), as well as websites of firms, Compustat, Delphion, LexisNexis and SDC Platinum.

Model Specification and Estimation

The unit of analysis in this essay is the firm's initial instance of technological investment in agricultural biotechnology. My interest is in examining whether a firm's technological investment in agricultural biotechnology leads to *product commercialization*. I

[10] My focus in this essay is to examine instances of product commercialization that were undertaken by for-profit firms. Although university scientists have been involved in the early stages of technology development, they were less likely to engage in product commercialization within their universities. The only instance is the case of transgenic papaya, which was introduced in 1997 by Cornell University. The transgenic papaya seeds were made freely available to farmers in Hawaii.

Although I exclude experiments that have been conducted under the control of university technology transfer offices, the sample includes experiments that have been conducted by university scientists in the context of university spin-offs.

track each investing firm from its initial investment in agricultural biotechnology until its exit from the risk pool of product commercialization.

I use the competing risks event history method (Fine & Gray, 1999) to estimate the hazard that a firm commercializes a product in the agricultural biotechnology industry. The competing risks estimation method is required for at least two reasons. First, firms may be removed from the risk of product commercialization due to occurrence of competing events such as getting acquired, or going bankrupt. In addition, the occurrence of each event may follow a distinct causal process and functional form. For example, a different set of explanatory variables may be related to the likelihood of getting acquired compared with the likelihood of bankruptcy. Second, data are right-censored for a few firms that were active in 2011 and have not yet experienced any of the events.

In order to conduct a competing risk event history analysis, three issues need to be specified: (1) the time at which the firm starts to be at the risk of product commercialization, (2) the type of the event experienced by the firm, and (3) the time at which the firm experiences an event that removes it from the risk of product commercialization. Below, I describe each of these specifications.

Time of the Initial Investment: A firm's first instance of investment in agricultural biotechnology is considered to be the time at which it becomes at the risk of product commercialization. I use the firm's SEC filings, annual reports, and LexisNexis records to identify the first mention of a firm's involvement in agricultural biotechnology. A firm's involvement in agricultural biotechnology is typically reflected in the form of establishing a new research division, engaging in research and development alliances, or acquiring relevant businesses. Although I use USDA records to create my sample, the date of first release permit is not assumed to be the first instance of firm investment in the new technology.

Type of the Event: The focal event of interest in this essay is product commercialization by firms; however, there are other competing events such as getting acquired and ceasing investment in agricultural biotechnology that remove a firm from the risk of product commercialization. My estimation strategy accounts for this heterogeneity in outcomes.

Using the information announced by U.S. regulatory agencies in the United States regulatory agencies unified biotechnology website[11], I obtain a comprehensive list of transgenic crops that are cleared for commercialization in the United States. Products in the agricultural biotechnology industry should conform to the regulatory procedures indicated in the coordinated framework for regulation of plant biotechnology. Three regulatory agencies, the USDA, the EPA and the FDA, evaluate and oversee transgenic plants. I track all firms with a transgenic crop that was ready to be commercialized on the basis of regulatory requirements, and identify the commercialized transgenic crops using the firm's reports, LexisNexis, and SEC filings. The first instance of product commercialization of a transgenic crop by a firm is coded as occurrence of the focal event.

If a third party acquired a firm's agricultural biotechnology unit, I code its event as *getting acquired*. In the case of startups, it means that the whole firm was acquired; whereas for established firms, it refers to sales of the agricultural biotechnology unit. If a firm ceased its investment in agricultural biotechnology, I code its event as *ceasing agricultural*

[11] Please see: http://usbiotechreg.epa.gov/usbiotechreg/

biotechnology investment. For the remaining firms that have not experienced either of these events, continued investment in agricultural biotechnology as of 2011 is confirmed. Among 69 investing firms, 10 firms (14.5 percent) have commercialized a product, 22 firms (32 percent) were acquired, 17 firms (24 percent) ceased their investments in agricultural biotechnology, and 20 firms (30 percent) are active as of 2011.

Time of the Event: For the focal event of product commercialization and the other two competing events, the time of event occurrence is recorded on a yearly basis. The median time since a firm's investment until an event for investing firms in the sample is 10 years.

Explanatory Variables

Reconfiguration Experiences: In order to measure a firm's experience in reconfiguration, I use the number of times that a firm has reconfigured its units through addition or divestment of business segments in the five-year window prior to its investment in agricultural biotechnology. This measure is consistent with operationalization of similar concepts in the existing literature. For instance, King and Tucci (2002) measured transformational experience using a dummy variable indicating whether the firm had any transition experience due to entry into new market niches.

Technical Capabilities: Expertise in plant biotechnology is the technical capability required for operation in agricultural biotechnology. I measure a firm's technical capabilities using the (logged) number of agricultural biotechnology relevant patents granted to a firm. A firm's stock of patents is typically used to measure technical capabilities in the prior literature (Ahuja & Katila, 2001; Nerkar & Roberts, 2004). The list of 7-digit IPCs relevant to agricultural biotechnology is compiled based on Graff (2003), which provides a comprehensive analysis of patent classes related to agricultural biotechnology[12]. Technical capabilities are measured at two points in time: (1) at the time of firm's initial investment in agricultural biotechnology, and (2) at the time of product commercialization and other competing events.

Complementary Assets: Within the context of agricultural biotechnology, access to elite varieties of crops is considered the key complementary asset. I use the (logged) number of protected plant varieties of a firm as an indicator of the extent to which a firm has access to a stock of elite varieties of crops. Under the Plant Variety Protection Act of 1970, plant breeders are granted a protection certificate for their new, distinct, uniform, and stable plant varieties[13]. Subject to research and crop exemption, this certificate gives the breeder the right to exclude other firms from selling the variety. These complementary assets are measured at two points in time: (1) at the time of firm's initial investment in agricultural biotechnology, and (2) at the time of product commercialization and other competing events.

This measure draws on Teece (1986)'s conceptualization of complementary assets as downstream industry-specific resources that facilitate product commercialization. Different scholars have identified complementary assets that are relevant to each industry context such as the sales and service relationships in the medical devices industry (Mitchell, 1989), distribution channels in the pharmaceutical industry (Rothaermel, 2001), proprietary font

---

[12] The full list of patent classes is available upon request.

[13] An alternative measure for complementary assets may be the firm's stock of patents that cover elite varieties of crops. Prior to 1980, firms were only eligible to protect their plant varieties under the Plant Variety Protection Act of 1970. In 1980, the Supreme Court decision of Diamond v. Chakrabarty suggested that firms are also eligible to apply for utility patents for their protected varieties. Accordingly, firms typically pursue both intellectual property protection options in parallel since early the 1990s. Because the use of patents to protect elite varieties of crops was ineligible in the 1980s, it is not relevant for measuring complementary assets at the time of firm's investment.

libraries in the typesetters industry (Tripsas, 1997), ownership of coal reserves in the synthetic fuels industry (Helfat, 1997), and infrastructure of switching networks in the wireless communications industry (Rothaermel & Hill, 2005).

Control Variables

I also control for a number of variables that have been identified as relevant in the prior literature. I include *Investment Year* to represent the differential effect of time. In addition, investment year may capture effects of early mover (dis)advantages for product commercialization (Lieberman & Montgomery, 1988). To account for *Firm Size,* I use a dummy variable that equals one for large public firms. Firm size has been suggested to influence a firm's innovativeness (Acs & Audretsch, 1988), or research productivity (Henderson & Cockburn, 1996). I also include a dummy variable that equals one for *Foreign Firm*. Due to unfamiliarity with the institutions and collaboration opportunities, foreign firms may face different conditions. In addition, evolutionary changes in the industry, measured through the density of firms at each year, has been suggested as important in determining firm performance (Gort & Klepper, 1982; Hannan & Carroll, 1992); hence, I include the linear and quadratic terms for the *Number of Investing Firms* in agricultural biotechnology at the firm's year of investment. Moreover, I control for *Industry Demand* in by using the acreage (in million acres) of genetically modified crops one year prior to a firm's experience of an event. A large industry demand may allow for product commercialization by more firms. For hypothesis 1, I include *Firm Tenure in Agricultural Biotechnology* as the number of years that a firm has been investing in the agricultural biotechnology prior to the focal event. In the main models, this variable is already embedded in the structure of a competing risk model.

Table 2-1 presents the summary statistics and correlation between key variables.

[Table 2-1 about here]

RESULTS

Table 2-2 presents the results of the competing risk model. This table shows the sub-hazard ratio of which a firm commercializes a product in the context of agricultural biotechnology. Because I use a competing risks model, the model accounts for the possibility of firm exit through being acquired or through failure. A coefficient larger than one implies that the variable of interest has a positive effect on the sub-hazard of product commercialization. Model 1 only includes the control variables. Models 2 to 4 include a firm's stock of capabilities at the time of event. Consistent with the existing literature, these models show that the stock of a firm's technical capabilities and complementary assets at the time of the event has a positive and statistically significant relationship with the hazard of product commercialization. Thus, models 2 to 4 corroborate Stylized Facts 1 and 2. In models 5 to 10, I examine the effect of a firm's stock of capabilities at the time of investment. The models show that neither the stock of firm's technical capabilities, nor the stock of firm's complementary assets has a statistically significant relationship with the hazard of product commercialization. Although this is an important non-finding, implying that firms lack key technical capabilities and complementary assets at the time of investment, this result should be interpreted with caution due to the small sample size. When a firm's prior reconfiguration experience is added as a pre-investment factor in models 7 to 10, this variable has a positive and statistically significant relation with hazard of product commercialization. The experience gained through each additional instance of reconfiguration increases the hazard of product commercialization by 36 percent. Thus, the results corroborate hypothesis 2 – that a firm's experiences in reconfiguration at the time of first investment are important for entry into a nascent industry.

[Table 2-2 about here]

To examine the mediation effect in hypothesis 3, I follow Baron and Kenny's (1986) approach, which has been used in prior empirical research in strategic management (Dushnitsky & Shapira, 2010; Ethiraj, Ramasubbu & Krishnan, 2012; Lee, 2008; Quigley & Hambrick, 2012). Tables 2-2, 2-3, and 2-4 present the three conditions required for presence of a mediation effect. The first condition is to establish a relationship between the independent variable and the dependent variable. The coefficient of pre-investment reconfiguration experience in Model 10 of Table 2-2 shows that pre-investment reconfiguration experience is positively related to the likelihood of market entry. The second condition is to establish a relationship between the independent variable and the mediating variables. Table 2-3 uses the Tobit estimation method to show the effect of pre-investment reconfiguration experience on mediator variables. The dependent variable in these models – a firm's stock of pre-entry capabilities (logged) – takes values that cannot be smaller than zero; thus, a limited dependent variable estimation technique such as Tobit is appropriate. The coefficient of reconfiguration experience in model 2 is positive and statistically significant at the level of 5 percent, implying that pre-investment reconfiguration experience is positively related to pre-entry technical capabilities. This result provides empirical support for hypothesis 1a. Similarly, the coefficient of reconfiguration experience in model 4 is positive and statistically significant at the level of 1 percent, implying that pre-investment reconfiguration experience is positively related to pre-entry complementary assets. This result provides support for hypothesis 1b. The third condition is established in Table 2-4, which shows that pre-entry technical capabilities and complementary assets absorb all the effect of pre-investment reconfiguration experience on the likelihood of market entry.

[Tables 2-3 and 2-4 about here]

A key issue in establishing a mediation relationship is to ensure that mediating variables and the dependent variable are theoretically distinct constructs. Based on strategic management theories and accounting for temporal precedence of these variables, the likelihood of market entry and pre-entry stock of capabilities are indeed two different theoretical constructs. It should also be noted that although the theory of mediation implies a causal chain of relationships, its empirical design only shows a correlation between variables of interest. Overall, these results show that pre-entry technical capabilities and complementary assets mediate the relationship between a firm's pre-investment reconfiguration experience and entry into a nascent industry.

Supplementary Analyses

To confirm robustness of my empirical results, I conducted additional analyses with alternative model specifications. First, I compared the main results based on competing risks estimation model with Logit estimation and Cox proportional hazard estimation models. Both models corroborate the overall pattern of the reported findings. Second, the results are robust for using of the (logged) number of firm's patents in the international patent class C12N [14] as an alternative measure for technical capabilities at the time of firm investment. The agricultural biotechnology relevant patent classes identified in Graff (2003) cover all the

[14] International patent class of C12N represents micro-organisms or enzymes; compositions thereof, namely, propagating, preserving, or maintaining micro-organisms; mutation or genetic engineering culture media.

agricultural biotechnology patents, and provide an accurate criterion to identify technology domains with which a firm should be familiar at the time of entry. However, these patents may not be prevalent during the incubation stage of the industry life cycle. Rather, because firms often benefit from technical capabilities in related domains that could be leveraged to new industries (Silverman, 1999), patent classes in related technological domains, based on which agricultural biotechnology is built, may be relevant technical capabilities at the time of initial investment.

An alternative explanation for the empirical findings of this essay may be that a firm's financial standing, rather than the experience accumulated as a result of past reconfiguration efforts, is associated with further development of capabilities and the consequent entry into the industry. A firm's financial standing may have three parallel effects: first, a firm with more access to financial resources may be at an advantageous position in forming alliances or undertaking acquisitions; thus, it may be more likely to gain access to required technical capabilities and complementary assets. Second, financial resources of a firm may facilitate the extent to which it can enforce its intellectual property rights; hence, it may act as an incentive for it to pursue product commercialization. Third, financial resources may be related to a firm's ability to conform to all the regulatory requirements; thus, a firm with more financial resources may be more incentivized to pursue product commercialization. Since many of the firms in my sample are private firms that are no longer active in the industry, their historical financial information is not readily available. Similar to the prior work in the area, I am not able to disentangle the effects of financial resources from reconfiguration experience in my main models. To the extent that firm size is related to a firm's revenue and financial standing, the control variable for firm size may address this issue. That being said, I further explore this issue through analyses of a subsample of firms for which I have detailed financial information. In Table 2-5, I include a firm's revenue as an additional control variable. The effect of a firm's prior reconfiguration experiences is robust to inclusion of this variable. Similar results hold when controlling for a firm's total assets and cash.

[Table 2-5 about here]

DISCUSSION AND CONCLUSIONS

This essay examines the underlying capabilities that are required for market entry into nascent industries. Although firms' pre-entry capabilities have been suggested as a critical factor determining the likelihood of their entry to an industry, existing literature has largely conceptualized pre-entry capabilities as the stock of a firm's capabilities at the time of its market entry (Helfat & Lieberman, 2002). Drawing on the advances in this literature, the current essay addresses a critical research gap: Because firms' technological investments in a new industry start at a time before their market entry, there is a need to distinguish between a firm's pre-entry and pre-investment capabilities. Accordingly, I focus on a firm's pre-investment capabilities as key drivers of entry into a nascent industry.

Using a rich data set of firms' technological investments within the agricultural biotechnology industry, this essay shows that although it is critical for a firm to have access to technical capabilities and complementary assets at the time of market entry, these capabilities, when measured at the time of first investment, do not explain the likelihood of product commercialization. Instead, I identify another capability that has not received attention in the literature in industry evolution – the firm's ability to reconfigure itself and leverage alternative modes of change – as the primary pre-investment capability. Moreover, I provide empirical evidence for how a firm's pre-entry capabilities mediate the relationship between a firm's pre-investment capabilities and the likelihood of entry.

While these findings have important implications for theory and practice, this is a single industry study with potential limitations in generalizability. First, the implications of appropriability regimes and intellectual property enforcement need to be considered. Following the Supreme Court decision regarding the case of Diamond v. Chakrabarty in 1980 and the case of J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred International, Inc. in 2001, which held that biological organisms may be eligible for utility patent protection, the biotechnology industry has heavily relied on patents for intellectual property protection. Potential entrants to industries with different levels of reliance on patent protection may have different incentives regarding entry into those industries. Second, entry into other contexts may not require the extensive reconfiguration efforts that were imperative for operations in agricultural biotechnology; thus, despite their importance, the magnitude of the effect of pre-investment reconfiguration experiences may become smaller in other industry contexts.

This essay also calls for three streams of future research. First, it is an important line of research inquiry to distinguish between a firm's characteristics at the time of investment and entry. Future research studies may account for the time-varying nature of firm capabilities during incubation and its implications for established theoretical and empirical relationships in the field. Second, this essay focuses on how pre-investment reconfiguration experiences enable capability development in anticipation of entry to nascent industries. Future research in the strategic management field may elaborate on the breadth and depth of firm reconfiguration activities prior to entry. Third, this essay examines the likelihood of product commercialization as an important outcome measure for a firm's investment in a new industry. Although this is consistent with the approach in industry evolution literature, future research may look at the effect of pre-investment capabilities for post-entry performance measures such as survival, innovativeness, financial performance, and growth rate.

This essay provides several theoretical and empirical contributions. To begin with, this essay highlights the importance of research analysis of firms' investments prior to their market entry into nascent industries. I suggest that studying entrepreneurial entry of firms into a new industry by considering the first product commercialization as the point of firm entry into an industry may provide an incomplete picture of when and which firms enter a new industry and how firms and industries co-evolve. By explicit analysis of a firm's capabilities at the time of initial investment in an industry, I show that pre-investment capabilities required for successful product commercialization may be different from what is observed as pre-entry capabilities of a firm at the time of commercialization.

This essay also adds to the stream of research in the dynamic capabilities literature (Teece et al., 1997; Winter, 2003). While a firm's prior experiences in reconfiguration have been studied in the context of development of dynamic capabilities, this essay emphasizes their critical role in enabling a firm's entry into a nascent industry, and the consequent incubation of the industry. The incubation stage of nascent industries has distinct characteristics that deserve consideration. For example, entry into established industries may be through outright acquisition of firms that are already active in that industry; however, given the absence of any producer firms during the incubation stage, entry into nascent industries can only be through a firm's own efforts in capability reconfigurations. In addition, it is not clear as to what the capabilities required for success are and how these capabilities should be configured. Thus, this essay joins the two literature streams of dynamic capabilities and pre-entry experience to provide insights on critical reconfiguration efforts being made prior to entry, particularly prior to inception of a new industry.

From a managerial perspective, the time of initial investment into a nascent industry is the time to make critical strategic decisions regarding entry. Whether or not a firm possesses the required capabilities for entry needs to be assessed before a firm's initial investment in an industry. Thus, it is important to understand pre-investment factors that enable entrepreneurial entry of their firms into an industry. Research studies that elaborate on the required capabilities for entry at the time of initial investment, thus, are especially valuable from the standpoint of managers contemplating about entry into nascent industries.

Empirically, much of the industry evolution literature has operationalized pre-entry experience with dummy variables: simple indicators that distinguish diversifying entrants from de novo entrants (Bayus & Agarwal, 2007; Khessina & Carroll, 2008), and incumbents from entrants, or diversifying entrants based on their prior industry of operation (Carroll et al., 1996; Klepper & Simons, 2000). Although the heterogeneity in firm type is assumed to be indicative of these underlying capabilities, these studies did not use direct measures of the capabilities. Another contribution of this essay is to study firm-level heterogeneity by using finer-grained measures. Not only do the finer-grained measures of capabilities account for the heterogeneity across firm types, but they also enable analysis of the time-varying nature of the capabilities.

Furthermore, I emphasize the role of deliberate reconfiguration efforts, rather than passive leveraging of existing resource endowments. Contrary to prior literature that has focused on stocks of endowments, this essay shows that firms actively engage in entrepreneurial reconfiguration of capabilities and, in doing so, impact the evolution of a nascent industry. In doing so, I disentangle *stock* and *flow* effects that prior literature has largely attributed to a single concept of pre-entry capabilities. When viewed at the time of market entry, my findings are consistent with the existing literature that indicates the importance of a firm's technical capabilities and complementary assets for entry into nascent industries. However, at the time of initial investment, it is more important for firms to benefit from reconfiguration experiences that enable development of technical capabilities and complementary assets. For example, while specialized complementary assets are a source of competitive advantage for industry entrants (Mitchell, 1989; Teece, 1986), it is the ability to gain access to complementary assets that becomes more important than actual possession of them at the time of initial investment.

Overall, the second essay of my dissertation takes the first step in highlighting the importance of firms' capability reconfiguration efforts prior to entry into nascent industries. In particular, I discuss the role of firms' pre-investment reconfiguration experiences as an enabling factor for development of pre-entry capabilities, and the consequent entry of firms to nascent industries.

Table 2-1: Correlation between Key Variables

	Variables	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1	Pre-investment Experience in Reconfiguration	2.25	2.39	1	11	1.00											
2	Pre-investment Technical Capabilities	0.48	0.90	0	3.14	0.60	1.00										
3	Pre-investment Complementary Assets	0.92	1.37	0	4.60	0.01	0.08	1.00									
4	Pre-entry Technical Capabilities	1.84	1.91	0	5.58	0.65	0.66	0.16	1.00								
5	Pre-entry Complementary Assets	1.46	1.88	0	6.07	0.34	0.33	0.77	0.43	1.00							
6	Investment Year	1993.19	7.61	1980	2010	-0.42	-0.36	-0.18	-0.61	-0.47	1.00						
7	Firm Size	0.39	0.49	0	1	0.58	0.57	0.29	0.65	0.45	-0.63	1.00					
8	Foreign Firm	0.14	0.35	0	1	0.34	0.31	0.16	0.24	0.09	-0.06	0.26	1.00				
9	# Investing Firms	29.01	12.91	2	47	-0.43	-0.31	0.03	-0.57	-0.34	0.64	-0.53	-0.02	1.00			
10	# Investing Firms, Squared	1006.12	688.14	4	2209	-0.42	-0.28	0.00	-0.50	-0.30	0.52	-0.48	-0.05	0.97	1.00		
11	Industry Demand	1.70	1.66	0	4.17	-0.11	0.06	0.30	0.08	0.21	0.04	-0.04	-0.04	0.29	0.30	1.00	
12	Firm Tenure in Agricultural Biotechnology	9.96	5.63	1	21	0.23	0.14	0.08	0.43	0.28	-0.51	0.34	0.07	-0.39	-0.37	-0.03	1.00

Table 2-2: The Effect of Pre-investment and Pre-entry Capabilities on Entry

	Pre-entry Capabilities (Stylized Facts)				Pre-investment Capabilities (Hypotheses 2 and 3)					
Sub-hazard ratio of *Entry*	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Pre-investment Experience in Reconfiguration							1.161*	1.269***	1.221**	1.359***
							(0.093)	(0.112)	(0.118)	(0.132)
Pre-investment Technical Capabilities						1.014			0.684	0.622
						(0.273)			(0.296)	(0.234)
Pre-investment Complementary Assets					1.388			1.877		2.006
					(0.507)			(0.824)		(0.929)
Pre-entry Technical Capabilities			2.354**	2.527**						
			(0.827)	(1.030)						
Pre-entry Complementary Assets		1.853***		1.758***						
		(0.433)		(0.362)						
Investment Year	1.138	1.251*	1.262**	1.391**	1.184	1.138	1.147	1.257	1.150	1.263
	(0.134)	(0.145)	(0.146)	(0.232)	(0.133)	(0.134)	(0.121)	(0.186)	(0.111)	(0.183)
Firm Size	3.395	2.684	2.033	1.567	2.596	3.350	2.207	1.206	2.785	1.664
	(6.572)	(2.984)	(3.434)	(1.311)	(4.707)	(6.710)	(4.261)	(1.769)	(4.887)	(2.075)
Foreign Firm	1.647	2.280	1.065	1.656	1.830	1.629	1.744	2.044	2.036	2.341
	(1.465)	(1.906)	(0.932)	(1.298)	(1.522)	(1.481)	(1.426)	(1.446)	(1.444)	(1.408)
# Investing Firms	0.975	1.114	1.059	1.231	0.919	0.975	0.966	0.866	0.956	0.836
	(0.117)	(0.157)	(0.141)	(0.172)	(0.109)	(0.117)	(0.117)	(0.123)	(0.122)	(0.147)
# Investing Firms, Squared	0.997	0.993	0.995	0.991	0.997	0.997	0.997	0.998	0.997	0.998
	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Industry Demand	1.034	0.627	0.857	0.605*	0.952	1.034	1.022	0.867	1.026	0.838
	(0.189)	(0.183)	(0.182)	(0.137)	(0.200)	(0.189)	(0.181)	(0.192)	(0.189)	(0.208)
N. Observations	69	69	69	69	69	69	69	69	69	69
Log pseudo-likelihood	-29.882	-25.813	-27.185	-23.394	-29.323	-29.881	-28.708	-27.106	-28.276	-26.421
Wald Chi2	21.85***	30.35***	20.10***	47.04***	16.14**	22.51**	41.34***	29.57***	93.06***	87.77***

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Table 2-3: The Effect of Pre-investment Capabilities on Pre-entry Capabilities

	DV = Pre-entry Technical Capabilities (Hypothesis 1a)		DV = Pre-entry Complementary Assets (Hypothesis 1b)	
	(1)	(2)	(3)	(4)
Pre-investment Experience in Reconfiguration		0.250^{**}		0.341^{***}
		(0.115)		(0.113)
Pre-investment Technical Capabilities	1.130^{***}	0.895^{***}	0.768^{**}	0.464
	(0.291)	(0.295)	(0.311)	(0.294)
Pre-investment Complementary Assets	0.130	0.202	1.527^{***}	1.592^{***}
	(0.167)	(0.163)	(0.191)	(0.180)
Firm Tenure in Agricultural Biotechnology	0.162^{***}	0.152^{***}	0.123^{*}	0.111^{*}
	(0.045)	(0.043)	(0.048)	(0.044)
Firm Size	1.472^{*}	0.985	0.436	-0.222
	(0.584)	(0.596)	(0.640)	(0.623)
Foreign Firm	0.170	-0.115	-0.586	-0.933
	(0.635)	(0.617)	(0.666)	(0.603)
Constant	-1.648^{**}	-1.801^{**}	-2.776^{***}	-2.960^{***}
	(0.593)	(0.576)	(0.719)	(0.682)
Sigma				
Constant	1.692^{***}	1.606^{***}	1.653^{***}	1.480^{***}
	(0.198)	(0.188)	(0.227)	(0.202)
N. Observations	69	69	69	69
Pseudo R2	0.226	0.244	0.326	0.365
Log Likelihood	-97.842	-95.588	-73.787	-69.516
LR chi2	57.20^{***}	61.71^{***}	71.28^{***}	79.82^{***}

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Table 2-4: The Effect of Pre-investment Capabilities and Mediators on Entry

Sub-hazard ratio of *Entry* (Hypotheses 3a and 3b)	(1)	(2)	(3)
Pre-investment Experience in Reconfiguration	1.052 (0.120)	1.080 (0.092)	0.967 (0.103)
Pre-entry Technical Capabilities		2.207^{*} (0.907)	2.591^{**} (1.058)
Pre-entry Complementary Assets	1.793^{**} (0.480)		1.783^{***} (0.371)
Investment Year	1.248^{*} (0.146)	1.248^{*} (0.148)	1.402^{*} (0.243)
Firm Size	2.583 (2.840)	1.546 (2.642)	1.642 (1.399)
Foreign Firm	2.076 (1.683)	1.151 (1.017)	1.704 (1.344)
# Investing Firms	1.123 (0.168)	1.048 (0.143)	1.224 (0.168)
# Investing Firms, Squared	0.993 (0.005)	0.995 (0.003)	0.991^{**} (0.004)
Industry Demand	0.628 (0.188)	0.901 (0.174)	0.602^{**} (0.133)
N. Observations	69	69	69
Log pseudo-likelihood	-25.714	-26.935	-23.355
Wald Chi2	29.03^{***}	27.70^{***}	49.28^{***}

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Table 2-5: Robustness Analysis

Sub-hazard ratio of *Entry*	(1)	(2)	(3)
Pre-investment Experience in Reconfiguration			1.246** (0.122)
Pre-investment Technical Capabilities			0.777 (0.253)
Pre-investment Complementary Assets			1.781 (0.924)
Pre-entry Technical Capabilities		1.924* (0.671)	
Pre-entry Complementary Assets		1.653** (0.418)	
Investment Year	1.083 (0.095)	1.296** (0.131)	1.223 (0.181)
Revenue	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
# Investing Firms	0.984 (0.119)	1.182 (0.140)	0.812 (0.187)
# Investing Firms, Squared	0.998 (0.002)	0.994** (0.003)	1.001 (0.003)
Industry Demand	0.919 (0.250)	0.520** (0.163)	0.871 (0.230)
N. Observations	22	22	22
Log pseudo-likelihood	-21.309	-17.251	-19.768
Wald Chi2	8.66	28.78***	15.65**

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

CHAPTER 4: ESSAY 3

FILLING HETEROGENOUS CAPABILITY GAPS: RECONFIGURATION STRATEGIES IN ANTICIPATION OF ENTRY INTO NASCENT INDUSTRIES

Within the rich literature that spans across economics, sociology, and strategy a critical issue relates to performance differentials between heterogeneous firms that enter a nascent industry. De novo startups, diversifying firms and industry incumbents from the obsolescing industry differ in terms of their entry patterns (Klepper & Simons, 2000; Mitchell, 1989), innovative activity (Khessina & Carroll, 2008), strategic renewal (Chen, Williams & Agarwal, 2012) and post-entry survival (Bayus & Agarwal, 2007; Carroll, Bigelow, Siedel & Tsai, 1996). In this stream of research, de novo or startup firms are those that are born in the focal industry context, and diversifying firms are pre-existing firms which enter (diversify) into the nascent industry. While the heterogeneity in outcomes across these three types of firms has been mostly attributed to the differences in the distinct histories of firms and their resource endowments (Helfat & Lieberman, 2002), the precise mechanisms by which the heterogeneity in firm type translates into economic outcome are less examined.

One important mechanism through which heterogeneity in firm type may be related to a firm's economic outcomes is through influencing the capability reconfiguration strategies that are pursued by firms in anticipation of entry into the focal industry. Capability reconfiguration strategies refer to the strategies that are undertaken by firms to modify their resource base and capability portfolio (Karim & Mitchell, 2000) and may include addition, deletion, and/or retention of capabilities. Whether entry to a nascent industry is undertaken by de novo startups, diversifying firms from related industries or incumbents from the obsolescing industry, a critical strategic action for firms is to engage in capability reconfiguration strategies required for filling their capability gap with the nascent industry. As different types of firms engage in activities to achieve the required configuration of capabilities for operations in the new industry, the *content*, *sequence*, and *source* of their capability reconfiguration mechanisms may differ (Agarwal & Helfat, 2009). Because these differential capability reconfiguration strategies may lead to persistent effects on firms' subsequent performance, it is critical to understand the differences in the paths that different types of firms pursue when reconfiguring themselves for entry into nascent industries.

In this essay, I study the extent to which de novo startups, diversifying firms and industry incumbents differ in the reconfiguration strategies pursued in anticipation of entry into a nascent industry. In the discussion of reconfiguration strategies, I focus on three dimensions of content – i.e., what capabilities to reconfigure–, sequence – i.e., in what order to reconfigure capabilities–, and source of capabilities –i.e., whether to rely on internal or external sources of capabilities. At the time of initial investment in a nascent industry, different types of firms may leverage heterogeneous bundles of capabilities, cognition and incentives. The differences in the initial conditions of these firms may imply that they pursue heterogeneous strategies to prepare themselves for entry into a new industry.

In terms of the content of capability reconfiguration strategies, I suggest that the capability requirements of a nascent industry require firms to narrow their capability gaps toward the same portfolio of capabilities. Even though the details of capabilities may differ across industries and firms, existing literature predominantly highlights the critical role of technical capabilities (Helfat & Raubitschek, 2000; Nerkar & Roberts, 2004) and specialized complementary assets (Gans & Stern, 2003; Teece, 1986) as two general categories of capabilities required for entry into nascent industries. In anticipation of entry into a nascent industry, startups, diversifying firms and incumbents focus their reconfiguration strategies on achieving the required configuration of technical capabilities and specialized complementary assets. In doing so, the content of their reconfiguration strategies is dependent on the types of capabilities that they lack as well as the types of capabilities that they possess at the time of initial investment. For instance, startups lacking specialized complementary asset are more likely to focus their efforts on gaining access to specialized complementary asset from scratch, while due to their initial technical capabilities, they are likely to focus their efforts on enhancing and modifying their current technical capabilities toward the nascent industry. However, in terms of the sequence of capability reconfiguration strategies and sources of capabilities, the differences across de novo startups, diversifying firms and incumbents are more salient.

To illustrate the implications of my propositions, I discuss the reconfiguration strategies of three firms in the agricultural biotechnology industry in the form of three case studies. Specifically, I focus on the capability reconfiguration strategies of Monsanto, DeKalb Genetics and Mycogen from the time of their initial technological investment until their market entry into the agricultural biotechnology industry as three illustrative examples.

This essay's main contribution is to show while reconfiguration strategies of firms in anticipation of entry into a nascent industry may focus on achieving the same content of technical capabilities and complementary assets, firms may undertake different paths given the differences in their initial conditions. In addition, I highlight that all three types of firms undertake extensive reconfiguration efforts since the time of their initial investments in a nascent industry by the time of market entry. In doing so, I complement the literature that has emphasized the importance of engaging in reconfiguration strategies for prior industry regime incumbents (Lavie, 2006).

This essay proceeds as follows. I first compare and contrast these three types of firms based on dimensions of firm capabilities, incentives and cognition. Then, I suggest how the underlying heterogeneity in firm types may be related to the reconfiguration strategies that each undertake. Finally, I describe the three descriptive cases from the agricultural biotechnology industry.

LITERATURE REVIEW

Performance Differences between Incumbents, Startups and Diversifying Entrants

Two related literature streams have examined the effect of heterogeneity in firm type on various outcome measures when entering into a nascent industry. The first stream examines the performance differentials of industry incumbents versus new entrants in the face of a discontinuous technological change (Cooper & Schendel, 1976; Henderson & Clark, 1990; Tushman & Anderson, 1986). Drawing on Schumpeter's (1942) discussion of creative destruction of existing industries by new ones, these studies have highlighted the tension between incumbents and new entrants during times of technological change, specifying conditions under which new entrants may replace industry incumbents. In particular, obsolescence of technological capabilities of industry incumbents at times of competence-destroying technological change (Tushman & Anderson, 1986) or in presence of architectural innovation (Henderson & Clark, 1990) has been noted as major reasons for incumbent failure; whereas possession of application-specific R&D capabilities (Sosa, 2009) or industry-specific complementary assets (Rothaermel, 2001; Teece, 1986; Tripsas, 1997), which retain value in the new industry, and are costly to access by entrants may favor of incumbent advantage. Moreover, managerial processes and organizational structures of incumbents (Hannan & Freeman, 1984; Tripsas & Gavetti, 2000), under-investment in disruptive technologies that do not cater to current customer needs (Adner, 2002; Christensen & Bower, 1996), or anticipation of unfavorable stock market reactions (Benner, 2007) may impede incumbent response to the entrepreneurial entry of new firms. Many of the insights from this literature are also similar to the dynamics of heterogeneity between incumbents and new entrants following any major change in the institutional environment such as industry deregulation (Walker, Madsen & Carini, 2002).

While the above literature focuses on incumbent–entrant dynamics, it does not address the heterogeneity within industry entrants. A parallel literature has examined the performance differentials across diversifying versus startup entrants (Carroll et al., 1996; Ganco & Agarwal, 2009; Klepper & Simons, 2000), while abstracting away from the concept of incumbency. Although both diversifying and startup entrants are new to the focal industry context, diversifying entrants may leverage some resources and capabilities from their prior experiences in other industries. This literature has compared diversifying and startup firms on various aspects of post-entry performance such as survival (Bayus & Agarwal, 2007; Carroll et al., 1996; Klepper & Simons, 2000), growth and strategic renewal (Chen et al., 2012), product portfolios (Khessina & Carroll, 2008) and market share (Klepper & Simons, 2000).

This literature review indicates that researchers have either compared incumbents to entrants without distinguishing between diversifying firms and startups, or compared diversifying firms to startups while abstracting away from incumbents. Few studies have called for making a distinction between the three types of firms (Sosa, 2013) and have compared all three firms simultaneously (Methe, Swaminathan & Mitchell, 1996). I follow this stream of research and distinguish between the three types of firms.

Underpinning Sources of Heterogeneity across Firms

When entering into a nascent industry, sources of heterogeneity across these different firm types may be attributed to their underlying capabilities, cognitive framing of the nascent industry and incentives for investment. In this section, I discuss how de novo startups, diversifying firms and industry incumbents differ across these dimensions when they seek to enter a nascent industry during its early stages. In terms of underlying capabilities, these studies underscore the importance of technical capabilities and complementary assets. By technical capabilities, I refer to a firm's expertise in the technology or scientific disciplinary area of the nascent industry. While industry incumbents from the obsolescing industry typically lack technical capabilities of the new industry regime, technical capabilities have been identified as a source of competitive advantage for both de novo and diversifying entrants. Since startups are created for the context of the new industry, their technical capabilities are core for the new industry and thus presumably a good fit (Agarwal, Echambadi, Franco & Sarkar, 2004; Khessina & Carroll, 2008; Klepper & Sleeper, 2005). Nonetheless, the related technical capabilities possessed by diversifying entrants have been noted to be equally if not more important (Bayus & Agarwal, 2007; Carroll et al., 1996; Klepper & Simons, 2000; Methe et al., 1996).

Complementary assets may confer an advantage to established firms relative to startups. By complementary assets, I refer to downstream market-related factors which are required for profiting from technical capabilities and facilitate product commercialization (Teece, 1986). Complementary assets may be generic or specialized for a particular context.

While specialized complementary assets are under control of industry incumbents, the advantages related to generic complementary assets could be reaped by both industry incumbents and diversifying entrants. Because specialized complementary assets such as production facilities, distribution channels and marketing expertise are specific to a particular context, it is likely that industry incumbents could leverage these industry-specific specialized complementary assets from their prior operations (Mitchell, 1989; Rothaermel, 2001; Tripsas, 1997). Nevertheless, diversifying and de novo entrants typically lack access to specialized complementary assets. The case is different for generic complementary assets such as the ability to manage businesses, the ability to conduct alliances and acquisitions, and access to financial capital (Helfat & Lieberman, 2002). Given the presence of both diversifying entrants and industry incumbents in pre-existing value chains and the experiences gained due to reconfiguration efforts for prior entry attempts, they are likely to have accumulated generic complementary assets that could be leveraged to the new industry context. For example, diversifying entrants have been found to fare better in the face of impediments to growth as they are more likely to engage in strategic renewal (Chen et al., 2012) and incumbents are better at learning by doing (Balasubramanian, 2011). De novo entrants, however, lack access to either form of complementary assets.

Firms also differ in terms of their cognitive framing of the nascent industry and their interpretation of the associated technological change. Managerial cognition may shape a firm's strategic actions during periods of environmental change (Barr, 1998) and may impact a firm's response to technological discontinuities (Eggers & Kaplan, 2009; Kaplan, Murray & Henderson, 2003). Similarly, researchers' beliefs and perceptions about the nascent technology may shape their key technical choices (Garud & Rappa, 1994) and in turn impact organizational outcomes. The heterogeneity in the beliefs and assumptions about the nature and direction of a technological change may be based on prior experiences of entrepreneurs (Shane, 2000) or managers in other industry contexts (Benner & Tripsas, 2012). Thus, prior histories of industry incumbents, de novo firms and diversifying firms may lead to their distinct cognitive framing of the opportunities within the nascent industry. For industry incumbents, past experiences in prior industry regime may impede their efforts in identification of opportunities related to the nascent industry (Tripsas & Gavetti, 2000) and thus become core rigidities (Leonard-Barton, 1992). However, entrants, regardless of their type, may be better at perceiving a wide range of opportunities. Although de novo startups have been often associated with flexibility and nimbleness, diversifying firms in the nascent industry context also have the ability to overcome organizational inertia that characterizes most established firms (Chen et al., 2012).

Another dimension that differentiates these three types of firms is their differential strategic incentives for investment in a new technology. Incumbents often have less incentive to invest in new technologies that would replace their existing competences (Arrow, 1962; Reinganum, 1983). Moreover, their dependence on a particular group of customers may lead to less investment in new technological domains that do not serve existing core customers (Christensen & Bower, 1996). However, de novo and diversifying entrants' investment behavior is less likely to be shaped by their existing commitments to particular customer bases or technological trajectories. Therefore, they have more incentive to invest in a nascent technology.

Table 3-1 summarizes this discussion. Heterogeneity in de novo startups, diversifying entrants and industry incumbents when entering into a nascent industry could be sorted along five dimensions of possession of technical capability, possession of specialized and generic complementary assets, cognitive framing of the nascent industry and incentives for investment in the new technology. Industry incumbents often benefit from the specialized and generic complementary assets that they leverage from their prior operations in the obsolete industry. However, they lack access to technical capabilities, have less incentive for investment and suffer from incorrect or incomplete cognition of the opportunities within the nascent industry. De novo firms may be characterized as the flip side of industry incumbents. While they lack specialized and generic complementary assets, they benefit from technical capabilities, have high incentive for investment in the nascent technology and are better at cognition of the opportunities within the nascent industry. Diversifying entrants lack access to specialized complementary assets whereas all the other dimensions are in their favor.

[Table 3-1 about here]

In the next section, I draw on these underpinning sources of heterogeneity in order to discuss the reconfiguration strategies that different types of firms undertake in anticipation of product commercialization and entry into a nascent industry.

PROPOSITIONS

For entry into a nascent industry, firms typically need to fill the capability gap that exists between their pre-existing endowments of capability and the capability requirements of the particular industry context (Helfat & Lieberman, 2002). Although potential entrants leverage some capabilities from their prior operations to the nascent industry, it is essential that they undertake additional capability reconfiguration efforts to achieve the configuration of capabilities needed for introduction of products and successful operation within the nascent industry. The second essay of my dissertation discussed two key capability factors for successful commercial performance of firms at the face of a technological change that characterizes nascent industries. First factor is a firm's technical capabilities in order to develop new products (Helfat & Raubitschek, 2000; Nerkar & Roberts, 2004), and the second is possession of specialized complementary assets in order to appropriate the economic benefits of a new product (Teece, 1986; Tripsas, 1997). I also showed that a firm's stock of technical capabilities and specialized complementary assets at the time of market entry is positively related to the likelihood of a firm's market entry into a nascent industry. Given the importance of technical capabilities and specialized complementary assets for entry into a nascent industry, I develop the propositions of the third essay based on the assumption that firms focus their reconfiguration strategies on narrowing their capability gap in terms of technical capabilities and specialized complementary assets.

Capability Gaps and the "Content" of Reconfiguration Strategies

I first discuss the content of reconfiguration strategies that firms undertake in order to fill their capability gap. Firms' efforts in gaining access to the required configuration capabilities may take the two forms of *capability extension* or *capability deepening* (Karim & Mitchell, 2000). When firms pursue capability deepening, they typically build on their current capabilities and tend to accumulate capabilities that are similar to a firm's existing capabilities. However, when they pursue capability extension, the focus of capability reconfiguration is on addition of new capabilities that are distinct from a firms' current capability portfolio. Depending on their initial position, firms differ in the extent to which they engage in capability deepening versus capability extension for gaining access to the required technical capabilities and specialized complementary assets. Drawing on Table 3-1, I discuss these differences for incumbents, de novo startups and diversifying entrants.

Industry incumbents of the prior industry regime may benefit from their stock of specialized complementary assets which retain value in the nascent context. However, their technical capabilities are likely to have become obsolete at the face of the technological discontinuity associated with the nascent industry. Thus, while incumbents are likely to leverage their specialized complementary assets to the nascent industry context, it is important that they strategically renew themselves and build technical capabilities from scratch. Accordingly, their reconfiguration efforts are likely to focus on gaining access to the technical capabilities which are distinct from their existing obsolete technical capabilities and take the form of capability extension. For specialized complementary assets, however, they are more likely to engage in capability deepening.

In narrowing their capability gap, diversifying entrants need to advance their existing technical capabilities. Even though they leverage some related technical capabilities to the focal industry, these technical capabilities often provide the basis for further capability development and acquisition. In fact, the initial technical capabilities are rarely adequate or in the right format for operations in the nascent industry. For instance, when petroleum firms initiated investments in synthetic fuels, they leveraged key technical capabilities to the new domain. However, those technical capabilities needed to be expanded by further engaging in R&D (Helfat, 1997). Hence, diversifying entrants are likely to engage in capability deepening to achieve the required mass and configuration of technical capabilities. Furthermore, given their lack of prior activity in the nascent industry, they have not accumulated specialized complementary assets and need to build them anew. In doing so, addition of specialized complementary assets to their capability portfolio resembles capability extension.

Given the similarities between diversifying and de novo entrants in terms of their initial access to technical capabilities and specialized complementary assets, the content of de novo entrants' capability reconfiguration follows a similar pattern as diversifying entrants. It should be noted that the idiosyncrasies of technical capabilities of de novo and diversifying entrants may differ. For example, related technical capabilities of diversifying entrants may result from their prior activities in related technological domains, whereas de novo firms' technical capabilities may be in the focal technological domain. Nonetheless, both types of firms need to append to their technical capabilities and engage in capability deepening.

To summarize, incumbents are more likely to engage in capability extension for achieving the required portfolio of technical capabilities, while startups and diversifying firms are more likely to engage in capability deepening for achieving the required portfolio of technical capabilities. For obtaining specialized complementary assets, incumbents are more likely to engage in capability deepening, while startups and diversifying firms are more likely to engage in capability extension.

"Sequence" of Capability Reconfiguration Strategies

Although the previous section indicates that potential entrants are likely to converge in terms of the content of their capability reconfiguration strategies and focus on including technical capabilities of the nascent industry context and specialized complementary assets in their capability portfolio, it is likely that they undertake divergent paths. In particular, they may sequence their activities very differently. In this section, I provide theoretical propositions regarding the sequence of activities that heterogeneous firms pursue.

The focus of industry incumbents of the obsolescing industry is to engage in capability deepening of specialized complementary assets, and capability extension of technical capabilities. For these firms, it is more important to gain access to the technical capabilities of the nascent field than to further enhance their stock of complementary assets for a number of reasons. First, without gaining access to the technical capabilities of the nascent field, industry incumbents are not able to utilize their specialized complementary assets for introduction of commercial products. The value of specialized complementary assets arises due to facilitating product commercialization and value appropriation from technical capabilities. Thus, it is likely that industry incumbents would take a satisficing approach with regard to their initial stock of complementary assets and put higher priority on developing technical capabilities. Second, incumbents are likely to be among the late entrants to a nascent industry due to their lower incentives for investment in a nascent technology field and organizational inertia in perception of new opportunities. Hence, when they initiate their reconfiguration toward the nascent industry, not only do they face a capability gap relative to the requirements of the nascent industry, but also they lag behind the other two types of potential entrants. Accordingly, they need to compensate for their lack of asset mass efficiencies (Dierickx & Cool, 1989) and absorptive capacity (Cohen & Levinthal, 1990) by emphasizing on narrowing the gap in terms of technical capabilities and allocate all their efforts in doing so. This prioritized allocation of efforts across the two reconfiguration strategies implies that strategic actions related to extension of technical capabilities is likely to precede deepening of specialized complementary assets. Therefore, I suggest:

Proposition 1a: Incumbents are likely to engage in extension of technical capabilities prior to deepening of specialized complementary assets.

Unlike incumbents that may prioritize across different activities, diversifying entrants are likely to engage in concurrent efforts for deepening of technical capability and extension of specialized complementary assets. Diversifying entrants are less likely to be encumbered by their past experiences and thus may benefit from the right cognitive framing with regard to the nascent industry. Their greater incentives for investment and their cognition advantage imply that they are among the early cohort of potential entrants and have more time flexibility in experimenting with various arrangements of required capabilities. Hence, there is less need for them to prioritize between deepening of technical capability and extension of specialized complementary assets. Moreover, due to their generic complementary assets such as the ability to manage businesses, the ability to conduct alliances and acquisitions, and access to financial capital, they are capable of pursuit of deepening of technical capability and extension of specialized complementary assets at the same time. Therefore, I suggest:

Proposition 1b: Diversifying entrants are likely to engage in deepening of technical capabilities concurrent with extension of specialized complementary assets.

Startups are, however, constrained in terms of their access to generic complementary assets. Not only do they lack financial capital for funding various reconfiguration efforts, but they are also less likely to benefit from general managerial capabilities required for pursuit of alternative modes of change such as alliances and acquisitions. Thus, it is less likely that they concurrently pursue extension of specialized complementary assets and deepening of technical capability. The key question for them is which activity to focus on. Given that their technical capability is their potential source of competitive advantage moving forward in the nascent industry, I suggest that they give higher priority to deepening of technical capabilities over extension of specialized complementary assets. If startups allocate all of their efforts to gaining access to specialized complementary assets, they may have less financial capital and managerial resources to devote to accumulating additional technical capabilities. This is despite the possibility that they are less likely to reap any economic value from extension of specialized complementary assets without additional accumulation of technical capabilities. Hence, they are more likely to delay extension of complementary assets to a time when they have achieved the required mass of technical capabilities. Thus, I suggest:

Proposition 1c: De novo entrants are likely to engage in deepening of technical capabilities prior to extension of specialized complementary assets.

External versus Internal "Sources" for Capability Reconfiguration

Another important aspect of reconfiguration efforts for potential entrants when entering into a nascent industry is to decide whether to draw on internal or external sources of capabilities. When drawing on in internal sources of capabilities, firms create a new capability within their existing boundaries by recombining their existing capabilities. When engaging in external capability sourcing, firms draw on capabilities that exist outside of their boundaries through mechanisms such as acquisitions, alliances, and in-licensing. Internal capability development and external sourcing of capabilities are two points of a continuum. In discussing these possible sources of capabilities, I consider the dominant source for each type of firm. However, some firms may evenly distribute their efforts between internal and external sources (Parmigiani, 2007), which I refer to as plural sourcing of capabilities.

There are advantages and disadvantages associated with drawing on each of these sources of capability. In general, internal capability development is likely to be more effective when the size of the capability gap is small (Capron & Mitchell, 2009; Helfat & Lieberman, 2002). In these conditions, firms benefit from their absorptive capacity (Cohen &

Levinthal, 1990) and pursue a path-dependent process of accumulating additional capabilities (Nelson & Winter, 1982). However, there is a risk that the path-dependency in a firm's capability development efforts leads to organizational inertia and obsolescence of capabilities. On the other hand, external capability sourcing provides firms a way to source capabilities that are distinct from their existing capabilities (Rosenkopf & Nerkar, 2001) and overcome time compression diseconomies (Dierickx & Cool, 1989). Nonetheless, firms should have experience in implementation of external sourcing mechanisms (Kale, Dyer & Singh, 2002; Sampson, 2005; Zollo & Singh, 2004), and effective integration of externally sourced capabilities with their in-house capabilities (Karim & Mitchell, 2004). Drawing on the insights from this literature, I next discuss how potential entrants differ in the extent to which they draw on internal versus external sources of capabilities.

For industry incumbents, external sourcing of technical capability is likely to be the dominant mode. Given the size of the industry incumbents' technical capability gap, external sourcing enables them to narrow their capability gap effectively and quickly. Moreover, industry incumbents' efforts in internal capability development may be impeded due to their limited cognitive framing of the opportunities in the nascent industry context. However, external sourcing of technical capability is likely to alleviate these concerns. Furthermore, generic complementary assets of industry incumbents facilitate their undertaking of external sourcing mechanisms such as alliances and acquisitions. With regard to deepening of specialized complementary assets, it is likely that industry incumbents build on their initial stock of specialized complementary assets and draw on their internal sources of capabilities. Therefore, I suggest:

Proposition 2a: Incumbents are likely to engage in extension of technical capabilities through external sources.

Proposition 2b: Incumbents are likely to engage in deepening of specialized complementary assets through internal sources.

Diversifying entrants' initial stock of technical capabilities enables their effort in internal capability development. Given the size of their technical capability gap, internal capability development becomes feasible for these firms. In addition, their access to generic complementary assets such as financial capital and the ability to use alternative modes of change is likely to make external sourcing of technical capabilities also a considerable option. When drawing on external sources of capabilities, they may append additional components to their existing technical capability portfolio and be able to engage in experimentation regarding alternative configurations of technical capabilities. I suggest that diversifying entrants engage in plural sourcing of technical capabilities so that they benefit from the advantages of both internal and external sources. For gaining access to specialized complementary assets, however, the size of capability gaps implies that external sourcing is more effective. In particular, because of diversifying entrants' experiences in previous value chains, they are likely to be able to integrate the externally sourced specialized complementary assets within their value chain.

Thus, I suggest:

Proposition 3a: Diversifying entrants are likely to engage in deepening of technical capabilities through plural sourcing.

Proposition 3b: Diversifying entrants are likely to engage in extension of specialized complementary assets through external sources.

For de novo startups, internal development of technical capabilities is likely to be the effective mode to deepen their capability base. Their initial access to technical capabilities provides a starting point for further recombination and development of new capabilities. Unlike diversifying entrants, they are less likely to benefit from generic complementary assets that facilitate external sourcing of technical capabilities. Moreover, they may not be capable of integrating externally sourced technical capabilities with their in-house capabilities. Therefore, external sourcing of technical capabilities is less likely to be pursued.

De novo startups' initial lack of access to specialized complementary assets implies that they have difficulty in internal development of specialized complementary assets. Given that external sourcing may provide a speedy way to access these assets and compensate for the startups' initial position, extension of specialized complementary assets is likely to draw on external sources. It should also be noted that although this is the dominant source of specialized complementary assets for startups, they may face critical challenges in pursuing external sourcing mechanisms such as acquisition due to their lack of prior experiences and lack of adequate financial resources.

Therefore, I suggest:

Proposition 4a: De novo entrants are likely to engage in deepening of technical capabilities through internal sources.

Proposition 4b: De novo entrants are likely to engage in extension of specialized complementary assets through external sources.

Taken together, these propositions highlight that due to the differential historical antecedents, incumbents of the obsolescing industry, de novo startups and diversifying firms differ in how they pursue capability extension and capability deepening for achieving the required configuration of technical capabilities and specialized complementary assets.

DESCRIPTIVE CASES

To illustrate the implication of my theoretical propositions, I provide abbreviated case histories of three firms in the agricultural biotechnology industry: DeKalb Genetics, Monsanto and Mycogen. First, I briefly describe the industry context of agricultural biotechnology and the capability requirements for entry into this nascent industry. I then provide a detailed discussion of the reconfiguration strategies that these three firms pursued since their initial technological investments in the industry. This discussion is based on information available in various secondary sources such as the USDA Biotechnology Research Service, the USDA Agricultural Marketing Service, the OECD BioTrack database, LexisNexis, SDC Platinum, Delphion, websites of firms, and their SEC filings.

The choice of these three firms is based on a number of reasons. First, given that my propositions focus on the differences across incumbents of the obsolescing industry, diversifying firms, and startups, I selected one firm from each category. DeKalb Genetics, Monsanto and Mycogen serve as examples of an incumbent, a diversifying firm, and a startup, respectively. Second, I selected firms that have achieved the required configuration of technical capabilities and specialized complementary assets at least to some extent so that description of their capability reconfiguration strategies in anticipation of entry into the agricultural biotechnology becomes meaningful. Finally, these three firms have all invested in the agricultural biotechnology in the same time period and thus faced similar environmental and industry context as they engaged in heterogeneous reconfiguration strategies. This method for selection of cases is consistent with the recommendations that illustrative cases may be chosen based on theoretical criteria rather than statistical sampling criteria (Eisenhardt, 1989).

Overview of the Agricultural Biotechnology Industry

Agricultural biotechnology is the use of modern biotechnology techniques to improve or modify plants with a particular focus on enhancing agricultural traits such as herbicide tolerance, pest resistance, and resistance to environmental stresses. This industry builds on a scientific discovery in 1977 that showed viability of genetic modification of plants. This scientific discovery laid the foundation for inception of the agricultural biotechnology industry when the first product of the agricultural biotechnology was introduced in 1995.

In the aftermath of this scientific discovery, firms with diverse historical backgrounds committed resources to transforming the technological opportunity related to agricultural biotechnology to a product with commercial value. Specifically, three types of firms that invested in agricultural biotechnology were: incumbents of the conventional agriculture industry, de novo startups, and diversifying firms from related industries, particularly chemical. Regardless of their type, these different firms focused their reconfiguration efforts in gaining access to technical capabilities and specialized complementary assets required for operations in the nascent industry. In the context of agricultural biotechnology, expertise in plant biotechnology – i.e., knowledge of gene sequences as well as methods of genetic transformation of plants – is considered the key technical capability, while access to elite varieties of crops – i.e., crop varieties that have been bred to show superior characteristics sought by farmers in each agro-climatic condition – is considered the key specialized complementary asset. In the second essay of my dissertation, I provided an in-depth discussion of these capability requirements using the example pest-resistant soybeans.[15]

[15] Please see page 67.

DeKalb Genetics, 1982-1997

DeKalb Corporation, founded in 1917, was a producer and supplier of agricultural products and services. Given its prior activity in the conventional agriculture industry, I categorize DeKalb Corporation as an industry incumbent. Prior to introduction of agricultural biotechnology, DeKalb Corporation relied on plant breeding capabilities to introduce elite varieties of crops. However, the advent of biotechnology and the associated discontinuous technological shock implied that plant breeding capabilities were no longer adequate and that firms needed to integrate plant breeding techniques with modern biotechnology for entry into the nascent field.

In 1982 and at the face of the technological changes in the agricultural biotechnology, DeKalb initiated technological investments toward this nascent industry. The initial instance of DeKalb’s technological investment in agricultural biotechnology was formation of a joint venture with Pfizer Inc. DeKalb’s management team identified Pfizer’s technical capabilities in the field of plant biotechnology as a major reason for formation of this joint venture named DeKalb-Pfizer, mentioning that: “Pfizer's extensive genetic engineering research program gives the new venture the opportunity to lead in application of this significant new science to the improvement of our products” (PR Newswire, 1982). Following this initial technological investment, DeKalb pursued a number of additional capability reconfiguration strategies till its first product commercialization and entry into agricultural biotechnology industry in 1997.

Capability portfolio of DeKalb in 1982 was comprised of a strong endowment of specialized complementary assets. DeKalb was involved in development of elite varieties of crops for years. Not only did DeKalb possess plant breeding capabilities, but it also had access to numerous protected plant varieties. In terms of technical capabilities, however, it was not considered to be in a strong position. During the 15 years since its technological investment in the industry by the time of its entry, DeKalb modified its portfolio of technical capabilities and specialized complementary assets in multiple ways. Table 3-2 shows the timeline of major events in the history of DeKalb.

[Table 3-2 about here]

In order to enhance its technical capabilities and its plant biotechnology knowledge, DeKalb was involved in alliances with Pfizer (in 1982 and 1989), Calgene (in 1988), and DuPont (in 1996). It also pursued technological acquisitions of BioTechnica (in 1991) and MGI Pharma (in 1996). Since 1988 and buyback of shares in DeKalb-Pfizer joint venture, DeKalb changed its name to DeKalb Genetics and set up in-house research centers. Despite the existence of this in-house research center, DeKalb's source of technical capabilities seemed to be mainly external sources. This observation is consistent with proposition 2a that incumbents are likely to engage in extension of technical capabilities through external sources. Drawing on these external sources of technical capabilities, DeKalb started conducting field trials and filing for agricultural biotechnology patents as early as 1990. Its endeavors in gaining access to technical capabilities of plant biotechnology culminated in 1995 when it applied for a petition for non-regulated status for an herbicide tolerant corn genetic modification event. This application later turned into its first commercialized product in 1997. These outcomes imply that DeKalb's efforts in modifying its technical capabilities were successful.

For specialized complementary assets, DeKalb mainly relied on its internal units for deepening of its pre-existing stock of specialized complementary assets. Since 1982, it continued its research in plant breeding, obtained several new protected plant varieties for corn and soybean, and also applied for several patents of elite corn and soybean varieties. DeKalb's focus on internal sources for deepening of specialized complementary assets is consistent with proposition 2b.

Also, the sequence of activities pursued by DeKalb may be modeled using some proxies of the extent to which it focused on reconfiguring its technical capabilities versus reconfiguring specialized complementary assets. The dotted line in Figure 3-1 shows the accumulated number of protected plant varieties that have been assigned to DeKalb. Protected plant varieties serve an indication of the extent to which a firm has access to specialized complementary assets within the context of agricultural biotechnology. The solid line shows the accumulated number of external technical capability sourcing activities that DeKalb pursued. The comparison of these two charts indicates that DeKalb focused on reconfiguring technical capabilities at an earlier time relative to reconfiguring its specialized complementary assets, which is consistent with proposition 1a.

[Figure 3-1 about here]

Mycogen, 1982-1998

Mycogen was a startup founded in 1982 by a biochemist from Stanford University and a venture capitalist from the San Diego area. Because Mycogen was founded for the objective of operating in the agricultural biotechnology industry, I consider its initial investment in the agricultural biotechnology as its time of founding. Similar to other agricultural biotechnology startups, Mycogen leveraged technical capabilities to the nascent industry. However, it lacked specialized complementary assets. Initially, Mycogen was more focused on developing biological pesticide and plant protection products based on microorganisms. Later, it expanded its scope of operations to develop pesticide incorporated plants. Its main technical capability, as evident through its patenting history and EPA records, was discovery of several toxins that can be encapsulated in transgenic plants and make them resistant to pests. Table 3-3 shows the timeline of major events in the history of Mycogen.

[Table 3-3 about here]

Given its portfolio of capabilities at the time of initial investment, reconfiguration efforts of Mycogen focused on further development of its plant biotechnology expertise as the critical technical capability and gaining access to plant breeding capability and elite varieties of crops as the critical specialized complementary assets. For deepening of its technical capabilities, Mycogen predominantly pursued in-house research and draw on the internal sources of technical capabilities available within its boundary. Its extensive patenting activity in the area of agricultural biotechnology is an indication of its strong in-house research. By 1992, Mycogen held 21 out of 39 US patents issued for strains of Bt toxin. In addition, these efforts were complemented with alliances with Monsanto (in 1987 and 1990), Lubrizol's Agrigenetics unit (in 1992) and Ciba Seeds (in 1993). This record of activity is consistent with proposition 4a which suggests internal sources as the major source for technical capability deepening by startups.

With regard to specialized complementary assets, Mycogen did not have a history of activity in the agriculture industry and lacked access to elite varieties of crops. In obtaining these specialized complementary assets, it mainly relied on external sources such as other seed firms and conventional agriculture firms. Alliances with Ciba Seeds (in 1993 and 1995), and Cargill (in 1996) as well acquisitions of United AgriSeeds (in 1996) and Morgan Seeds (in 1996) are examples of efforts in reconfiguring its portfolio of specialized complementary assets through external sources. Given that Mycogen was not involved in any internal development of specialized complementary assets, this line of activity is strongly consistent with proposition 4b which suggests external sources as the major source for extension of specialized complementary assets by startups.

The sequence of reconfiguration activities pursued by Mycogen is also consistent with proposition 1c in that deepening of technical capabilities precedes extension of specialized complementary assets. Figure 3-2 provides an illustration. The dashed line and the dotted line show the accumulated number of external technical capability sourcing activities and the accumulated number of patents as an indication of in-house research, respectively. The comparison with the solid line which shows the accumulated number of external specialized complementary assets sourcing activities indicates that Mycogen focused on reconfiguring technical capabilities at an earlier time relative to reconfiguring its specialized complementary assets. Prior to 1993, Mycogen devoted most of its resources and attention to development of technical capabilities. Jerry Caulder, CEO of Mycogen at the time, has once said: “By the early 1990s, it was apparent to us that biotechnology would be deployed in a manner that Mycogen was not organized to address. At that time, Mycogen did not have the capability to put genes into plants; it did not have the freedom to operate from an intellectual property standpoint; and it was not in the seed business in order to deliver the technology” (Kalaitzandonakes, 1997).

[Figure 3-2 about here]

Monsanto, 1980-1995

Monsanto was founded as a chemical company in 1901. Its first technological investment in the agricultural biotechnology related to its in-house research activities in

1980. Because of its background in the chemical industry, I categorize Monsanto as a diversifying firm that diversified from a related industry into the nascent agricultural biotechnology context. Similar to other diversified firms with chemical background, Monsanto lacked agricultural biotechnology capabilities in the either form of technical capabilities or specialized complementary assets prior to its investment. However, it was engaged in production of agriculture-related products such as herbicides and pesticides. In anticipation of entry into agricultural biotechnology industry, Monsanto sought to reconfigure both technical capabilities and specialized complementary assets. These efforts led to product commercialization by Monsanto in 1995. Table 3-4 shows the timeline of major events in the history of Monsanto.

[Table 3-4 about here]

In an effort to gain access to technical capabilities, Monsanto heavily relied on both internal and external sources of plant biotechnology expertise. Not only did it pursue a very strong in-house research center, but also it formed several alliances with other companies such as Biogen (in 1980), BioTechnica (in 1983), Ecogen (in 1987), Plant Genetics (in 1987), Mycogen (in 1990), Agracetus (in 1991) and Calgene (in 1993) as well as university scientists at the Washington University of Saint Louis. These efforts a concurrent focus on reconfigure technical capabilities drawing on both internal and external sources consistent with proposition 3a.

For specialized complementary assets, Monsanto relied on external sources of capability. For example, it benefitted from elite varieties of crops and distribution channels of Ciba Seeds (in 1993) and Sandoz Seeds (in 1995). This record of activity is consistent with preposition 3b.

CONCLUSIONS

This essay provides theoretical propositions regarding a firm's reconfiguration strategies in anticipation of entry to a nascent industry. I suggest that potential entrants to a nascent industry – i.e., incumbents of the obsolescing industry, de novo startups and diversifying entrants – are likely to pursue different reconfiguration strategies. While they all strive for gaining access to the critical configuration of technical capabilities and specialized complementary assets, the paths undertaken by these heterogeneous firms are different due to the differences in their historical antecedents. Specifically, they differ in the extent to which they pursue capability extension versus capability deepening, in the time sequence of pursuing different reconfiguration strategies, and in the source of capabilities.

Discussion of three case histories of firms in the agricultural biotechnology illustrates some of the implications of the model, and elaborates on the nature of reconfiguration strategies that are pursued. For future research and in preparation for journal submission, I plan to extend this essay by appending additional qualitative and quantitative data to the descriptive case histories.

Contributions of this essay to the strategic management literature are threefold. First, by delineating reconfiguration strategies undertaken by firms in anticipation of entry, this essay provides additional insights to the strategic renewal literature. The strategic renewal literature is interested in analyzing both the content and the process of firms' reconfiguration strategies (Agarwal & Helfat, 2009). A key conclusion of this essay is that firms pursue divergent processes for achieving a convergent content. For example, while their generic complementary assets and cognitive frames required them to undertake different sequence of activities or draw on different sources of capabilities, they were all focused on attaining a similar configuration of technical capabilities and specialized complementary assets.

In addition, although existing literature has examined how industry incumbents reconfigure themselves at the face of a technological breakthrough that has rendered their capabilities obsolete (Hill & Rothaermel, 2003; Lavie, 2006), less attention has been devoted to how de novo and diversifying firms reconfigure their capability portfolio in anticipation of entry into an industry. This essay underscores that de novo and diversifying firms also engage in capability reconfigurations and that their capability reconfiguration efforts are critical for their entry. Indeed, entry of diversifying and de novo entrants to a nascent industry is accompanied by critical challenges related to reconfiguring themselves based on the requirements of the nascent industry. Therefore, industry incumbents are not the only firms that undergo reconfiguration.

Finally, by examining the implications of firms' heterogeneity in shaping their reconfiguration strategies, the third and final essay of my dissertation extends the literature that has connected a firm's type to interim strategic decisions such as product demography (Khessina & Carroll, 2005), technology strategy (Bayus & Agarwal, 2007), and vertical integration (Qian, Agarwal & Hoetker, 2012). Historical antecedents of firms may impact the bundle of capabilities and cognitive frames that potential entrants leverage into a nascent industry. However, these underlying sources of heterogeneity are important because of how they translate into strategic activities that firms pursue. In this essay, capability reconfiguration efforts of firms in anticipation of entry into a nascent industry are discussed as an activity influenced by firms' historical antecedents.

Table 3-1: Underpinning Sources of Heterogeneity across Firms

		Sources of Heterogeneity When Entry into a Nascent Industry				
		Technical capabilities	Specialized complementary assets	Generic complementary asset	Cognition toward the nascent industry	Incentives for Investment
Firm Type	De novo startups	Y	N	N	Y	Y
	Diversifying firms	Y	N	Y	Y	Y
	Industry incumbents	N	Y	Y	N	N

Y indicated that a column item is in favor of a firm's operation within the nascent industry.
N indicated that a column item is not in favor of a firm's operation within the nascent industry.

Table 3-2: History of DeKalb Genetics

Year	Event	Reconfiguration Strategy
1917	DeKalb Corporation was founded.	
1982	DeKalb Corporation and Pfizer Inc. formed a joint venture, DeKalb-Pfizer Genetics.	Initial investment – Focus on technical capabilities
1988	Agreement with Crop Genetics to conduct large-scale field trials and market Crop Genetics' genetically engineered bio-insecticide directed against corn's major pest.	
1988	Agreement with Calgene to develop elite DeKalb hybrids containing the GlyphoTol(R)1 gene.	Focus on technical capabilities
1988	DeKalb Corp spun off its agricultural genetics businesses, changing its name to DeKalb Genetics.	
1989	The DeKalb Genetics Corporation said it had agreed to buy Pfizer Inc.'s 30 percent interest in DeKalb-Pfizer Genetics.	
1989	DeKalb Genetics said it would continue to conduct agricultural biotechnology research for at least five years at Pfizer's research center.	Focus on technical capabilities
1990	First field trial application.	
1991	DeKalb Genetics acquired Plant Science Research from BioTechnica.	Focus on technical capabilities
1995	Seeking petition for non-regulated status for HT corn.	
1996	DeKalb Genetic acquired certain non-core agricultural patents of MGI Pharma.	Focus on technical capabilities
1996	DeKalb Genetics Corp and EI DuPont Nemours entered into a cross licensing agreement in which DeKalb received the rights to DuPont's Biostic gene gun and DuPont received the right to nutritionally enhanced corn and soybeans.	Focus on technical capabilities
1996	Monsanto acquired 38 percent of DeKalb Genetics share.	
1997	First transgenic trait (HT corn) sales.	
1998	Monsanto acquired 60 percent remaining shares of DeKalb Genetics.	

Table 3-3: History of Mycogen

Year	Event	Reconfiguration Strategy
1982	Mycogen founded by David H. Rammler, a partner in the venture capital firm of Vanguard Associates, and Andrew C. Barnes, a biochemist.	Initial investment
1984	First series of patent applications.	
1987	Initial public offering of 1.6 million shares of common stock	
1987	Agreement with Monsanto to benefit from Monsanto's microencapsulation delivery technology	Focus on technical capabilities
1990	Agreement with Monsanto to develop plants resistant to nematode	Focus on technical capabilities
1991	First approval of genetically engineered bio-insecticides for commercial sale by the Environmental Protection Agency.	
1992	Agreement with Lubrizol, Acquisition of Agrigenetics to generate pest resistant crop varieties to be commercialized through the seed business of Agrigenetics.	Focus on technical capabilities
1993	First field trial application.	
1993	Agreement with Ciba Seeds	Focus on both technical capabilities and complementary assets
1993	Agreement with Forage Genetics to introduce genes from Bacillus thuringiensis (Bt) bacteria into alfalfa varieties	
1995	Agreement with Pioneer Hi-Bred to develop transgenic crops with built-in insect resistance.	
1995	Agreement with Ciba Seeds to distribute Mycogen seeds	Focus on complementary assets
1996	Agreement with Cargill to distribute Mycogen seeds	Focus on complementary assets
1996	Agreement with DowElanco, Acquisition of United AgriSeeds	Focus on complementary assets
1996	Acquisition of Morgan Seeds	Focus on complementary assets
1998	Dow AgroSciences acquired Mycogen.	

Table 3-4: History of Monsanto

Year	Event	Reconfiguration Strategy
1901	Monsanto was founded.	
1980	Agricultural biotechnology research center was established.	Initial investment – focus on technical capabilities
1980	Research agreement with Biogen	Focus on technical capabilities
1983	Announcement of a major technological discovery by Monsanto scientists	
1983	Research agreement with BioTechnica	Focus on technical capabilities
1986	First field trial application.	
1987	Research agreement with Ecogen	Focus on technical capabilities
1987	Research agreement with Plant Genetics	Focus on technical capabilities
1990	Agreement with Mycogen	Focus on technical capabilities
1991	Research agreement with Agracetus	Focus on technical capabilities
1993	Research agreement with Calgene	Focus on technical capabilities
1993	Agreement with Ciba Seeds	Focus on complementary assets
1995	Agreement with Sandoz Seeds	Focus on complementary assets
1995	First transgenic trait sales.	
2013	Monsanto continues its operations in agricultural biotechnology.	

Figure 3-1: Sequence of Reconfiguration Efforts of DeKalb Genetics

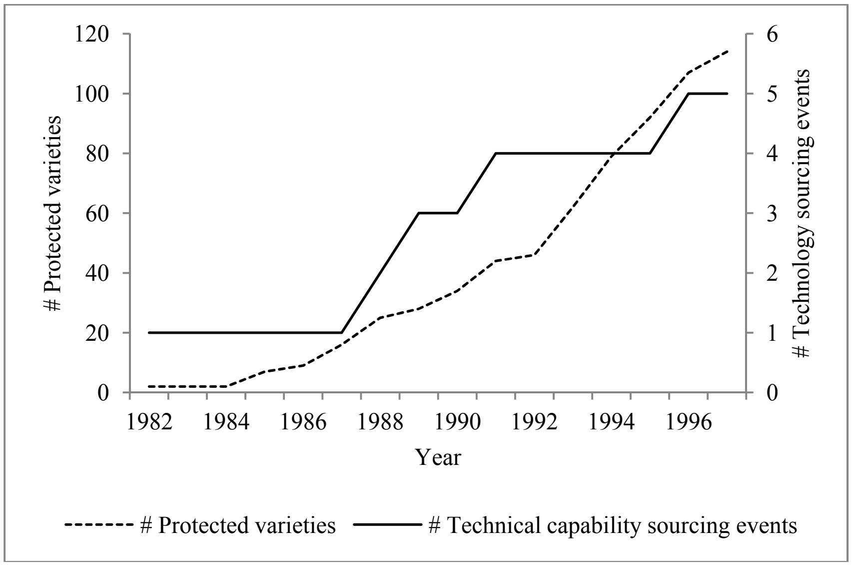
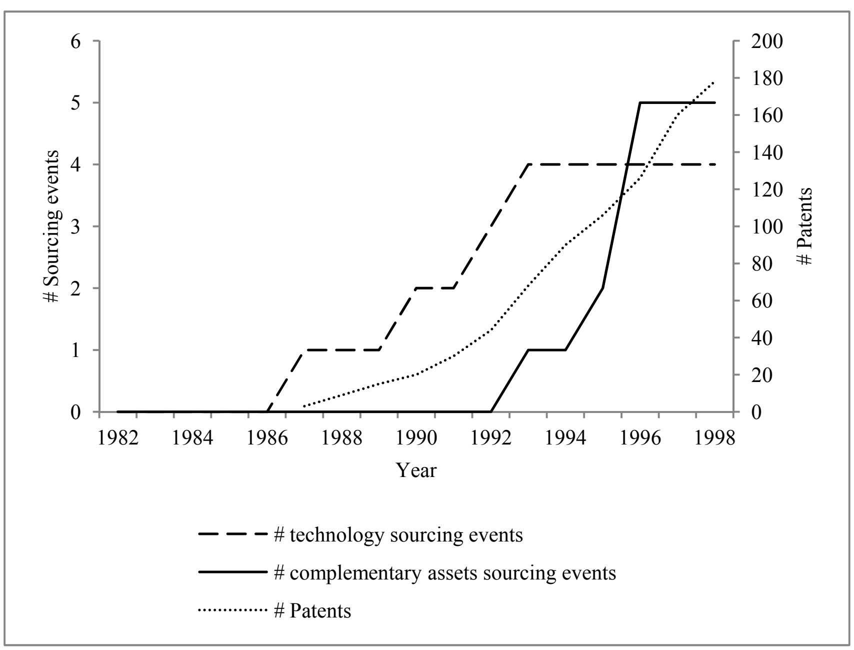


Figure 3-2: Sequence of Reconfiguration Efforts of Mycogen



REFERENCES

Abernathy, W. J., & Utterback, J. M. 1978. Patterns of industrial innovation. *Technology Review*, 80(7), 40-47.

Acs, Z. J., & Audretsch, D. B. 1988. Innovation in large and small firms: An empirical analysis. *American Economic Review*, 78(4): 678-690.

Adner, R. 2002. When are technologies disruptive? A demand-based view of the emergence of competition. *Strategic Management Journal*, 23(8): 667-688.

Adner, R. 2006. Match your innovation strategy to your innovation ecosystem. *Harvard Business Review*, 84(4): 98-107.

Adner, R., & Kapoor, R. 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal*, 31(3): 306-333.

Agarwal, R., & Bayus, B. 2002. The market evolution and sales takeoff of product innovations. *Management Science*, 48(8): 1024-1041.

Agarwal, R., Echambadi, R., Franco, A. M., & Sarkar, M. 2004. Knowledge transfer through inheritance: Spin-out generation, development, and survival. *Academy of Management Journal*, 47(4): 501-522.

Agarwal, R., & Gort, M. 1996. The evolution of markets and entry, exit and survival of firms. *The Review of Economics and Statistics*, 78(3): 489-498.

Agarwal, R., & Helfat, C. E. 2009. Strategic renewal of organizations. *Organization Science*, 20(2): 281-293.

Agarwal, R., Sarkar, M., & Echambadi, R. 2002. The conditioning effect of time on firm survival: An industry life cycle approach. *The Academy of Management Journal*, 45(5): 971-994.

Agarwal, R. & Tripsas. M. 2008. Technology and industry evolution, in S. Shane (Ed.), *Handbook of Technology and Innovation Management* (pp. 3-55). West Sussex, UK: John Wiley and Sons Ltd.

Ahuja, G., & Katila, R. 2001. Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study. *Strategic Management Journal*, 22(3): 197-220.

Amburgey, T. L., Kelly, D., & Barnett, W. P. 1993. Resetting the clock: The dynamics of organizational change and failure. *Administrative Science Quarterly*, 38(1): 51-73.

Argyres, N., & Zenger, T. 2013. Capabilities, transaction costs and firm boundaries. *Organization Science*, forthcoming.

Arikan, I. 2003. Exit decisions of entrepreneurial firms: IPOs versus M&As, in A. Ginsberg and I. Hasan (Eds.), *New Venture Investment: Choices and Consequences* (pp. 103-151). Amsterdam, Netherlands: Elsevier B.V.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. Cambridge, MA: MIT Press.

Arora, A., & Nandkumar, A. 2011. Cash-out or flameout! Opportunity cost and entrepreneurial strategy: Theory, and evidence from the information security industry. *Management Science*, 57(10): 1844-1860.

Arrow, K. 1962. Economic welfare and the allocation of resources for inventions in R. R. Nelson (Ed.), *The Rate and the Direction of Inventive Activity: Economic and Social Factors* (pp. 609-625). Princeton, NJ: Princeton University Press.

Balasubramanian, N. 2011. New plant venture performance differences among incumbent, diversifying, and entrepreneurial firms: The impact of industry learning intensity. *Management Science*, 57(3): 549-565.

Baron, R. M., & Kenny, D. A. 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6): 1173-1182.

Barr, P. S. 1998. Adapting to unfamiliar environmental events: A look at the evolution of interpretation and its role in strategic change. *Organization Science*, 9(6): 644-669.

Bayus, B. L., & Agarwal, R. 2007. The role of pre-entry experience, entry timing, and product technology strategies in explaining firm survival. *Management Science*, 53(12): 1887-1902.

Benner, M. J. 2007. The incumbent discount: Stock market categories and response to radical technological change. *Academy of Management Review*, 32(3): 703-720.

Benner, M. J., & Tripsas, M. 2012. The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras. *Strategic Management Journal*, 33(3): 277-302.

Bercovitz, J. E. L., & Feldman, M. P. 2007. Fishing upstream: Firm innovation strategy and university research alliances. *Research Policy*, 36(7): 930-948.

Brau, J., Francis, F., & Kohers, N. 2003. The choice of IPO versus takeover: Empirical evidence. *Journal of Business*, 76(4): 583-612.

Camp, R. 1989. *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance*. Milwaukee, WI: Quality Press.

Capron, L. 1999. The long-term performance of horizontal acquisitions. *Strategic Management Journal*, 20(11): 987-1018.

Capron, L., Dussauge, P., & Mitchell, W. 1998. Resource redeployment following horizontal acquisitions in Europe and North America, 1988-1992. *Strategic Management Journal*, 19(7): 631-661.

Capron, L., & Mitchell, W. 2009. Selection capability: How capability gaps and internal social frictions affect internal and external strategic renewal. *Organization Science*, 20(2): 294-312.

Capron, L., Mitchell, W., & Swaminathan, A. 2001. Asset divestiture following horizontal acquisitions: A dynamic view. *Strategic Management Journal*, 22(9): 817-844.

Carroll, G., Bigelow, L. S., Seidel, M. D. L., & Tsai, L. B. 1996. The fates of de novo and de alio producers in the American automobile industry 1885-1981. *Strategic Management Journal*, 17(S1): 117-137.

Carroll, G., & Hannan, M. T. 1989. Density dependence of populations of newspaper organizations. *American Sociological Review*, 54(4): 524-541.

Carroll, G., & Hannan. M. T. 2000. *The Demography of Corporations and Industries*. Princeton, NJ.: Princeton University Press.

Carroll, G., & Khessina. O. M. 2005. The ecology of entrepreneurship in R. Agarwal, S. A. Alvarez, O. Sorenson (Eds.), *Handbook of Entrepreneurship: Disciplinary Perspectives* (pp. 167-200). New York: Kluwer.

Cassiman, B., & Veugelers, R. 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, 52(1): 68-82.

Chatterjee, S., & Wernerfelt, B. 1991. The link between resources and type of diversification: Theory and evidence. *Strategic Management Journal*, 12(1): 33-48.

Chandler, A. D. 2005. *Shaping the Industrial Century: Remaking Story of the Evolution of Modern Chemical and Pharmaceutical Industries*. Cambridge, MA: Harvard University Press.

Chaudhuri, S., & Tabrizi, B. 1999. Capturing the real value in high-tech acquisitions. *Harvard Business Review*, 77(5): 123-130.

Chen, P., Williams, C., & Agarwal, R. 2012. Growing pains: Pre-entry experience and the challenge of transition to incumbency. *Strategic Management Journal*, 33(3): 252-276.

Christensen, C. M., & Bower, J. L. 1996. Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal*, 17(3): 197-218.

Cohen, W. M., & Levinthal, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1): 128-152.

Cooper, A. C., & Schendel, D. 1976. Strategic responses to technological threats. *Business Horizons*, 19(1): 61-69.

Danneels, E. 2002. The dynamics of product innovation and firm competences. *Strategic Management Journal*, 23(12): 1095-1121.

Dierickx, I., & Cool, K. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science*, 35(12): 1504-1511.

Dushnitsky, G., & Lenox, M. J. 2005. When do firms undertake R&D by investing in new ventures? *Strategic Management Journal*, 26(10): 947-965.

Dushnitsky, G., & Shapira, Z. 2010. Entrepreneurial finance meets organizational reality: Comparing investment practices and performance of corporate and independent venture capitalists. *Strategic Management Journal*, 31(9): 990-1017.

Eggers, J. P., & Kaplan, S. 2009. Cognition and renewal: Comparing CEO and organizational effects on incumbent adaptation to technical change. *Organization Science*, 20(2): 461-477.

Eisenhardt, K. M. 1989. Building Theories from Case Study Research. *Academy of Management Review*, 14 (4): 532-550.

Ethiraj, S. K., Ramasubbu, N., & Krishnan, M. S. 2012. Does complexity deter customer-focus? *Strategic Management Journal*, 33(2): 137-161.

Financial Times. 1997. Monsanto in $1.02bn life sciences acquisition. January 7.

Fine, J. P., & Gray, R. J. 1999. A proportional hazards model for the subdistribution of a competing risk. *Journal of the American Statistical Association*, 94(446): 496-509.

Forbes, D. P., & Kirsch, D. A. 2011. The study of emerging industries: Recognizing and responding to some central problems. *Journal of Business Venturing*, 26(5): 589-602.

Fortune, A., & Mitchell, W. 2012. Unpacking firm exit at the firm and industry levels: The adaptation and selection of firm capabilities. *Strategic Management Journal*, 33(7): 794-819.

Ganco, M., & Agarwal, R. 2009. Performance differentials between diversifying entrants and entrepreneurial start-ups: A complexity approach. *Academy of Management Review*, 34(2): 228-252.

Gans, J. S., Hsu, D. H., & Stern, S. 2002. When does start-up innovation spur the gale of creative destruction? *RAND Journal of Economics*, 33(4): 571-586.

Gans, J. S., & Stern, S. 2003. The product market and the market for "ideas": Commercialization strategies for technology entrepreneurs. *Research Policy*, 32(2): 333-350.

Garud, R., & Rappa, M. A. 1994. A socio-cognitive model of technology evolution: The case of cochlear implants. *Organization Science*, 5(3): 344-362.

Ghemawat, P. 1991. *Commitment: The Dynamics of Strategy*. New York: Free Press.

Golder, P. N., Shacham, R., & Mitra, D. 2009. Innovations' origins: When, by whom, and how are radical innovations developed? *Marketing Science*, 28(1): 166-179.

Goldfarb, B., Kirsch, D., & Miller, D. A. 2007. Was there too little entry during the dot com era? *Journal of Financial Economics*, 86(1): 100-144.

Gompers, P. A. 1995. Optimal investment, monitoring, and the staging of venture capital. *Journal of Finance*, 50(5): 1461-1489.

Gort, M., & Klepper, S. 1982. Time paths in the diffusion of product innovations. *Economic Journal*, 92(367): 630-653.

Graff, G. D. 2003. Observing technological trajectories in patent data: Empirical methods to study the emergence and growth of new technologies. *American Journal of Agricultural Economics*, 85(5): 1266-1274.

Hannan, M. T. & Carroll, G. R. 1992. *Dynamics of Organizational Populations: density, legitimization and competition.* Oxford, UK: Oxford University Press.

Hannan, M. T., & Freeman, J. 1977. The population ecology of organizations. *American Journal of Sociology*, 82(5): 929-964.

Hannan, M. T., & Freeman, J. 1984. Structural inertia and organizational change. *American Sociological Review*, 49(2): 149-164.

Hargadon, A., & Douglas, Y. 2001. When innovations meet institutions: Edison and the design of the electric light. *Administrative Science Quarterly*, 46(3): 476-501.

Helfat, C. E. 1997. Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strategic Management Journal*, 18(5): 339-360.

Helfat, C. E., & Lieberman, M. B. 2002. The birth of capabilities: Market entry and the importance of pre-history. *Industrial and Corporate Change*, 11(4): 725-760.

Helfat, C. E., & Peteraf, M. A. 2003. The dynamic resource-based view: Capability lifecycles. *Strategic Management Journal*, 24(10): 997-1010.

Helfat, C. E., & Raubitschek, R. 2000. Product sequencing: Co-evolution of knowledge, capabilities and products. *Strategic Management Journal*, 21(10-11): 961-979.

Henderson, R. 1993. Underinvestment and incompetence as responses to radical innovation: Evidence from the photolithographic alignment equipment industry. *RAND Journal of Economics*, 24(2): 248-270.

Henderson, R., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, 35(1): 9-30.

Henderson, R., & Cockburn, I. 1994. Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic Management Journal*, 15(S1): 63-84.

Henderson, R., & Cockburn, I. 1996. Scale, scope, and spillovers: The determinants of research productivity in drug discovery. *RAND Journal of Economics*, 27(1): 32-59.

Hill, C. W. L., & Rothaermel, F. T. 2003. The performance of incumbent firms in the face of radical technological innovation. *Academy of Management Review*, 28(2): 257-274.

Hoetker, G., & Agarwal, R. 2007. Death hurts, but it isn't fatal: The post-exit diffusion of knowledge created by innovative companies. *Academy of Management Journal*, 50(2): 446-467.

Jacobides, M. G., & Winter, S. G. 2005. The co-evolution of capabilities and transaction costs: Explaining the institutional structure of production. *Strategic Management Journal*, 26(5): 395-413

James, C. 2011. Global status of commercialized biotech/ gm crops: 2011. International service for the acquisition of agri-biotech applications. *ISAAA Brief*s.

Jovanovic, B. 2004. The pre-producers. *NBER Working Paper*, No. w10771.

Kalaitzandonakes, N. 1997. Mycogen: Building a Seed Company for the Twenty-First Century *Review of Agricultural Economic*, 19(2): 453-462

Kale, P., Dyer, J. H., & Singh, H. 2002. Alliance capability, stock market response, and long-term alliance success: The role of the alliance function. *Strategic Management Journal*, 23(8): 747-767.

Kaplan, S. 2008. Cognition, capabilities, and incentives: Assessing firm response to the fiber-optic revolution. *Academy of Management Journal*, 51(4): 672-695.

Kaplan, S., Murray, F., & Henderson, R. 2003. Discontinuities and senior management: Assessing the role of recognition in pharmaceutical firm response to biotechnology. *Industrial and Corporate Change*, 12(2): 203-233.

Kapoor, R., & Lim, K. 2007. The impact of acquisitions on the productivity of inventors at semiconductor firms: A synthesis of knowledge-based and incentive-based perspectives. *Academy of Management Journal*, 50(5): 1133-1155.

Karim, S. 2006. Modularity in organizational structure: The reconfiguration of internally developed and acquired business units. *Strategic Management Journal*, 27(9): 799-823.

Karim, S., & Mitchell, W. 2000. Path-dependent and path-breaking change: Reconfiguring business resources following acquisitions in the US medical sector, 1978-1995. *Strategic Management Journal*, 21(10-11): 1061-1081.

Karim, S., & Mitchell, W. 2004. Innovating through acquisition and internal development: A quarter-century of boundary evolution at Johnson & Johnson. *Long Range Planning*, 37(6): 525-547.

Katila, R., & Ahuja, G. 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal*, 45(6): 1183-1194.

Khessina, O. M., & Carroll, G. R. 2008. Product demography of de novo and de alio firms in the optical disk drive industry, 1983-1999. *Organization Science*, 19(1): 25-38.

King, A., & Tucci, C. 2002. Incumbent entry into new market niches: The role of experience and managerial choice in the creation of dynamic capabilities. *Management Science*, 48(2): 171-186.

Klepper, S., & Simons, K. L. 2000. Dominance by birthright: Entry of prior radio producers and competitive ramifications in the US television receiver industry. *Strategic Management Journal*, 21(10-11): 997-1016.

Klepper, S., & Sleeper, S. 2005. Entry by spinoffs. *Management Science*, 51(8): 1291-1306.

Knott, A. M., & Posen, H. E. 2005. Is failure good? *Strategic Management Journal*, 26(7): 617-641.

Kohli, R., Lehmann, D. R., & Pae, J. 1999. Extent and impact of incubation time in new product diffusion. *Journal of Product Innovation Management*, 16(2): 134-144.

Lavie, D. 2006. Capability reconfiguration: An analysis of incumbent responses to technological change. *Academy of Management Review*, 31(1): pp. 153-174.

Lee, G. K. 2008. Relevance of organizational capabilities and its dynamics: What to learn from entrants' product portfolios about the determinants of entry timing. *Strategic Management Journal*, 29(12): 1257-1280.

Leonard-Barton, D. 1992. Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, 13(S1): 111-125.

Levinthal, D. A. 1998. The slow pace of rapid technological change: Gradualism and punctuation in technological change. *Industrial and Corporate Change*, 7(2): 217-247.

Lieberman, M. B. 1990. Exit from declining industries: shakeout or stakeout? *RAND Journal of Economics*, 21(4): 538-554.

Lieberman, M. B., & Montgomery, D. B. 1988. First-mover advantages. *Strategic Management Journal*, 9(S1): 41-58.

Lomi, A., Larsen, E. R., & Wezel, F. C. 2010. Getting there: Exploring the role of expectations and preproduction delays in processes of organizational founding. *Organization Science*, 21(1): 132-149.

Lowe, R. A., & Ziedonis, A. A. 2006. Overoptimism and the performance of entrepreneurial firms. *Management Science*, 52(2): 173-186.

MacKinnon, D. 2008. *Introduction to Statistical Mediation Analysis*. New York: Taylor and Francis Group.

Mahoney, J. T., & Pandian, J. R. 1992. The resource-based view within the conversation of strategic management. *Strategic Management Journal*, 13(5): 363-380.

Malerba, F., & Orsenigo, L. 1999. Technological entry, exit and survival: An empirical analysis of patent data. *Research Policy*, 28(6): 643-660.

Methe, D., Swaminathan, A., & Mitchell, W. 1996. The underemphasized role of established firms as the sources of major innovations. *Industrial and Corporate Change*, 5(4): 1181-1203.

Mitchell, W. 1989. Whether and when - probability and timing of incumbents entry into emerging industrial subfields. *Administrative Science Quarterly*, 34(2): 208-230.

Mitchell, W. 1991. Dual clocks - entry order influences on incumbent and newcomer market share and survival when specialized assets retain their value. *Strategic Management Journal*, 12(2): 85-100.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1996. Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal*, 17: 77-91.

Nelson, S. G., & Winter, R. R. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap.

Nerkar, A., & Roberts, P. W. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. *Strategic Management Journal*, 25(8-9): 779-799.

New York Times. 1997. Monsanto in a big seed deal whose price raises eyebrows. January 7.

Parmigiani, A. 2007. Why do firms both make and buy? An investigation of concurrent sourcing. *Strategic Management Journal*, 28(3): 285-311.

Paruchuri, S., Nerkar, A., & Hambrick, D. C. 2006. Acquisition integration and productivity losses in the technical core: Disruption of inventors in acquired companies. *Organization Science*, 17(5): 545-562.

Penrose, E. T. 1959. *The Theory of the Growth of the Firm*. New York: John Wiley & Sons.

PR Newswire. 1982. Dekalb AgResearch and Pfizer announced a joint venture. July 15.

Puranam, P., Singh, H., & Chaudhuri, S. 2009. Integrating acquired capabilities: When structural integration is (un)necessary. *Organization Science*, 20(2): 313-328.

Qian, L., Agarwal, R., & Hoetker, G. 2012. Configuration of value chain activities: The effect of pre-entry capabilities, transaction hazards, and industry evolution on decisions to internalize. *Organization Science*, 23(5): 1330-1349.

Quigley, T. J., & Hambrick, D. C. 2012. When the former CEO stays on as board chair: Effects on successor discretion, strategic change, and performance. *Strategic Management Journal*, 33(7): 834-859.

Reinganum, J. F. 1983. Uncertain innovation and the persistence of monopoly. *American Economic Review*, 73(4): 741-748.

Rosenbloom, R. S., & Cusumano, M. A. 1987. Technological pioneering and competitive advantage: The birth of the VCR industry. *California Management Review*, 29(4): 51-76.

Rosenkopf, L., & Almeida, P. 2003. Overcoming local search through alliances and mobility. *Management Science*, 49(6): 751-766.

Rosenkopf, L., & Nerkar, A. 2001. Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, 22(4): 287-306.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic Management Journal*, 22(6-7): 687-699.

Rothaermel, F. T., & Hill, C. W. L. 2005. Technological discontinuities and complementary assets: A longitudinal study of industry and firm performance. *Organization Science*, 16(1): 52-70.

Sampson, R. C. 2005. Experience effects and collaborative returns in R&D alliances. *Strategic Management Journal*, 26(11): 1009-1031.

Schumpeter, J. A. 1942. *Capitalism, Socialism, and Democracy*. New York: Harper.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. *Organization Science*, 11(4): 448-469.

Silverman, B. S. 1999. Technological resources and the direction of corporate diversification: Toward an integration of the resource-based view and transaction cost economics. *Management Science*, 45(8): 1109-1124.

Song, J., Almeida, P., & Wu, G. 2003. Learning–by–hiring: When is mobility more likely to facilitate interfirm knowledge transfer? *Management Science*, 49(4): 351-365.

Sosa, M. L. 2009. Application-specific R&D capabilities and the advantage of incumbents: Evidence from the anticancer drug market. *Management Science*, 55(8): 1409-1422.

Sosa, M. 2013. Decoupling market incumbency from organizational prehistory: Locating the real sources of competitive advantage in R&D for radical innovation. *Strategic Management Journal*, 34(2): 245-255.

Teece, D. J. 1986. Profiting from technological innovation - implications for integration, collaboration, licensing and public-policy. *Research Policy*, 15(6): 285-305.

Teece, D. J., Pisano, G., & Shuen, A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7): 509-533.

Tripsas, M. 1997. Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal*, 18(S1): 119-142.

Tripsas, M., & Gavetti, G. 2000. Capabilities, cognition, and inertia: Evidence from digital imaging. *Strategic Management Journal*, 21(10-11): 1147-1161.

Tushman, M. L., & Anderson, P. 1986. Technological discontinuities and organizational environments. *Administrative Science Quarterly*, 31(3): 439-465.

Utterback, J. M., & Suárez, F. F. 1993. Innovation, competition, and industry structure. *Research Policy*, 22(1): 1-21.

Walker, G., Madsen, T. L., & Carini, G. 2002. How does institutional change affect heterogeneity among firms? *Strategic Management Journal*, 23(2): 89-104.

Wernerfelt, B. 1984. A resource-based view of the firm. *Strategic Management Journal*, 5(2): 171-180.

Winter, S. G. 2003. Understanding dynamic capabilities. *Strategic Management Journal*, 24(10): 991-995.

Zollo, M., Reuer, J. J., & Singh, H. 2002. Interorganizational routines and performance in strategic alliances. *Organization Science*, 13(6): 701-713.

Zollo, M., & Singh, H. 2004. Deliberate learning in corporate acquisitions: Post-acquisition strategies and integration capability in U.S. bank mergers. *Strategic Management Journal*, 25(13): 1233-1256.

Zollo, M., & Winter, S. G. 2002. Deliberate learning and the evolution of dynamic capabilities. *Organization Science*, 13(3): 339-351.

Zucker, L. G., Darby, M. R., & Armstrong, J. S. 2002. Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science*, 48(1): 138-153.