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ABSTRACT

Combining Cyert and March’s (1963) model of search with foundational concepts from evolutionary theory (Nelson & Winter, 1982), this dissertation scrutinizes the expansion of search and develops a refined framework for organizational search behavior. Special emphasis is put on the aspect of search in organizationally vulnerable areas (Cyert & March, 1963). Considering pressure to innovate as a potential driver, the dissertation develops a conceptual model based on open innovation (Chesbrough, 2003a). Three pre-studies and two main studies illuminate broadcast search in the pharmaceutical industry and test the theoretical model.

The pre-studies elucidate the use of broadcast search in the pharmaceutical industry from various angles. One investigation uses public data from an intermediary to test for the uniqueness of pharma-related broadcast search. Findings indicate that pharma-related challenges are frequented less by solvers. Another pre-study administered surveys to managers from pharmaceutical firms interested in open innovation for R&D. Results indicate alignment between the academic literature and practice. The tenor of the pre-studies is that broadcast search in the pharmaceutical industry deserves legitimate consideration. Also, anecdotal evidence supports the notion that broadcast search, at current, is used after other attempts have failed—as a search mechanism at the margin.
The two main studies test the theoretically developed ideas. Building on prior work, study 1 singles out the breadth of the knowledge base as the defining factor for forming strategic knowledge groups. Study 2 supports the notion that innovation pressure is associated with changes in organizational search behavior. Since study 2 does not find a direct link between innovation pressure and broadcast search engagement, a post-hoc analysis follows which combines study 1 findings with study 2 data. Results support the idea that a broad knowledge base precedes broadcast search.

Theory development benefits from this dissertation by emphasizing on a better understanding of organizational search processes and setting a foundation for future investigations. For practitioners the dissertation cautions of blind adoption of broadcast search while at the same time pointing to its potential. Having supplemental capabilities becomes crucial. The nature of these capabilities requires further scientific investigation.
Dedication

In loving memory of my aunt, Waltrud “Trudi” Johannes.

My childhood and my life would not have been the same without you.

Many great memories will always keep you in my heart.
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1.0 INTRODUCTION

The search for new revenue streams is a frequent priority for organizations. In industries which are highly reliant on new technological discoveries and intellectual property (IP) protection, many organizations engage in formal research and development (R&D). The centrality of R&D to these firms’ strategies means that such firms experience a pressure to innovate, which has been a long-time concern in the economic literature (Villard, 1958; Williamson, 1965). Both monopoly or oligopoly effects as well as competition have been noted as factors for the occurrence of a pressure to innovate (Villard, 1958; Williamson, 1965).

Due to increased pressure to innovate, large firms in particular are forced to look outside of their currently established markets for opportunities and develop new approaches to locating product creation options (Huston & Sakkab, 2006). There are various ways in which companies can source the knowledge necessary to develop breakthrough innovations and new product trajectories (Christensen & Raynor, 2003; Christensen, 1997; Dosi, 1982). This dissertation reviews several knowledge sourcing alternatives and places them in a framework reviewing changes in firms’ search intensity and behavior. The model developed in this dissertation builds on two related theoretical streams of research, the behavioral theory of the firm (Cyert & March, 1963) and evolutionary economics (Nelson & Winter, 1982), and places particular emphasis on broadcast search as an alternative approach for knowledge sourcing. Broadcast search has been characterized as a “problem-solving process [which operates] by disclosing the details of the problem at hand and inviting the participation of anyone who deems themselves qualified to solve the problem. Upon learning of the existence of the problem, solvers self-select to attempt to create a solution and are rewarded for their efforts if they are successful” (Jeppesen &
Lakhani, 2010, p. 1016). Specifically, the concern is with broadcast search as an emerging mode of search being employed in knowledge intensive industries.

The following sub-section develops several interrelated questions. The two main questions are “When do organizations employ alternative modes of search to source knowledge for R&D activities?” and, in regards to broadcast search, “Who engages in broadcast search?” Furthermore, I address these related questions: “What are the specific characteristics of broadcast search in the pharmaceutical industry?” “Does past behavior of organizations influence the choice of organizational search processes when seeking solutions to problems?” “What influences organizational search intensity?” “What guides the choice of organizational search modes?”

1.1 Research Questions

An important point of departure for this dissertation is to better understand the use of broadcast search in the pharmaceutical industry and to investigate related boundary conditions. The underlying question here becomes “What are specific characteristics of broadcast search in the pharmaceutical industry?” To address this question, I employ an investigative approach using three pre-studies to understand the phenomenon and the industry more deeply prior to moving into a more scientific examination of my theoretically derived model. The theoretical model is then tested using two main studies designed to examine the questions outlined next.

Within the general concern for structuring organizational search, my dissertation is chiefly concerned with the overarching question of “When do organizations employ alternative modes of search to source knowledge for R&D activities?” I suggest that in response to an increased pressure to innovate, organizational search first intensifies for routine search activities and then expands into non-routine search activities. A specific focus in this context lies on the
use of broadcast search as a non-routine search alternative and the question “Who engages in broadcast search?” These general ideas are broken down into three specific concerns.

The first sub-question of my investigation asks “Does past behavior of organizations influence the choice of organizational search processes when seeking solutions to problems?” I expect the individual position of an organization in terms of its past experience to influence its search behavior and its willingness to experiment. This notion is a reflection of firm heterogeneity (Barney & Hoskisson, 1990) and raises questions of path dependence (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010) such as whether past behavior has an influence on the decision to engage in broadcast search and whether or not organizations with certain sets of firm characteristics are more prone to engage in broadcast search. As such, this question is closely tied to the question of who engages in broadcast search. It is unlikely that an extensive shift in knowledge sourcing is equally beneficial to all types of organizations. To reflect groups of characteristically similar organizations, the current dissertation revisits the idea of generic knowledge strategies observed in the pharmaceutical industry (Bierly & Chakrabarti, 1996a) to investigate changes in the strategic positions of firms within the industry. Particular interest in my dissertation is placed on the characteristics of established organizations who are actively engaged in broadcast search approaches contrasted with those that seem to refrain from engaging in broadcast search.

The second sub-question put forth is “What influences organizational search intensity?” I suggest that the pressure to innovate plays a role in the intensity of employment of search activities that a firm commonly engages in. As such, I expect that innovation pressure recognized by an organization will trigger an increase in the intensity of routine search behavior by a focal organization.
Closely related to the previous question, the third sub-question asks “What guides the choice of organizational search modes?” This question relates to the idea of search expansion (Cyert & March, 1963) and is central to the model proposed in this dissertation. Building on the idea of expanding search (Cyert & March, 1963), I expect that search will become more distant and non-routine if no satisfactory solution is found. This question investigates whether there is a hierarchy of search modes that firms follow in their search for solutions to R&D problems. Problemistic search both in the behavioral theory of the firm (Cyert & March, 1963) and evolutionary economics (Nelson & Winter, 1982) suggests that there is a hierarchy of search expansion triggered by search failure. The failure in terms of diminishing returns of commonly used search activities may lead to experimentation with new approaches that a company is unfamiliar with. The latter category includes broadcast search. Seeing broadcast search being employed by well-established organizations in areas that rely heavily on formal IP protection, such as the pharmaceutical industry, raises the question if failed attempts to alleviate innovation pressure leads to the use of more experimental, new to the firm, innovation processes.

In addressing these questions, the current dissertation outlines and empirically tests a revised model of organizational search behavior. The proposed model is largely based on the model described in the behavioral theory of the firm by Cyert and March (1963) expanded by influences from the evolutionary economics perspective formed by Nelson and Winter (1982). The empirical investigation examines the individual steps of the expansion of search in regards to its problem-driven motivation and gradual increase of locations to seek potential solutions until solving the problem (Cyert & March, 1963). This search starts from local and distant search routines and ends in non-routine distant search. The problem faced by the firms in the current work is set to be a pressure to innovate in a research intensive industry. I organize the
steps of expanding search in a framework in which search expands from local routine search, via distant routine search, to non-routine distant search.

My investigations start from an exploratory assessment which ensures a detailed understanding of the use of broadcast search in the pharmaceutical using three separate pre-studies. The combined set of these pre-studies functions as a foundation for understanding the phenomenon in the context of the pharmaceutical industry and explicate the importance of this research stream for practice. This approach ensures that the research is concerned with an actual problem rather than a “toy problem” (Sprague & Sprague, 1976, p. 57). The pre-studies furthermore lay the groundwork for the scientific investigations conducted in the main studies and for future research on the theoretical model developed in this dissertation. Following the pre-studies, study 1 builds on a study of knowledge strategies previously conducted by Bierly and Chakrabarti (1996a). Study 2 then builds on a restricted sample reflecting the theoretically described organizations to empirically test the model developed in this dissertation. My investigations close with a post-hoc analysis combining findings from study 1 with data from study 2.

1.2 Theoretical Core Concepts

In the following, I briefly address core concepts as they relate to the placement of my theoretical model within the literature employed. This will guide the understanding of both the heritage of the model as outlined in chapter 2 and the development of the model in chapter 3.

1.2.1 Organizational Learning

To understand the problem at hand better, it is important to understand how organizations learn. Organizational learning has received considerable attention in the strategic management and related literature (Argyris & Schön, 1978; Grant, 1996; Huber, 1991; Kogut & Zander, 1992;
Organizational learning has garnered much attention in the current literature and has developed into a broad field with various subareas such as experience, context, as well as knowledge creation, retention and transfer (Argote, 2011). From the perspective of organizational learning, the current dissertation can be seen as falling into the category of new forms of organizing (Argote, 2011) with respect to knowledge sourcing, while focusing on the collective view of organizational learning where knowledge is viewed as being stored in organizational routines and structures (Dosi & Marengo, 2007; Levitt & March, 1988; Nelson & Winter, 1982; Schulz, 2005). An exemplary implication of this view is that “[t]he organizational nature of learning is reflected by its being linked with changes in organizational practices that might not display any evident correlation with what individuals ‘know’” (Dosi & Marengo, 2007, p. 495). Therefore, while recognizing the importance of knowledge and learning at the individual level, the current dissertation is chiefly concerned with the collective level and learning reflected in aspects of organizational structures and processes. Organizational learning was outlined by Cyert & March as one of four major relational concepts\(^1\) underlying the behavioral theory of the firm (Cyert & March, 1963, p. 116).

1.2.2 Broadcast Search as a Reflection of Search in Organizationally Vulnerable Areas

However, the question arises what happens if search fails and when should search be considered as having failed? This question can only be addressed when we understand the full search cycle, including the idea of search in organizationally vulnerable areas. Therefore, the

\(^1\) The other concepts are (1) quasi resolution of conflict, (2) uncertainty avoidance, and (3) problemistic search.
current dissertation evaluates the idea of search in organizationally vulnerable areas with broadcast search as a reflection of such a search approach. The idea of broadcast search as a reflection of search in an organizationally vulnerable area seemed best illustrated in an open innovation framework (Chesbrough, Vanhaverbeke, & West, 2006; Chesbrough, 2003a), which I employed to constrain and explicate the boundaries of my study. Setting the boundaries in this fashion was necessary since the framework developed in this dissertation was not situated within the organization and its boundaries. Instead, it was outlined in a broader frame which incorporates external aspects of the R&D process to reflect modern research organizations. In order to understand this interplay between an organization and its external environment, it is necessary to first revisit the innovation process itself. As “theories ought to be microfounded” (Dosi & Marengo, 2007, p. 492), the innovation process itself serves as the micro-foundation of the evolutionary process described in my dissertation.

1.2.3 Importance of Innovation

Innovation has become a critical factor for firm competition (Schilling, 2009a). Reasons for this push towards innovation include the quest for growth (Corsino & Gabriele, 2011; Nerkar & Roberts, 2004), competitive success (Artz, Norman, Hatfield, & Cardinal, 2010; Schilling & Green, 2011), and survival (Fontana & Nesta, 2009). Oftentimes, firms need to grow at a faster rate than that which is possible by the expansion of current markets alone in order to meet owner expectations (Huston & Sakkab, 2006) such as shareholder demands in publicly traded firms. Other times, the growth in new areas is needed to replace current business areas that are either becoming obsolete (Christensen, 1997) or in which competitive advantages are eroding and returns are depleting due to an influx of competition. For large firms these growth demands translate into the need of building the equivalent of new billion dollar companies year after year.
(Huston & Sakkab, 2006). In order to meet these demands firms often turn to the development of new products as a way to achieve firm growth (Corsino & Gabriele, 2011). Since firms that initiate major technological changes are generally growing faster than the competition (Tushman & Anderson, 1986), a particular emphasis in meeting these growth demands through innovation is placed on breakthrough innovation.

1.2.4 Alternative Modes of Search

Internal R&D employing a closed innovation process keeps close control over the questions addressed but at the same time is associated with issues of local search (Cyert & March, 1963; Katila & Ahuja, 2002; Stuart & Podolny, 1996). Local search has been equated with organizational inertia (Stuart, 2005), a central albeit often overlooked question in strategy research (Rumelt, Schendel, & Teece, 1994). Overcoming local search is one reason why firms lean towards quasi-market R&D approaches. Alliances (and mobility) have been suggested to be ways of overcoming local search problems (Rosenkopf & Almeida, 2003). However, while such approaches generally allow for control of the question asked, and thus the search direction, they require large upfront commitments and still offer limited reach in terms of potential partners.

With exploding internal R&D budgets necessary to keep on par with growth expectations, companies have developed alternatives for generating and sourcing knowledge and are experimenting with more and more explorative approaches. R&D Alliances, and the special case of joint ventures (JVs) (Schilling, 2009a), have become common in today’s high-tech business environment as a way to combine knowledge bases. Licensing is also a widespread method to source crucial external knowledge. Another common approach to localize development options that allows for faster growth is the acquisition of start-up companies (Arrow, 2000) which can be vehicles for explorative and exploitative innovation (Phene, Tallman, & Almeida, 2012). Arrow
(2000) outlines the acquisition of start-ups as one approach to break up the innovation process between entrepreneurs and large corporations. All these approaches reflect ways to internalize external knowledge and thus can be considered inbound open innovation mechanisms (Chesbrough, 2003a). More recently, large firms have started to experiment with more direct inbound open innovation approaches which have actually oftentimes just been termed ‘open innovation’ in practitioners’ communications of this approach.

Broadcast search is employed by organizations as an alternative knowledge sourcing approach with the goal of fostering technological change, in turn helping to achieve the previously addressed growth demands. The increasing variety of approaches for knowledge generation and acquisition reflects that staying on top of their industry in changing markets is one of the main concerns of multinational corporations (MNCs) (Bower & Christensen, 1995), a category into which many large firms fall. Alternatively, the broadcast search phenomenon is often termed crowdsourcing (Afuah & Tucci, 2012; Howe, 2006, 2009), although the description of crowdsourcing can be seen to be somewhat broader. When referring to the crowdsourcing of problem-solving (Afuah & Tucci, 2012), the terms can be used largely interchangeably. However, generally speaking the understanding of crowdsourcing might be broader, emphasizing different directions, and thus might differ. An example would be the inherent marketing aspect of crowdsourcing and the notion that participants in crowdsourcing initiatives are often not seen as ‘professionals’ (Poetz & Schreier, 2012) but rather as some sort of hobbyists. The broadcast search activities in the current study do however rely on highly specialized professionals. An overview of my research questions is presented in Table 1.
Table 1: Overview of research questions

**Exploratory question:**
1) What are specific characteristics of broadcast search in the pharmaceutical industry?

**Main research questions:**
1) When do organizations employ alternative modes of search to source knowledge for R&D activities?
2) Who engages in broadcast search?

**Sub-question:**
1) Does past behavior of organizations influence the choice of organizational search processes when seeking solutions to problems?
2) What influences organizational search intensity?
3) What guides the choice of organizational search modes?

1.3 Contributions and Findings

This dissertation contributes to the theoretical literature by complementing organizational search processes outlined by the behavioral theory of the firm (Cyert & March, 1963) with concepts underlying evolutionary economics (Nelson & Winter, 1982). As such the research fits in with the broader goal to move in the direction of more integrated theories of organizational economics (Barney & Ouchi, 1986; Mahoney, 2005). Building on research on open innovation (Chesbrough et al., 2006; Chesbrough, 2003a) and on the organizational economics literature, this dissertation places the open innovation more firmly in organizational economics. In return, this placement allows for the extension of behavioral theory and evolutionary economics to firm-level analysis beyond the boundary of the firm. In so doing, different (open) innovation approaches are contrasted with each other. These approaches include internal R&D, alliances, and acquisitions as reflections of routine search, and broadcast search as a reflection of non-
routine search. In the process, the research also introduces both M&As and broadcast search as ‘modes of development’ (Schilling, 2009a) or more precisely, what I termed “modes of search”.

I explicate the idea of organizational search routines theoretically founded in a combination of the behavioral theory (Cyert & March, 1963) with aspects of evolutionary economics (Nelson & Winter, 1982). This conceptual alignment answers the call for organizational theory integration (Barney & Ouchi, 1986; Mahoney, 2005). Inherent in the development of the concept of organizational search routines, both local and distant, is the idea of control over the search direction, which is commonly neglected in the literature.

In addition, I introduce the idea of non-routine distant search as a contrast to commonly employed search mechanisms. Also, this research fills a gap in going beyond the discussion of local versus distant search (Katila & Ahuja, 2002; Nelson & Winter, 1982; Stuart & Podolny, 1996) by looking more closely at Cyert and March’s (1963) concept of expanding search, investigating the underlying mechanisms and contrasting potential solution paths.

In the past, most management research concerned with the innovation process has focused on the mechanical aspects (Souriau, 1881, as cited by Campbell, 1960) of how to find solutions to stated problems (Katila & Ahuja, 2002; Nelson & Winter, 1982; Stuart & Podolny, 1996). The importance of controlling the question has generally been neglected. In the theoretical expansion on my model, I stress the importance of controlling the research direction by being able to formulate and pose questions most suitable for a given focal firm. In doing so, I build on basic innovation processes (Campbell, 1960; Souriau, 1881, as cited by Campbell, 1960). This underlying aspect of the theoretical model lays the groundwork for some particularly exciting opportunities for future research.
Empirically, as a result of study 1, I was able to tease out the breadth of a firm’s knowledge base as a key driver for firm clustering in regards to knowledge strategies and as a necessary but not sufficient condition for broadcast search. Study 2 offered some support for the idea of innovation pressures affecting organizational search behavior. Innovation pressure in the form of resource depletion measured as expiring patents to some extent affected both the intensity of local and of distant routine search, especially as a short-term solution. Rivalry with regards to other firms’ patents in core research areas had similar effects on local search, but opposite effects on the expansion to routine distant modes of search in regards to alliances. Since no support was found in the current sample when using a probit regression analysis with broadcast search as the dependent variable, I conducted a follow-up analysis. This post-hoc analysis indicated that broadcast search was employed contingent on a broad knowledge base of an organization. As such, it supported the notion from study 1 that knowledge dispersion was a necessary but not a sufficient condition for broadcast search in the pharmaceutical industry.

For practitioners in the pharmaceutical industry, this dissertation offered support that broadcast search might be an option for pharmaceutical R&D. Importantly, despite anecdotal evidence (Agres, 2012; Fleming Europe, 2012; pre-study C of this dissertation), a direct link between innovation pressure and the use of broadcast search could not be established. As such, recommendations to employ broadcast search to alleviate innovation pressure would be premature. The dissertation does however offer support for the notion that search behavior changes in response to innovation pressure, so that firms should consider both routine and non-routine modes of search to source knowledge in a competitive environment under increased innovation pressure. When considering broadcast search as an alternative, a broad knowledge base seems necessary in order to handle and benefit from such an approach.
In chapter 2, I review relevant fundamental theories and outline basic concepts underlying the construction of my model. In chapter 3, I construct a revised model of the organizational search process with regard to organizations’ external search. Chapter 4 outlines how I address the theoretical model with a series of four studies. Chapter 5 reports the findings of the individual studies. Chapter 6 concludes with an extraction of the findings and a discussion of future research.
2.0 LITERATURE REVIEW

This dissertation draws from various aspects of organizational economics (Barney & Ouchi, 1986; Mahoney, 2005), primarily theories of firm behavior (Cyert & March, 1963) and theories of technological change and innovation (Nelson & Winter, 1982; Schumpeter, 1934), and investigates organizational search patterns related to the innovation process. Historically, large organizations relied on an internal R&D focus to develop innovations (Chandler, 1990). However, there also exist external, (quasi-)market approaches to generating ideas (Christensen & Anthony, 2001). Integrating customers into the development process (Thomke & Von Hippel, 2002) or using external sources anywhere in the innovation process (Chesbrough, 2003a) forces people inside the organization to overcome not-invented-here (NIH) mentalities (Katz & Allen, 1982) and leads to considerations of adequate levels of search depth and scope (Katila & Ahuja, 2002). It also raises concerns regarding potential knowledge spillovers (Marshall, 1890) to competitors, present and future. As such, the current study views firms as problem-solving institutions (Nickerson & Zenger, 2004) and examines factors influencing the choice between search alternatives reflected in modes of development (Schilling, 2009a) for the innovation process, with a focus on open innovation (Chesbrough, 2003b).

2.1 Theoretical Concepts

Building on various theories of organizational economics allows for an integration of different views to aid our understanding of organizations. This integration has been called for in recent outlines of organizational economics and is viewed as a valuable research goal (Mahoney, 2005). I posit that such a theory-spanning integration is necessary in order to come closer to understanding the complex structures we are dealing with in phenomenon driven research such
as the one in hand. For example, while much can be explained by transaction cost economics (TCE) arguments (Coase, 1937, 1988; Williamson, 1975, 1981), it is necessary to view TCE and behavioral theories as complementary rather than contradictory. Only when they are aligned, the necessary changes can occur that allow for a decrease in transaction costs. If behavioral aspects get in the way of the formation of firms or market contracts, it will itself create transaction costs that make changes prohibitively expensive. The acknowledgement that theories of organizational economics are largely compatible and interrelated (Mahoney, 2005) is by far not a totally recent idea. A case in point is Arrow’s (1974) considerations of “The limits of organization”, which despite is brevity is concerned with much more than merely transaction costs.

Open innovation approaches (Chesbrough et al., 2006; Chesbrough, 2003a) involve complex interactions both between members inside the organization and interactions of members from inside the organization with non-members. These behavioral implications require the incorporation of behavioral aspects (Cyert & March, 1963) related to theories of technological change and innovation (Nelson & Winter, 1982; Schumpeter, 1934). In the following I briefly sketch out the most relevant aspects of these theories for the current work.

2.2 Behavioral Theory of the Firm

The behavioral theory of the firm outlined by Cyert and March (1963) relates to “large, multi-product firm[s] operating under uncertainty in an imperfect market” (Cyert & March, 1963, p. 115) and is broken up into three sub-theories which in turn are founded on four related core concepts. The sub-theories relate to organizational goals, organizational expectations, and organizational choice. The pillars (or concepts) on which these theories mainly stand are “(1) quasi resolution of conflict, (2) uncertainty avoidance, (3) problemistic search, and (4)
organizational learning” (Cyert & March, 1963, p. 116). Out of those, this dissertation focused
in particular on the aspect of organizational learning and problemistic search. The other two
basic concepts underlying Cyert and March’s (1963) organizational decision making process—
quasi-resolution of conflict and uncertainty avoidance—are also present as valid assumptions in
the current work, although they are not addressed directly. The model developed in this
dissertation is focused on the search aspect of organizational change rather than the complete
decision making process. In turn, I take a detailed reconnaissancce of the organizational search
process, which is seen as an expanding process in terms of its complexity.

2.2.1 Organizational Learning

At the organizational level, learning is seen as adaptation over time (Cyert & March, 1963, p. 123). Cyert and March (1963) point to three phases of the organizational decision
process that are distinctly related to adaptation and which are a function of an organization’s
experience, namely (a) the adaptation of goals, (b) the adaptation of attention rules, and (c) the
adaptation of search rules (Cyert & March, 1963, p. 123). This dissertation is focused on the
latter by examining organizational search and its adaptation in response to external pressure.
High level goals remain constant over extended periods of time and as such do not influence the
model as a variable factor. The underlying theory—the behavioral theory of the firm (Cyert &
March, 1963)—and my model derived from it, refer primarily to the “large, complex
organization” (Cyert & March, 1963, p. 1). As such, I explicitly assume that firms are stable in
their goal to generate innovation to foster growth. I assume that the organizations of interest
focus on the creation or internalization of innovation in order to pursue their long-term
organizational financial goals. Therefore, the overall goals remain constant, reflected in the
desire to innovate and create appropriable intellectual property. The same assumption of
consistency is made for attention rules which, analogue the goals, remain unchanged with a focus on generating or internalizing innovative knowledge. The theoretical focus on mature organizations further supports these assumptions. The adaptation of goals is seen as a function of prior goals, and performance of the organization and prior performance of similar organizations (Cyert & March, 1963, p. 123)—as such it should be more stable for incumbent organizations than for relatively less experienced organizations. Cyert & March (1963) concur to the assumption of stability for the adaptation in attention rules, at least when considering short-term models (Cyert & March, 1963, p. 124).

2.2.2. Problemistic Search

Another one of the four relational concepts outlined in Cyert and March’s (1963) behavioral theory of the firm is the concept of problemistic search. Problemistic search is search that is conducted in response to a specific problem with the goal of finding a solution to that problem (Cyert & March, 1963). As such this type of search differs from “random curiosity and the search for understanding” (Cyert & March, 1963, p. 121), or search that could generally be viewed as basic research. As Cyert and March (1963) put it, “problemistic search is engineering rather than pure science” (Cyert & March, 1963, p. 121). In line with Cyert and March (1963), I adopt the assumptions that organizational search is (1) motivated, (2) simple-minded, and (3) biased. The motivation stems from failure or anticipated failure to reach set goals and search will only stop if the problem is solved (Cyert & March, 1963). Simple-minded search refers to an expansion of search outlined by Cyert and March (1963, p. 122) as regressing from first being conducted proximate to current knowledge to then being performed in more and more distant areas. This aspect of local versus distant search has been substantially addressed in the literature (Katila & Ahuja, 2002; Nelson & Winter, 1982; Stuart & Podolny, 1996). The concept of search
expansion from local to distant search will be discussed further when highlighting the concepts underlying evolutionary economics (Nelson & Winter, 1982). The literature does, however, mainly ignore\(^2\) a further aspect of search pointed to by Cyert and March (1963), namely the search in “organizationally vulnerable areas” (Cyert & March, 1963, p. 122). The lack of acknowledgement could potentially be caused by this term not being well defined in Cyert and March’s (1963) account of their behavioral theory. However, a detailed investigation of this aspect could offer some valuable insights to the organizational search process, because an incomplete understanding of the full search process could hinder our ability to make recommendations in regards to preferred search paths and anticipated outcomes. For example, if it is not clear where search might lead and what costs will be associated with undertaking a search if no solution is found through local and distant search, our predictions could be misleading. If we do not understand the full process, we cannot know how and when search ends. The general assumption is that search does not end until a solution is found (Cyert & March, 1963). To avoid redundancy, a more detailed discussion of search in organizationally vulnerable areas is deferred to the development of my theoretical model in chapter 3.

The three types of search bias relate to (a) heterogeneity of experience and training within the organization, (b) interactions between expectations and hopes, and (c) unresolved conflict stemming from communication issues (Cyert & March, 1963). The aspects of bias in search will not be individually deciphered in the current dissertation. Rather, the essence of bias is collectively reflected in evolutionary economics (Nelson & Winter, 1982) which will be

\(^2\) A search on Google Scholar (http://scholar.google.com/ last accessed 11/12/2012) revealed a total of four (4) hits when searching for the exact term “organizationally vulnerable areas” and none (0) for “organizationally vulnerable area”. Similarly, a search on “organizationally vulnerable” which would include both prior searches, revealed zero (0) hits from the ISI Web of Knowledge (http://apps.webofknowledge.com/ last accessed 11/12/2012).
addressed next and which will be incorporated in my theoretical model in chapter 3. Bias reflecting prior experience is furthermore included through the concept of path dependency (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010); constituting again a core aspect of evolutionary economics (Nelson & Winter, 1982).

2.3 Evolutionary Economics

Evolutionary economics combines the concepts of tacit knowledge and routines with the dynamics of Schumpeterian competition (Nelson & Winter, 1982). The key idea here is that organizational capabilities are based on routines which are not explicitly comprehended, but which are developed and improved through repetition and practice. The micro-link to learning-by-doing implies that the set of current capabilities of a firm is a function of history in the form of path dependency (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010) which makes it impossible to simply copy best practices even when they are observed.

Evolutionary economics is an area that looks at economic change from the perspective of technological innovation, contrasting a neo-classical (orthodox microeconomic theory) perspective. Two fundamental constructs of this theoretical approach—organizational routines and search—entail important implications for knowledge sourcing from a firm perspective. A third base concept of evolutionary economics is termed ‘selection environment’ (Nelson & Winter, 1982).

“The key ideas of evolutionary theory [...]are that firms] at any time are viewed as possessing various capabilities, procedures, and decision rules that determine what they do given external conditions. They also engage in various ‘search’ operations whereby they discover, consider, and evaluate possible changes in their ways of doing things. Firms whose decision rules are profitable,

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given the market environment, expand; those firms that are unprofitable contract.

The market environment surrounding individual firms may be in part endogenous to the behavioral system taken as a whole; for example, product and factor prices may be influenced by the supply of output of the industry and the demand for inputs.” (Nelson & Winter, 1982, p. 207)

This quote sketched the general connection of organizational routines (described as capabilities, procedures, and decision rules) and search in an evolutionary framework. The behavioral aspects are of eminent importance as they lay the foundation for “problemistic search” (Cyert & March, 1963). In the following, the key concepts of organizational routines and search are laid out individually in more detail.

2.3.1 Organizational Routines

The concept of organizational routines was introduced by Stene (1940) and plays a central role in both organizational accomplishments as well as organizational failures (Feldman & Pentland, 2003). In reference to March and Simon (1958), Cyert and March (1963), Thompson (1967) and Nelson and Winter (1982), Feldman and Pentland (2003) note that organizational routines are regarded as a positive driver in established theories of firm behavior. However, they also warn that the concept has been recognized as a “source of inertia (Hannan & Freeman, 1984), inflexibility (Weiss & Ilgen, 1985; Gersick & Hackman, 1990), and even mindlessness (Ashforth & Fried, 1988)” (Feldman & Pentland, 2003, p. 94).

Stene (1940, p. 1129) posits that “[o]rganization[al] routine is that part of any organization’s activities which has become habitual because of repetition and which is followed regularly without specific directions or detailed supervision by any member of the organization”. It thus describes processes within a firm that regularly occur without active leadership
involvement. Stene (1940) speaks of an “acquired habit of coördination”, which places the concept of organizational routines as the anti-thesis to leadership. ‘Coördination‘ is a continuous process based on learned individual tasks and relationships leading to the establishment of routinized interactions (Stene, 1940). Leadership actively interferes with the status quo in that it initiates a new process while organizational routines, a concept overlooked prior to Stene (1940), keeps coordination continuous. The two mechanisms are illustrated and contrasted by (a) Mooney (1937) pointing out that a coordinated effort such as lifting an item by two people needs to be organized through (verbal) signaling—a leadership act—and (b) Stene (1940) pointing out that continuous, more complex processes such as a game of tennis or workers in an office or store can go on for substantial amounts of time without direct, observable leadership. Leadership is thus not a continuous activity (Stene, 1940). The continuous flow of coordinated processes is based on learned tasks and structures and does not require conscious attention (Stene, 1940). It could be argued that active-reactive processes within the coordinated mechanism serve as signals that, once learned, trigger the appropriate response for the next step in the process to be executed. In learned, complex tasks the leadership signaling is thus replaced by clues stemming from previously executed steps. Leadership, or strategic/conscious involvement, then only becomes necessary when one is aiming to change patterns of behavior or when circumstances are unknown and tasks are non-routine.

It is important to keep in mind that an “organization is not a perpetual motion machine; it is an open system that survives through some form of exchange with its environment.” (Nelson & Winter, 1982, p. 113). As such, the importance of interaction with the environment has been acknowledged. Nelson and Winter (1982) do not discuss leadership per se but they talk about ad hoc problem solving as the opposition of routine tasks (p. 113). This wording is reconcilable
with that of Stene (1940) and Mooney (1937) if one recognizes that Nelson and Winter (1982) come from a higher level perspective of observation. The *ad hoc* problem solving can be seen as being done by an individual in the organization who assumes a formal or informal leadership role in a given situation to change routine behavior or deal with situations for which no routine behavior exists and thus an unfamiliar or low frequency situation needs to be resolved. The current work adopts Nelson and Winter’s (1982) terminology of “*ad hoc* problem-solving efforts” with the understanding that this constitutes some act of leadership.

Nelson and Winter (1982) outline the concept of organizational routines and its central position in their ‘*evolutionary theory of economic change*’ and distinguish between organizational routines as (a) organizational memory, (b) truce, and (c) targeting control, replication, and imitation: “routine operation as the target of efforts directed to organizational control, to replication of existing routines, and to imitation of routines employed by other organizations” (p. 99). This latter aspect of organizational routines has also been labeled “desired norm” (Becker, 2004; Nelson & Winter, 1982).

Nelson and Winter (1982, p. 97) “use ‘routine’ in a highly flexible way, much as ‘program’ (or, indeed, “routine”) is used in discussion of computer programming. It may refer to a repetitive pattern of activity in an entire organization, to an individual skill, or, as an adjective, to the smooth uneventful effectiveness of such an organizational or individual performance.” This use is contrasted by later work which aims to restrict the term routine to the collective level and reserves the term skill for the individual level (Dosi, Nelson, & Winter, 2000). The attempt to reserve ‘skill’ for the individual level and ‘routine’ for the collective level certainly has merit in attempting to clarify our vocabulary, however it misses a critical point. Skill is used by Nelson and Winter (1982) as a metaphor to illustrate what a routine is at the
organizational level. Specifically, they point to three attributes of a skill that are reflected in an organizational routine at the collective level. A skill is (a) programmatic, requiring subsequent steps triggered by one another, (b) largely based on tacit knowledge which the performer often uses unconsciously and lacks the ability to express, and (c) requires making choices, often based on heuristics (Nelson & Winter, 1982). Using these three characteristics to illustrate parallels between individual-level skills and organizational routines, most notably, does not exclude the existence of routines at the individual level. In fact, individual routines have been recognized in psychology as far back as James (1890) in his classic book “The Principles of Psychology” using examples such as the opening and closing of cupboards and even the use of a restroom. People can individually use certain routine processes (James, 1890; Betsch, Haberstroh, Molter, & Glöckner, 2004) that require them to employ various skills. As such the word routine cannot be exclusively reserved for the collective level. To illustrate, consider the following example. There might be differences between individuals on how to accomplish a certain task. In order to enjoy coffee in the morning, two people might have different routines even though both possess the skill to make coffee with a coffee maker. One person might fix everything in the evening so when she gets up in the morning, all she has to do is flip the switch and wait for the coffee to be ready while the other person gets up a few minutes earlier to prepare everything in the morning. While the skill is the same, the daily routine differs. As such, a ‘skill’ is focused on the outcome and one is considered to have a certain skill if one is able to arrive at an outcome. A ‘routine’ at the individual level is focused on the process and concerned with how the outcome is arrived, not the outcome itself. People may differ in their routines even if they possess the same skills. At the organizational or collective level this basic distinction is accomplished by breaking routines down into performative and ostensive aspects (Feldman & Pentland, 2003; Pentland & Feldman,
As per Feldman and Pentland’s (2003, p. 94) definitions, “the ostensive aspect enables people to guide, account for, and refer to specific performances of a routine, and the performative aspect creates, maintains, and modifies the ostensive aspect of the routine”, similar to the distinction between what is commonly understood by a skill versus a routine at the individual level. It is thus unavoidable to have routines at both the individual and the collective level since routines and skills at the individual level are not fully congruent. In order to be clear on the terminology in research instead of using skill as a reflector of the individual level and routine at the collective level, I posit that authors need to be clear in their writing when they talk about organizational routines and when they are referring to individual routines, as there is currently no definition on which basis this predicament could be resolved.

Being more precise about the distinction between ‘routines’ in general and ‘organizational routines’ in particular would also help to avoid misinterpretations of previous work. For example, Becker (2004) quotes Nelson and Winter (1982, p. 73) as viewing “[r]outines […] [as a] collective phenomena”, which is an incorrect, or at least an incomplete understanding of previous work, as the earlier quote on the usage of the term by Nelson and Winter (1982, p. 97) shows, where a “routine […] may refer […] to an individual skill […] or individual performance.” All that can be inferred from classic reasoning (Stene, 1940; Nelson & Winter, 1982) is that routines can be a collective phenomenon, but not to the exclusion of the construct existing also at the individual level. This misconception is a major flaw in recent theorizing that has trickled through the literature as a reflection of social constructionism (Berger & Luckmann, 1966).

In Becker’s (2004) defense it should be noted that recently even Nelson and Winter in a book edited along with Dosi argue that “clarity would be served by reserving the term ‘skill’ to
the individual level and ‘routines’ to the organizational level” (Dosi et al., 2000, p. 5). Indeed, Nelson and Winter (Dosi et al., 2000) directly criticize their own previous 1982 seminal work but also recognize that their “suggestions about terminology reflect [their] own understanding and preferences, but [they] are not under the illusion that terminological anarchy is easily suppressed” (Dosi et al., 2000, p. 4). On the grounds provided, I argue against the exclusive reservation of the term ‘routines’ to the organizational level. Instead of eliminating a useful construct from the individual level without offering a replacement, this paper suggests that, the “terminological anarchy” (Dosi et al., 2000, p. 4) can be overcome simply by clarity in writing—specifying the level of concern by speaking about organizational routines rather than simply routines—without restricting the notion of routines to the collective level. It should be clear that the term routine has vastly different meanings at each level. Since both are valid, there is no substantiated reason to eliminate this term from the individual level vocabulary.

2.3.2 Search

On the subject of search, a commonly used distinction found in the strategy literature is that of ‘local’ versus ‘distant’ search (Cyert & March, 1963; Katila & Ahuja, 2002; March & Simon, 1958; Nelson & Winter, 1982; Teece, 2007). Local search, as understood by Stuart and Podolny (1996) equates to what Cyert and March (1963) specified as the starting point for ‘simple-minded search’—one of the underlying assumptions of problemistic search. Simple-minded search means that, at the outset, search is conducted (a) “in the neighborhood of the problem symptom” and (b) “in the neighborhood of the current alternative” (Cyert & March, 1963, p. 121). This focus is unlikely to lead to “radically new alternatives” (Cyert & March, 1963, p. 122) so that local search can be a source of inertia and in fact has been equated to it (Baum, 2005). If local search is unsuccessful in generating adequate, threshold-dependent (i.e.,
satisficing) solutions, search is first expanded to distant search, and subsequently conducted in “organizationally vulnerable areas” (Cyert & March, 1963, p. 122). In other words, this distinction specifies that in a natural course, search starts out as being conducted close to the knowledge that is already possessed by the organization or person searching and extends to more distant knowledge spheres if no adequate solution can be found to solve a given problem in close proximity to currently held knowledge and frameworks (Cyert & March, 1963). Sometimes the distinction from local search is termed exploratory search which generally reflects the notion that a firm is purposely (i.e. strategically) moving towards exploration (March, 1991; Katila & Ahuja, 2002). This would be the case if a firm actively decides to search for potentially radical or breakthrough innovations. Another way of phrasing the same idea would be to call it ‘heuristic’ or ‘cognitive’ search (Nickerson & Zenger, 2004). In their terminology, Nickerson and Zenger (2004) distinguish between ‘directional’ (they also call it ‘local’3) search and ‘heuristic’ (or ‘cognitive’) search. This distinction is made at the individual level as they are concerned with managers’ organization of individuals, reflected in their research question asking “how a manager should organize individuals to generate knowledge that the firm seeks” (Nickerson & Zenger, 2004, p. 618, italics added). However, such a distinction is also important at the organizational level as search might be structured differently in different systems.

The way firms organize search for new ideas has been recognized as being essential to the innovation process and the move towards open innovation models is viewed as a reflection of altered search processes (Laursen & Salter, 2006). Katila and Ahuja (2002, p. 1184)(based on Winter, 1984) “defined product search as an organization's problem-solving activities that

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3 The notion of ‘local’ search here seems slightly different from the local search discussed in the literature on breadth and depth of search (Katila & Ahuja, 2002) and thus the term ‘directional’ is preferred here in order to avoid confusion.
involve the creation and recombination of technological ideas.” They lay out the ideas of scope and depth of search (Katila & Ahuja, 2002). Search scope (local versus distant—as discussed above) is defined as “the degree to which it entails the exploration of new knowledge” while search depth is defined as “the degree to which existing knowledge [that is, knowledge held by the firm] is reused or exploited” (Katila & Ahuja, 2002, p. 1184).

The above discussion stressed the idea that search in organizations is ‘problemistic’ (Cyert & March, 1963); in other words it is aimed at solving problems. As Nelson and Winter (1982) phrase it in regards to this notion, search is “stimulated by a particular problem, and the symptoms of the problem define a neighborhood in which the search takes place”. The symptoms in this case are issues with the current situation that come to the attention of organizations. The idea of the neighborhood is reflected in the idea of local search (Stuart & Podolny, 1996) and has led to the metaphor of the search environment taking a geographic shape in the form of rugged landscapes (Levinthal, 1997). To illustrate, Nelson and Winter (1982, p. 173) give the example of the problem being a reduction of profits due to an increase in an input factor, which constitutes the symptom, and leading to a focus in terms of solving the problem on

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4 The term search as it is used here refers to both looking for existing solutions as well as creating new ones: “Use of the term ‘search’ to denote a firm’s activities aimed at improving on its current technology invokes the idea of a preexisting set of technological possibilities, with the firm engaged in exploring this set. This connotation seems natural when one is considering R&D aimed to find, say, a seed variety with certain properties or a chemical compound with certain characteristics. It seems less natural when one is considering R&D aimed to develop a new aircraft, or, more generally, R&D activities where the terms ‘invention’ or ‘design’ seem appropriate. Instead of exploring a set of preexisting possibilities, R&D is more naturally viewed in these contexts as creating something that did not exist before. And surely modern research on hybrid seeds and pharmaceuticals involves creating as much as discovering.

But for the purpose of our evolutionary modeling, the distinction here is one of semantics not substance. The R&D activities of our firms will be modeled in terms of a probability distribution for coming up with different new techniques. We will discuss this in terms of sampling from a distribution of existing techniques. But alternatively we could discuss it in terms of a distribution of things that a firm might ‘create.’ In either case, that distribution might be a function of time (opportunities might evolve over time), a firm’s R&D policy (some firms might spend more or perform different kinds of R&D than others), the firm’s existing technique (search may be largely local), and other variables.” (Nelson and Winter, 1982, p. 210).
the products and activities that most use this factor. Questions such as how to reduce the employment of this input factor can be addressed internally or, in an open innovation mindset (Chesbrough et al., 2006; Chesbrough, 2003a), can be posed externally, for example through a broadcast search (Jeppesen & Lakhani, 2010) mechanism.

This outlined structure of organizational search processes has been the conceptual base for formal mathematical modeling. One of the most commonly used modeling techniques in this regard is the NK-model developed by Kauffman (1993), building on the idea of fitness landscapes developed by the biologist Sewall Wright (1931, 1932). In NK-modeling the letter N denotes the number of attributes in a decision and the letter K denotes the interdependence between choices. K ranges from 0 to N-1 where a higher value of K increases the influence of one attribute on others and leads to a more rugged landscape (Levinthal, 1997; Gavetti & Levinthal, 2000). If K is 0 there is only one optimal solution in the landscape, while an increase in K leads to the development of local peaks. NK-models of search have originally been designed to model genome alterations in biology research. They thus share a heritage in biology research with evolutionary economics. In addition to the general idea of organizational search, Chesbrough’s (2003a) specific reference to complexity theory (Levinthal, 1997; Gavetti & Levinthal, 2000) suggests that in regard to search it could be useful to employ NK modeling (Kauffman, 1993).

NK-models of search depict the area of search as a landscape in which optimal local solutions are portrayed as peaks. The models are based on an ‘off-line’ evaluation of options, in which the alternatives being considered are not executed and no path-dependent alterations are being made. In other words, various possibilities are examined independently of each other. As such, the models reflect a mental exercise of cognitively evaluating potential alternative moves.
Search (and in particular local search) often depends on trial-and-error learning which is reflected in the conceptual model as employing a different approach and retaining that approach if it leads to a better solution than the previous one while returning to the previous routine if the new approach results in lower performance (Gavetti & Levinthal, 2000). From purely local search, a firm cannot determine if it arrives at a local peak or the global peak of the landscape. The NK search model was used in research on open innovation (Almirall & Casadesus-Masanell, 2010) and was the foundation for a formal model on crowdsourcing (Afuah & Tucci, 2012).

2.4 The Innovation Process and its Parts

The general innovation process has not changed much over time (Schilling, 2009a, p. 5; Stevens & Burley, 1997). While it has become one of the most important drivers of firm success in many industries (Schilling, 2009a, p. 1), technological innovation is still built on “blind” variation and selective retention (VSR) processes (Campbell, 1960). Campbell’s (1960) VSR model is largely based on the selection process described by Souriau (1881, as cited by Campbell, 1960). Souriau (1881, as cited by Campbell, 1960) sees the innovation process as a mechanical trial and error process in which the problem formulation is the most important aspect. He states: “It is said that a question well posed is half answered. If so, then true invention consists in the posing of questions. There is something mechanical, so to speak, in the art of finding solutions. The truly original mind is that which discovers problems.” (Souriau, 1881, quoted by Campbell, 1960, p. 385). This view highlights the importance of keeping control over the questions posed in an R&D process (and thus being able to ask the right questions), while the production of the actual solution is considered merely a mechanical process. This mechanical process of finding
an adequate solution is based on large numbers of trial and error combinations from variant knowledge bases (Campbell, 1960).

The innovation process is often depicted as a funnel that represents the R&D activities, starting with many projects that are being narrowed down in number to finally lead to only one (or a few) new products that are brought to market (Schilling, 2009a, p. 5). One such funnel is depicted in Figure 1. The closest estimate we have as to how many raw ideas and written proposals it takes to develop one substantially new, successful product is 3000 ideas and 300 proposals (Stevens & Burley, 1997). These numbers have been derived from a triangulation involving primary research and a review of various previous studies concerned with different stages of the development funnel (Stevens & Burley, 1997). The numbers (based on patent, new project development, and venture capital data) suggest that, despite industry-specific differences, the ratio of input to output is relatively consistent (Stevens & Burley, 1997). Notably, there are expected differences in industries, for example the number of compounds screened to develop one successful new pharmaceutical drug has been estimated to be as high as 8000-10000 (Lowe & Taylor, 1986). There have also not been signs that the success rate has improved over time (Crawford, 1977; Edgett, Shipley, & Forbes, 1992). For example, a publication by Booz Allen & Hamilton, Inc. referring to a change of a 67% success rate in the mid 1960s to a 65% rate in the late 1970s to early 1980s states that “[m]ore companies are using a more sophisticated new product process [...] yet, there has been virtually no change in the rate of successful introductions” (Booz Allen & Hamilton, Inc., 1982, as cited by Stevens & Burley, 1997). Taken together, this evidence suggests that increasing the input, in terms of ideas that the company is exposed to, and improving the decision mechanisms on which ideas a company should focus on, should improve the output performance of the organization. It also suggests that companies
could benefit from entering into the R&D process at a later stage (i.e. the written proposal stage rather than the raw idea stage; or the development rather than the research stage), decreasing the number of necessary trials and thus the time and monetary requirement. Entering into the process later does, however, raise the issue of having control over which initial ideas make it to a more refined development stage or, more broadly, what the general research direction will be.

**Figure 1: The R&D innovation funnel**

Notably, each idea represents a potential solution to a problem that is either implicitly or explicitly raised by somebody. Knowing what questions to ask—or problems to pose—becomes critical for the generation of relevant variation and subsequent successful selection of solutions from an increased pool of ideas (Campbell, 1960). Remaining in control of the question means controlling the search direction and allows for guidance on what types of innovations are being generated (see Figure 2). Guiding the innovation process by controlling the problem formulation...
process (or the research question) is essential for companies for various reasons. Specifically, it can lead to cost savings through easier integration, ensure that resources and capabilities are secured and developed to fit the organization’s strategic intent, decrease the dependence on chance in terms of opportunities available in the market by controlling the direction of research, and alleviating the risk that needed components are not available because no one saw a need for developing them and investigating in certain areas of a firm’s knowledge landscape. Before discussing the importance of variation which closely ties in with the selective-retention-model (Campbell, 1960) underlying evolutionary theory (Nelson & Winter, 1982), I will briefly show that there are different ways to organize problem-oriented search leading to trade-offs among various aspects, including the control of the search direction.

2.4.1 Trade-offs between Modes of Search

The control over the question posed, and thus the direction of research, is affected by the choice of different (external) knowledge sourcing approaches. For example, in using in-licensing or employing the acquisition approach outlined by Arrow (2000), a major drawback is that the corporation gives up initial control over the question to ask. The focal corporation then is only able to purchase what is available in the market after the research process has been concluded. This leads to a small numbers bargaining problem (Williamson, 1973) that corporations are facing when looking for new areas of product development since only a limited number of suitable targets are available in the market at any given time. After all, selection can only be made from the choices known at any given point in time, which is referred to as the ‘contingent’ character of search (Nelson & Winter, 1982).

Both the small numbers bargaining problem (Williamson, 1973) associated with licensing and mergers & acquisitions (M&As), as well as the high upfront commitment and limited reach
issues associated with internal R&D and alliances, could potentially be overcome through broadcast search. It is essential though to note that broadcast search approaches come with their own set of challenges, most importantly knowledge leakage associated with the inherent openness concerns (Enkel, Gassmann, & Chesbrough, 2009; Srivastava & Gnyawali, 2011).

Organizational alternatives for search have also been labeled ‘modes of development’ (Schilling, 2009a). Table 1 builds on Schilling’s (2009a) categorization of the trade-offs of select modes of development and extends it by my conceptual categorization of M&As and broadcast search along the same parameters.

**Table 2: Extended summary of trade-offs between different modes of search**

<table>
<thead>
<tr>
<th></th>
<th>Speed</th>
<th>Cost</th>
<th>Control</th>
<th>Potential for Leveraging Competencies</th>
<th>Potential for Developing New Competencies</th>
<th>Potential for Accessing Other Firms’ Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solo Internal Development</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Strategic Alliances</td>
<td>Varies</td>
<td>Varies</td>
<td>Low</td>
<td>Yes</td>
<td>Yes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Joint Ventures</td>
<td>Low</td>
<td>Shared</td>
<td>Shared</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Licensing In</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>Sometimes</td>
</tr>
<tr>
<td><strong>M&amp;A</strong></td>
<td>Med / High</td>
<td>High</td>
<td>Low / Med</td>
<td>Sometimes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Broadcast Search</strong></td>
<td>Med / High</td>
<td>Low</td>
<td>High</td>
<td>No</td>
<td>Sometimes</td>
<td>Sometimes</td>
</tr>
</tbody>
</table>

Note: Based on Schilling (2009a) Table 8.4 (p. 169): “Summary of Trade-offs between Different Modes of Development” Extensions in bold

5 In order to avoid confusion with the definition of ‘development’ in Arrow’s (2000) model, I do not adopt this term but rather talk about either ‘alternatives for search’ or ‘search modes’.

6 The modes of development borrowed from Schilling (2009a) only extend to those specifically related to inbound processes to the exclusion of outbound processes such as ‘Licensing Out’ or ‘Outsourcing’, as well as broad collaborations such as ‘Collective Research Organizations’.
In addition to the categorization of modes of search and their respective trade-offs depicted in the above Table 1, there are additional aspects that should be considered\(^7\). Specifically, the trade-offs between modes of search along the aspects of (1) risk (related to uncertainty), (2) potential for small numbers bargaining problems, (3) potential knowledge leakage, and (4) appropriability are of special interest. Table 2 shows my placement of each mode along these aspects. The importance of variation will be addressed next.

### Table 3: Additional trade-offs between select modes of search

<table>
<thead>
<tr>
<th>Mode</th>
<th>Risk</th>
<th>Potential for small numbers bargaining</th>
<th>Potential for knowledge leakage</th>
<th>Appropriability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solo Internal Development</td>
<td>high/full</td>
<td>low</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Strategic Alliances/JV</td>
<td>medium/partial</td>
<td>low-medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Licensing In</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>medium</td>
</tr>
<tr>
<td>M&amp;A</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Broadcast Search</td>
<td>low</td>
<td>low-medium</td>
<td>medium-high</td>
<td>medium-high</td>
</tr>
</tbody>
</table>

#### 2.4.2 Variation and Selective Retention

Variation is essential to creating innovations. The (blind-)variation-and-selective-retention (VSR) model is based on three key aspects which are (a) some form of heterogeneity or variation, (b) a systematic mechanism to eliminate choices, and (c) a mechanism to store selected information and (in many cases) re-create the selected choices (Campbell in Ayala & Dobzhansky, 1974; Campbell, 1960). Campbell (1960) points to three aspects that warrant the

\(^7\) While Schilling (Schilling, 2009a) distinguished between strategic alliances and JVs, in the following those two are considered as one, since JVs are considered “a particular type of strategic alliance that entails significant structure and commitment” (Schilling, 2009a, p. 166) and as such cannot be fully and unambiguously separated.
process of generating variation to be considered ‘blind’—‘lacking prescience or foresight’. First, “variations emitted be independent of the environmental conditions of the occasion of their occurrence” (Campbell, 1960, p. 381). Second, “the occurrence of trials individually be uncorrelated with the solution, in that specific correct trials are no more likely to occur at any one point in a series of trials than another, nor than specific incorrect trials” (Campbell, 1960, p. 381). Third, “rejection of the notion that a variation subsequent to an incorrect trial is a "correction" of the previous trial or makes use of the direction of error of the previous one” (Campbell, 1960, p. 381). Strictly speaking, the latter in essence would exclude ‘local search’ (Cyert & March, 1963; Katila & Ahuja, 2002; Stuart & Podolny, 1996) from this process (and as such I do not view the process as being completely blind at the local level). However, the idea of the variation being blind is most notably reflected in the independence of idea generators and developers in a broadcast search system. Ideas that are entered into the system as an answer to the call for submissions are developed based both on public knowledge as well as specific knowledge of the developers. The developers do not, however, know of other ideas being submitted. Once submitted and made public, these parts of the other ideas become public knowledge.

No matter if organizational learning is based on individuals (Grant, 1996) or on other ways of learning (systems/heuristics/routines), the trial-and-error method (i.e. an evolutionary process) is underlying all learning processes (Campbell, 1960). Transposing from learning to search, outcomes from search activities might be different depending on the level at which search was conducted and the level at which the solution was sought (Afuah & Tucci, 2012).
2.4.3 The Compartmentalization of the Innovation Process

Arrow (2000) addresses the innovation process as one that can be compartmentalized and divided up between individual actors in a system and offers a frugal yet powerful description of the R&D funding process. In Arrow’s (2000) model the R&D process can be crudely divided into three stages. These are as a starting point (1) the concept—or innovation idea (viewed as random, yet not independent\(^8\), events), (2) research (defined as feasibility determination of the concept) and (3) development (defined as profitability determination of the concept). The latter two aspects of the overall process require investment which can be accomplished by two separate actors in Arrow’s (2000) model. Here, the entrepreneur is responsible for the research part while the development process is better accomplished by the corporation (Arrow, 2000). The above depiction matches with Mowery’s (2009) finding that small businesses are taking up a larger share of private firm financed R&D in the US economy. A clear shift in this can be witnessed in the early 1990s (Mowery, 2009, p. 14 - Figure 4). From the above model Arrow (2000) arrives at the following conclusion:

“[…] there is likely to be a tendency toward specialization—less costly and more original innovations will come from small firms, and those involving higher development costs but less radical departures in principle will come from larger firms. This specialization creates opportunities for trade, as all specialization does; in this case, the trade will frequently be in firms as such—that is, takeovers and mergers” (Arrow, 2000, p. 231).

\(^8\) In essence, path dependence and local search (“the state of knowledge in the relative specialty […] influenced by previous innovations in the same intellectual area”) are recognized to influence concept generation, but they are “not controllable and unaffected by policy”.

Therefore, Arrow (2000) offers a rational for the emergence of M&As as a mode of search. An alternative to this firm acquisition strategy is the deliberate separation of the solution idea search (i.e., research) from the internal development process. Using Arrow’s (2000) distinction, the separated R&D processes can be conceptualized as being conducted in an inbound open innovation approach in which an outside actor (i.e., entrepreneur, researcher, university, or small firm) provides the research and the focal organization, as a relatively larger, financially backed corporation, conducts the development. The former is often referred to as ‘solver’ while the latter is considered the ‘seeker’ in competition based broadcast search approaches (https://www.innocentive.com/ accessed November 6, 2012). The advantage of such an approach from the perspective of the seeker over the more traditional M&A approach is that the seeker retains control over the question to be researched. Naturally, such a divide between actors leads to behavioral considerations within the focal organization. Behavioral aspects are evident both in M&A approaches, where an integration ex post is necessary, and in broadcast search approaches, where issues such as not-invented-here (Katz & Allen, 1982) have to be overcome in achieving acceptance of such processes by internal research staff. As all approaches that concern themselves with the integration of and interaction with external actors fall into the realm of open innovation research (Chesbrough et al., 2006; Chesbrough, 2003b), the next section will address theory development in the open innovation arena. Afterwards, a section will investigate different usages of the term ‘open innovation’.

2.5 The Concept of Open Innovation

The structure and organization of the innovation process is an important decision for firms in technology-intensive industries. One frame of reference in this regard that has achieved traction in the literature is the perspective of open innovation (Dahlander & Gann, 2010;
Huizingh, 2011). Since Chesbrough’s (2003a) introduction of the open innovation concept, open innovation has received extensive, growing consideration (Dahlander & Gann, 2010) and has become a hot discussion topic in the literature (Huizingh, 2011). Open innovation is seen to be essential to the success of enterprises (Chesbrough, 2003a; Teece, 2007) to the extent that Teece (2007, p. 1322) referred to closed, internal innovation systems relying on local search as “strategic straitjackets”.

2.5.1 Academic Treatment of Open Innovation

As a conceptual frame, open innovation offers valuable guidance with the potential to lead to new insights that go beyond the constraints of the framework and the terminology of open innovation—informing the general understanding of research on innovation (Huizingh, 2011). To harvest these insights, it is however important not to convolute the term by building on loose definitions, particularly since it is an evolving concept. As such I will first clarify the use of open innovation in the literature and then present a narrower, constrained fraction of the concept suitable for the context of the current study.

In the academic literature, the term open innovation describes the integration of internal and external inputs into integrated structures through business models (Chesbrough et al., 2006; Chesbrough, 2003a). Through these business models, both internal and external ideas are employed to create appropriable value for the focal organization. R&D is viewed as an open system in which ideas can be generated inside the company or can enter from the external environment. Value capture from knowledge and products generated inside the company can respectively be achieved in current markets and through established channels or through external channels and new markets. In the following I will briefly sketch out this proposed dichotomization (Trott & Hartmann, 2009) between closed and open innovation.
In the traditional, or closed, innovation model ideas are generated within the firm and developed in corporate R&D labs (Chandler, 1990). The general process within these labs is that a researcher starts work on a relatively large number of projects which are exclusively based on the knowledge stock of the organization with the goal of developing new or improved products. As outlined in the general innovation process earlier, down the line the number of projects decreases as seemingly meritless projects are discontinued, until in the end few projects are being developed into final products which can be brought to established markets using current paths to market. A determining feature of the closed innovation model is that projects can only enter into the process at the outset and can only exit the process in one fashion, by being brought to the market through the focal firm (Chesbrough et al., 2006). From the perspective of open innovation, these boundaries to the innovation process which coincide with the boundaries of the organization, become permeable and thus allow for an exchange with the environment. This exchange includes both the integration of knowledge and ideas from the outside as well as the appropriation of value through new channels and paths to market.

In the depiction of the open innovation model, the boundaries of the funnel described earlier in the conceptualization of the general innovation process represent the boundaries of the R&D organization which are permeable in both directions and offer an exchange of ideas, knowledge, intellectual property, and products both from the outside into the organization and from the organization to the outside. This depiction allows for an integration of various aspects, such as in- and out-licensing, technology insourcing, and technology spin-offs, into the focal firm’s innovation process (Chesbrough et al., 2006).

While the literature is somewhat vague on the exact mechanisms, all mechanisms of knowledge sourcing considered in this dissertation would be considered mechanisms for inbound
open innovation. Therefore, the current study takes a more focused approach of analyzing what in practitioner’s terms is often considered “open innovation” by concentrating on specific inbound processes. I posit that open innovation mechanisms that in practice are labeled “open innovation” and which have recently emerged as experimental tools employed by large corporations are more precisely a reflection of a structured inbound open innovation approach which has been described in the academic literature as “broadcast search” (Jeppesen & Lakhani, 2010). It is important to stress the directional purpose (‘inbound’) as well as the intentional nature of these mechanisms. A review of some of the structuring attempts of open innovation in the academic literature will help to clarify this conclusion.

2.5.2 Framing Attempts within Open Innovation Research

Although Trott and Hartmann (2009) criticized the alleged dichotomization of open versus closed innovation, it is generally agreed by researchers on open innovation that innovation can be viewed as a continuum ranging from closed to open (Dahlander & Gann, 2010). Despite this surface agreement, the specific categorization is more ambiguous. Theorizing has attempted to disentangle the relatively general idea of open innovation into components that reflect specific organizational approaches in becoming more open in technology development and appropriation. Some of the relevant frameworks will be reviewed briefly. One general and widely adopted differentiating is that between inbound (outside-in) and outbound (inside-out) open innovation (Chesbrough et al., 2006; Chesbrough, 2003b; Dahlander & Gann, 2010) extended by a third option: coupled open innovation or co-creation through cooperation, joint ventures, alliances, and the like (Enkel et al., 2009). While emphasizing the importance of access to the industry network (Enkel et al., 2009) this framing is not concerned with a detailed differentiation between the modes of achieving access and knowledge exchange. Enkel and colleagues (2009, p. 312)
conclude that “cooperation with externals is core to increase innovativeness and reduce time to market.” As will be seen these are the two promises of open innovation that can be derived from its most accepted definition (Chesbrough et al., 2006).

Another frame is offered by Dahlander and Gann (2010) who combine the distinction between inbound and outbound open innovation with monetary considerations. By introducing a second dimension to the inbound versus outbound dimension, which they term pecuniary versus non-pecuniary, they create four basic groups of strategies; acquiring (inbound, pecuniary), sourcing (inbound, non-pecuniary), selling (outbound, pecuniary), and revealing (outbound, non-pecuniary) (Dahlander & Gann, 2010). Their distinction has been recognized as a potential starting point for empirical research in regards to understanding open innovation activities and their efficacy in varying situations (Huizingh, 2011). The current study is focused on the ‘acquiring’ quadrant as depicted in Figure 3, reproduced here from Dahlander and Gann (2010).

Table 4: Structure of Dahlander and Gann’s (2010) different forms of openness

<table>
<thead>
<tr>
<th></th>
<th>Inbound innovation</th>
<th>Outbound innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pecuniary</td>
<td>Acquiring</td>
<td>Selling</td>
</tr>
<tr>
<td>Non-pecuniary</td>
<td>Sourcing</td>
<td>Revealing</td>
</tr>
</tbody>
</table>

Reproduced from Dahlander & Gann (2010). For copyright agreement see Appendix A.

Chesbrough (2003b) offers a categorization that distinguishes between different actors in an open innovation framework. While subsequent literature reviewed does not seem to build explicitly on this typology, it does however point to the potential for specialization under the open innovation concept which otherwise seems implied but is not explicitly addressed in the
literature (Huizingh, 2011; Lichtenthaler & Lichtenthaler, 2009). The most noteworthy and relevant idea from Chesbrough’s (2003b) typology is the concept of ‘innovation intermediaries’ which have formed as distinct brokers of innovations in recent years. The most prominent example at current is probably InnoCentive, although there are several competitors, such as ChallengePost who runs many of NASA’s prize competitions through the challenge.gov website.

2.5.3 Academic Definitions of Open Innovation

Constructs, propositions as reflections of the relationships between constructs, and boundaries as assumptions about values, space, and time are the essential components of theory that allow for the generalization to circumstances beyond individual observations (Bacharach, 1989). Clearly defined constructs are the building blocks of good theory which in turn is essential to allow for better understanding and prediction of firm behavior (Klein & Zedeck, 2004). Generally speaking, the stronger the definition of a construct, the more valuable it is in terms of organizing knowledge, extending knowledge, and guiding action. Solid, well-specified definitions of constructs aid in their operationalization and form the basis for both theory development and testing. In theory development there is a constant struggle between scope of theory versus specificity; a struggle that seems to be evident in the open innovation realm. Chesbrough (2003a) seemed to have focused on breadth to combine observations under one umbrella and now the scientific community works on creating the specificity needed for empirical testing. Boundaries are being determined through theorizing as a reaction to observations of instances where the initial prescriptions given by the open innovation concept do not lead to better performance. Reaching falsifiability is a major struggle in moving from open innovation as an umbrella concept to a theory of open innovation that is able to confidently offer prescriptions. To make theorizing in the realm of open innovation falsifiable, the underlying
constructs and propositions have to be unambiguous in order to be able to operationalize these theory components in variables and hypotheses, respectively (Bacharach, 1989).

While some researchers on open innovation have criticized the focus on definitional issues by arguing that “[d]eveloping precise formal definitions and boundaries may satisfy academic rigor but is not likely to prove a very productive pursuit in practical terms” (Linstone, 2010, p. 556), the current work posits that we cannot offer guidance to practice without a formal scientific foundation. The importance of theory for practical development has been noted in the literature (Van de Ven, 1989; Lewin, 1945). Although an over-reliance on theory has been criticized in the past (Ghoshal, 2005), clarifying construct definitions and specifying concepts is a pre-requisite for scientific progress. As such, the clarification of the open innovation definition is anticipated to increase the value of open innovation as a framework in offering a practical understanding and a guideline for its use in research. Subsequently, this research helps to guide practice by developing or informing a prescriptive theory that is well founded and informs practice on that basis rather than the previously dominant extrapolation from case studies.

Starting from general open innovation definitions, I will move into a confined definition for the purpose of this study that is consistent with academic developments but reflects the practical understanding of open innovation currently employed. The approach taken in analyzing definitions on open innovation is guided by the idea that definitional precision is most likely found in the major foundational works of a concept, most consistently used by people specialized in the area, and most consistently developed in academic journals’ special issues focused on the specific topic. Following this logic, the analysis takes a chronological approach, starting with Chesbrough’s (2003a) original definition and then moving to the definition used in his introduction to a co-authored volume that is more focused on theory building than his
original work (Chesbrough et al., 2006). Next, definitions used by another prolific author and in articles published in special issues of R&D Management and Technovation are reviewed. The publication of one of the special issues on open innovation coincides with the publication of Chesbrough and colleagues’ (2006) second major work and a first spike in the number of journal articles published (Dahlander & Gann, 2010). An additional two—more recent—special issues evaluated, reflect current definitions used across authors.

2.5.3.1 Chesbrough 2003—The Beginnings of Open Innovation

The term open innovation was first introduced by Chesbrough (2003a) and early work on the idea of open innovation was mainly practitioner oriented with the intention to help managers of technology deal with a seemingly changing business environment in which more and more firms turned to external paths in the development process of new ideas and the appropriation of their value. The formal definition used in Chesbrough’s book reads as follows: “Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology.” (Chesbrough, 2003a, p. xxiv). The definition positions open innovation as a paradigm which suggests that it is viewed as an umbrella concept (Huizingh, 2011) and as such can be of very broad, loosely specified nature (Kuhn, 1962). As a starting point for a new theoretical viewpoint this is not problematic per se as theory development often starts from a broad perspective and subsequently is specified further in an iterative process (Van de Ven, 1989; Weick, 1989; Whetten, 1989). A potentially misleading component in the above definition that should be addressed from a scientific perspective is the general statement that (all) firms should employ an open innovation approach. This is specifically stated as an assumption by Chesbrough (2003a) in the definition above. Whether and when such approaches are leading to
performance improvements should be determined by theoretical and empirical research. The main task for research is to investigate the boundary conditions of the framework reflected in the extent and circumstances under which theoretically founded predictions can be observed. The definition also does not differentiate between the individual aspects of open innovation such as internal versus external ideas and internal versus external paths to market.

Based on the definitional understanding outlined above, the book (Chesbrough, 2003a) was written in a prescriptive fashion, indicating or directly stating how firms should or should not behave in the new landscape being portrayed. The foundations for these prescriptions were mainly popular press books, practitioner oriented journals, and case studies of individual firms based on previous accounts as well as direct interviews and personal experience. Many of the notes in the book are brief—more or less general—explanations rather than references to previous scientific literature and academic research. In some parts the book refers to foundational work in strategic management but only to a very limited account. Chandler (1962, 1977, 1990) and Penrose (1959) are mentioned in the discussion of the (outdated) closed innovation paradigm. Michael Porter (1980) is mentioned for his value chain arguments, and Teece, Pisano, and Shuen (1997) is referred to for further considerations in the management field. Relating to how firms structure their knowledge with the idea of bounded rationality and satisficing in mind (both these terms are not explicitly used but referred to on p. 70)\(^\text{10}\),

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\(^9\) The book has a “Notes” section instead of a “Reference” section and the citations given in Chesbrough’s (2003a) book are given as endnotes rather than references. As such, they many of them are annotated, brief descriptions of background and areas for further reading intermingled with a few specific references. It should be noted that they seem to be geared towards practitioners as guidance on where more information can be found regarding a topic and do not seem to be given primarily as a reference in an academic sense to pay tribute to the originator(s) of an idea.

\(^{10}\) “We know from earlier research that managers cannot—and do not—exhaustively evaluate every alternative when they confront such situations. Instead, they apply cognitive filters to reduce this complexity to a manageable level.” (Chesbrough, 2003a, p. 70)
Chesbrough refers to March and Simon (1958), Daft and Weick (1984), and Henderson and Clark (1990). Clayton Christensen’s (1997) concept of disruptive technologies, Prahalad and Bettis’ (1986) idea of dominant logic and the counter-point by Tripsas and Gavetti (2000), Moore’s (1996) ecosystem as a metaphor for business, as well as von Hippel’s (1988) user innovations, Rosenberg’s (1982) lack of the predictability of technology uses, and Teece’s (1986) technology commercialization focus are indicative of the type and breadth of previous work Chesbrough draws upon. Interestingly, however, most concepts are only touched upon briefly and not developed in any depth. Ideas such as knowledge leakage are discussed by Chesbrough (2003a) but receive no scientific citation whatsoever. Overall, the review of the citations used in the book reveals some reliance on previous literature; yet the depth of scientific foundation is highly limited as most works are only cited once—usually in a tangent manner. The only explicitly addressed theory in Chesbrough’s (2003a) description of the framework is complexity theory, referring to Gavetti and Levinthal’s (2000) work. Notably, while most of the aforementioned references are only made once, reference to complexity theory is made both in the first and final chapters of the book. Interestingly, this explicit reliance on complexity theory is not reflected in subsequent work on open innovation which has largely ignored it as an explicit theoretical base. A notable exception is Almirall and Casadesus-Masanell (2010) who employ mathematical modeling nested in complexity theory to inform research on open innovation.

Chesbrough’s (2003a) book was proclaiming a new era, building on cases of organizations that had been successful in either becoming large and competitive by open approaches to research, development, and commercialization, or on cases of companies that were making the switch towards more open models. While there were indications of success and a seeming necessity to become more open, it was clearly lacking a theoretically focused
foundation for why a change towards more openness was something that every company should strive for. This lack of theoretical foundation should be of concern to academics.

2.5.3.2 Chesbrough et al. 2006—The Move towards a More Theoretical Formulation

In an attempt to respond to such concerns, Chesbrough edited another book together with Vanhaverbeke and West in 2006, entitled “Open innovation – Researching a new paradigm.” The book formally defined open innovation as “the use of purposive inflows and outflows of knowledge to accelerate internal development, and expand the markets for external use of innovation, respectively. Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology” (Chesbrough et al., 2006, p. 1). A core part of the original definition is still present in the new formulation of the concept, including the above criticized general prescription for (all) firms to use open innovation. The focus, however, has shifted in that two new inherent assumptions regarding the purpose of open innovation have entered into the definition. These two are the goals to achieve time compression in the internal development process and to find and develop new markets. The tool to achieve those goals is stated to be the control of knowledge flows. Overall, the 2006 definition seems more concerned with the reasons for open innovation than its functioning, relative to the 2003 definition.

Although Chesbrough’s definition is widely used, much of the literature does not offer an explicit definition of the open innovation concept but rather outlines it in a paragraph or two, similar to the following description that is given here from a Strategic Management Journal article as an illustrative example:

“[Chesbrough’s open innovation] model suggests that the advantages that firms gain from internal R&D expenditure have declined. Accordingly, many
innovative firms now spend little on R&D and yet they are able to successfully innovate by drawing in knowledge and expertise from a wide range of external sources. The erosion in the strategic advantage of internal R&D is related to the increased mobility of knowledge workers, making it difficult for firms to appropriate and control their R&D investments. Chesbrough argues that open innovators commercialize external ideas by deploying outside (as well as in-house) pathways to the market (Chesbrough, 2003b). This process redefines the boundary between the firm and its surrounding environment, making the firm more porous and embedded in loosely coupled networks of different actors, collectively and individually working toward commercializing new knowledge.” (Laursen & Salter, 2006, p. 132).

A close examination of this excerpt reveals that there is a disconnect between the generally well understood idea behind open innovation that is reflected in descriptions of the concept, even in top journals, and the construct precision necessary for a solid definition that allows for empirical examination. While the above paragraph builds on Chesbrough’s general idea, the exact building blocks of the definition are not fully mirrored in the description.

2.5.3.3 Use of Definitions by Another Prolific Author and in Special Issues

One of the most published authors in the field in terms of number of publications is Ulrich Lichtenthaler (Dahlander & Gann, 2010). Looking across his publications shows that his employed definition is one that he developed himself in 2008 using terminology separate from Chesbrough’s (Lichtenthaler, 2008a). It reads as follows: “An open innovation approach refers to systematically relying on a firm’s dynamic capabilities of internally and externally carrying out the major technology management tasks, i.e., technology acquisition and technology
exploitation, along the innovation process. Thus, open innovation processes involve a wide range of internal and external technology sources, and a wide range of internal and external technology commercialization channels.” (Lichtenthaler, 2008a, pp. 148–149). Similar to the definition offered by Chesbrough in 2006, this definition also focuses on the strategic intention to employ internal and external sources, however instead of focusing on knowledge, Lichtenthaler focuses on technologies and bases his definition vocabulary in the dynamic capabilities literature (Teece et al., 1997). Lichtenthaler uses or explicitly refers back to his 2008 definition in various occasions (Lichtenthaler & Ernst, 2009; Lichtenthaler & Lichtenthaler, 2009; Lichtenthaler, 2009). While the definition has the advantage of not suffering from premature prescriptiveness, it does not seem to offer any advantages in terms of clarity and operationalizability. Similarly, reviews of special issues on open innovation by R&D Management (in 2006, 2010) and Technovation (in 2011) point to a common understanding in the field but little definitional rigor.

Not unusual for a young field (Boyd, Gove, & Hitt, 2005; Kuhn, 1962), the definitions reviewed allow for a broad range of understanding what open innovation is and bears the danger of developing a tautological theory of open innovation that basically states that any kind of knowledge is important. In order to avoid falling prey to this possibility, the assumptions of the open innovation framework need to be explicitly specified and theoretical foundations need to be established along with a clarification of the boundaries. Chesbrough, Vanhaverbeke, and West (2006) have started to do so, attempting to shift the discussion from the managerial implications to a more scientific endeavor and an extensive body of academic research is starting to accumulate on the topic (Dahlander & Gann, 2010).
Most importantly, before enough evidence is collected regarding where and how firms will benefit, it is important not to jump ahead of the collection and proper analysis of scientific evidence by generally advising every company to open up their innovation processes, adversely creating a management fad (Abrahamson, 1991). We need to be able to understand when and how it is beneficial and what the risks are, before we can make suggestions on where such risks should be taken and how they will likely pay off (Kline, 2003; Rivette & Kline, 2000a, 2000b). A solid theoretical foundation is a core building block in addressing such questions.

The open innovation idea has been developed in an inductive fashion from a collection of case studies, mainly on large firms (Chesbrough et al., 2006). More recent literature attempts to scrutinize and refine the premises arrived from observation and underscore the concept with theoretical foundations (Laursen & Salter, 2006). The main theoretical foundations (or ‘antecedents’) are seen by Chesbrough and colleagues (2006) to be the work by Joseph Schumpeter (1934, 1942), the idea of spillovers (Nelson, 1959, as cited by Chesbrough et al., 2006), the Not-Invented-Here syndrome (Katz & Allen, 1982), and mathematical modeling of a firm’s decision for external search by Nelson and Winter (1982). Further concepts underlying the open innovation paradigm include the ‘two faces’ of R&D leading to the idea of absorptive capacity (Cohen & Levinthal, 1990), the idea of lead users (Von Hippel, 1988), as well as research on strategic alliances (Gerlach, 1992; Gulati, 1995; Nooteboom, 1999), networks (Bekkers, Duysters, & Verspagen, 2002; Dyer, 1996; Gomes-Casseres, 1996; Mowery, Oxley, & Silverman, 1996; Powell, Koput, & Smith-Doerr, 1996), intermediate markets (Arora, Fosfuri, & Gambardella, 2001; Gans, Hsu, & Stern, 2000), and geographic knowledge spillovers (Baptista & Swann, 1998; Kenney, 2000; Porter, 1990). There are various other ideas that fed into the development of the open innovation concept which have been outlined (Chesbrough et al., 2006).
Out of the selection of antecedents, one that seems to have received some of the least attention is Nelson and Winter (1982). Their evolutionary theory of economic change, to which the above citation refers, is however in large part based on two concepts that seem to be highly relevant to the open innovation context. These concepts are organizational routines—the organizational equivalent for skills at the individual level (Nelson & Winter, 1982)—and search, which is considered to be problem-oriented in organizations—or “problemistic” (Cyert & March, 1963).

2.5.4 Use of the Term Open Innovation in Practice and the Definitional Focus in this Study

From the previously outlined academic categorizations of the open innovation framework, the most relevant here is the differentiation between inbound and outbound open innovation (Chesbrough et al., 2006; Chesbrough, 2003a; Dahlander & Gann, 2010). The current study explores the value of inbound open innovation structures reflected in broadcast search (Jeppesen & Lakhani, 2010).

Enkel and colleagues (2009) also point to some risks and barriers associated with open innovation activities that need to be addressed. The main risks according to an unpublished study conducted in 2008 include “loss of knowledge (48%), higher coordination costs (48%), as well as loss of control and higher complexity (both 41%)” (Enkel et al., 2009, p. 312). The core internal barriers are in descending order the “difficulty in finding the right partner (43%), imbalance between open innovation activities and daily business (36%), and insufficient time and financial resources for open innovation activities” (Enkel et al., 2009, p. 312). Of these risks and barriers, “loss of knowledge” and “loss of control” as well as integration, described as “imbalance between open innovation activities and daily business”, should be of highest concern for the organizations under investigation. “Higher coordination costs” and “higher complexity”
as well as “insufficient time and financial resources” should be of limited concern due to the relative low cost and complexity of broadcast search in relation to overall involvement in R&D of large pharmaceutical companies. Similarly, the “difficulty in finding the right partner” is strongly limited by design as broadcast search in its core is designed to directly address this aspect. Overall, Enkel et al.’s (2009) discussion resonates with confounding aspects of the “paradox of capabilities” outlined by Srivastava and Gnyawali (2011) who point out that the aforementioned NIH (Katz & Allen, 1982), “core rigidities” (Leonard-Barton, 1992), and “competency traps” (Levitt & March, 1988), along with the threat of knowledge expropriation (Heiman & Nickerson, 2004) may all induce organizations to refrain from using open innovation approaches to gain external knowledge.

In practice, many organizations are experimenting with open innovation approaches and as such the hype in the literature and popular press has arguably created quasi experimental laboratories of open innovation (Trott & Hartmann, 2009). Given the many approaches that are being experimented with, there is some kind of disconnect between the more theoretical, broader understanding of open innovation and the use of the term by practitioners. Practitioner use of the term is mainly focused on inbound open innovation and often refers to specific systems that are explicitly designed to openly draw attention to the solicitation of ideas to solve more or less clearly specified problems. Since, the use of the term ‘open innovation’ in practice often seems to be used more narrowly than its theoretical counterpart, it calls for a more narrow definition. As such, I restricted the focus of this dissertation to reflect what has been termed broadcast search (Jeppesen & Lakhani, 2010). As such, for the purpose of this dissertation, I constrained the definition to a commonly observed use of the term which positions broadcast search as an approach used by companies to source solutions to stated problems from external, non-affiliated
sources. Non-affiliated in this context means that no binding contracts covering the problem statement exist between the parties prior to the submission of a solution.

It is important at this point to take a closer look at the rationale offered for integrating the word *purposive* in the 2006 definition. In their work, the authors state that “prior concepts accorded little or no recognition to purposive outbound flows of knowledge and technology” (Chesbrough et al., 2006, p. 9) and specifically included the term *purposive* to recognize the distinction of outbound open innovation processes from knowledge spillovers (Chesbrough et al., 2006). However, they do not discuss the purposiveness of inbound open innovation processes. Rather, Chesbrough and colleagues (2006) seem to implicitly assume that all inbound open innovation processes are purposive, which is clearly contradictory to the argument that inflows of ideas for new products are often unpredictable under changing market conditions (Christensen, 2000). Thus, emphasizing the structured aspect of broadcast search ensures that the focus remains on intentional strategizing rather than the notion that in turbulent times the strategy-making process might be of an emergent nature and “[i]deas for new products flow somewhat unpredictably into a company” (Christensen, 2000, p. 3). It is indeed not quite clear why Chesbrough and colleagues (2006) speak of *purposive* inflows, as the argument has repeatedly been made more broadly that any inflow of knowledge constitutes open innovation opportunities (Chesbrough et al., 2006; Chesbrough, 2003a). The aim referred to in the 2006 definition is still to “accelerate internal development”, but also to decrease cost and alleviate pressure on competing knowledge sourcing practices. These anticipated outcomes, however, should not be part of the definition and are thus not included above. Using this narrowly circumscribed, more specific definition of broadcast search as opposed to the general notion of open innovation allows for a clear operationalization of the construct.
2.6 Problem Solving Perspective

Building on evolutionary economics (Nelson & Winter, 1982) in combination with TCE (Coase, 1937; Williamson, 1975), the problem-solving perspective has been explicitly addressed by Nickerson and Zenger (2004) in an attempt to outline a knowledge-based theory of the firm focused on the economics of various organizational structures for the generation of capabilities and knowledge. Similar to the focus on the transaction as the basic unit of analysis in TCE (Coase, 1937; Williamson, 1975), the problem-solving perspective is also not focused on the organization but instead on a smaller unit of analysis, the problem itself (Nickerson & Zenger, 2004). In their description, Nickerson and Zenger take a rather pro closed innovation view by stating that “[b]y internalizing valuable knowledge or keeping this knowledge internal, the firm positions itself to both exploit and protect knowledge” (Nickerson & Zenger, 2004, p. 617). This view is consistent with other work that has pointed to the risks of open innovation approaches (Kline, 2003). However, Nickerson and Zenger point to a very important question that is valid in both the open innovation paradigm and knowledge management overall: “[H]ow to organize to efficiently generate knowledge and capability” (Nickerson & Zenger, 2004, p. 617, italics in original). Although it is not knowledge itself that is valuable (Carlson, n.d.; Chesbrough, 2003a), access to and understanding of knowledge is a pre-requisit to the generation of new knowledge (Cohen & Levinthal, 1990) and its exploitation (March, 1991). One important question that arises for the open innovation concept is how to organize the sourcing and creation of ideas that ultimately lead to new commercializable outputs (products, patents, etc.). In essence this reflects a more focused inquiry (i.e. sub-question) of Nickerson and Zenger’s (2004) question—within inbound open innovation. At the same time, while Nickerson and Zenger (2004) are focused on the manager, the reformulated question moves away from the focus on the individual to a focus
on the mode of sourcing and creation. It is thus anchored in the process aspect of knowledge sourcing at the organizational level. Nonetheless, there are important aspects that might be transferable from Nickerson and Zenger’s (2004) conceptualization to the current work.

2.7 Integration of the Discussed Theory within the Open Innovation Framework

Informing the open innovation framework from an evolutionary economics perspective requires the understanding of the relationship between two key constructs employed in evolutionary economics, namely organizational routines and search. The relationship between the two is best described by their differences. Search is viewed and modeled by Nelson and Winter (1982) as a response to environmental influences. Organizational routines, despite being reactive to the environment as well, are regarded to be relatively stable traits of the organization ensuring continued functioning. As Nelson and Winter point out, “[s]earch differs from routinized response in three fundamental respects” (Nelson & Winter, 1982, p. 171), which are (a) that search is intrinsically an irreversible process, (b) search entails uncertainty, and (c) search has a ‘contingent’ character in that the outcome is dependent on what can be discovered or constructed through recombinations of existing knowledge. The interrelated nature of these three traits combined makes it a historical process (Nelson & Winter, 1982) and thus reflects their path dependence (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010).

Previous literature on open innovation has recognized the organization of search as an integral part in the innovation process for finding new ideas with commercial feasibility and has suggested that many innovative firms have adopted open search strategies, integrating a host of external sources (Laursen & Salter, 2006; Almirall & Casadesus-Masanell, 2010). This reflects an awareness that search is fundamental for open innovation—particularly for processes of inbound open innovation. As such, one central aspect driving the push towards more open
systems of innovation is the way firms organize their search for knowledge (Laursen & Salter, 2006). In the context of outbound open innovation search becomes similarly important in locating new opportunities for commercialization. Search, as outlined in the review earlier, comes into play whenever new situations arise for which no current organizational routine exists (Nelson & Winter, 1982). Whenever organizations change from closed innovation systems to more open ones or when new sources of information or channels of commercialization are integrated into the system, the conditions for current organizational routines change and have to be adopted through search. Also, due to the inherently flexible nature of open innovation systems, more ad hoc problem solving (Nelson & Winter, 1982) is required. Therefore, search is an integral part of any open innovation activity.

Similarly, organizational routines are connected to open innovation. The different functions of organizational routines—memory, truce, and desired norm—are all relevant in closed innovation as well as open innovation processes. It might be argued that such routines become even more important in open systems since the focus of attention shifts from governing internal processes to managing external relations. The focus of attention away from internal processes requires a well-functioning interplay of routines internally. Through search and adaptation, these routines are adjusted over time to fit with the external focus of the organization in their innovation processes. Evolutionary economics with its special attention to search and organizational routines thus has the ability to inform open innovation.

A specific example where the idea of organizational routines is reconcilable with a concept that has been recognized as important in considerations of open innovation is the NIH-syndrome (Katz & Allen, 1982). The idea that people are reluctant to change towards incorporating external ideas could at least in part be due to the fact that they are not willing to
change their individual and organizational routines without understanding the implications of such a step. As such, understanding organizational routines and how they can be adapted offer implications for open innovation systems.

Aside from the potential of open innovation to be informed by evolutionary economics, the earlier review of the open innovation literature has also shown that the construct of open innovation has not yet been well defined in the literature to an extent that it is used consistently, although the general notion is commonly understood by researchers and there is no intentional opposition between definitions. The field can more adequately be described as being careless and inadequately precise in defining constructs than being in disagreement about constructs. There is some discussion about the value of the concept as a whole, mainly with researchers outside the core area of open innovation, but there seems to exist at least surface-level agreement on the idea of open innovation within the core area of research. In large part, differences in definitions do not seem to stem from an attempt to build definitions on well-crafted concepts but are rather the result of a lack of definitional rigor in determining constructs. The resulting differences in wording, of course have implications on the focus of different definitions. On the other hand, changing definitions over time, even by the same author, might reflect attempts to specify constructs more precisely. For example, Chesbrough’s (2006) definition, while still broad, specifies time compression of internal development processes and new market expansion as two explicit goals, to be achieved through the control of knowledge inflows and outflows, notions not explicated in Chesbrough’s (2003a) earlier version of the definition.

What open innovation really attempts to accomplish is to open up the purpose of the firm such that the boundaries of the firm are much more blurred than the traditional perspective which focuses on protecting IP rights by doing everything within one organization. Therefore, when
thinking about open innovation, one issue to grapple with is the boundaries of the firm, and as such organizational economics becomes a vital consideration in improving our understanding of the concept. Traditionally, firms are interested in innovation and commercialization. Within the domain of open innovation, questions arise as to whether these processes should be conducted inside or outside the firm. The decisions on these questions lead to a continuum of openness. Since there have not been clear statements as to which is better under what circumstances, all we can say at this point is that firms might want to consider improving their processes by considering going outside the firm for innovation and commercialization in some cases, which is very different from general prescriptions to engage in open innovation.

Throughout time it appears that more and more emphasis has been laid on finding theoretical and empirical support for claims made early in the development of the open innovation framework. Notably, the more theory focused approach is not only limited to critics of the concept (Trott & Hartmann, 2009; Groen & Linton, 2010) but also is evident in work of its proponents (Chesbrough et al., 2006; Enkel et al., 2009). In order to avoid generic, misleading prescriptions of the employment of open innovation strategies, the boundaries of the open innovation framework need to be clarified. One of the first attempts in offering an overview of contingency factors has been made by Gassmann (2006) who points to globalization, technology intensity, technology fusion, new business models, and knowledge leveraging as factors influencing the appropriateness of open innovation approaches. Other factors that have been found to influence the success of open innovation approaches are in-house R&D investments in relation to market-oriented search strategies and technologically advanced environments (Sofka & Grimpe, 2010). Potential risks and rewards of open innovation processes were addressed by Jeppeson and Lakhani (2010) who built on Nickerson and Zenger’s (2004) work on the problem-
solving perspective of the firm. The central question which arises in terms of the boundary for open innovation is thus why do some firms use open innovation and others do not. The problem-solving perspective suggests that a high risk is associated with using open innovation approaches if internal knowledge needs to be made public. Under certain conditions, however, a broader view of the problem-solving perspective would suggest that the bigger risk might lie in not being able to innovate at all. In such cases, keeping internal knowledge confidential might not lead to an appropriation of such knowledge and the knowledge in question would be rendered worthless.

The strategy field in much of its development was often based on the idea of proper positioning (Porter, 1980) and to a large extent was also considering the limitations of success, or “limiting factors” (Barnard, 1938). The idea of limiting factors has lead to the conceptualization of success factors, which however have turned out to be a weak foundation for strategy (Ghemawat, 1991). Ghemawat (1991) offers “commitment” as the underlying core of strategic choice. Commitment is defined as “the tendency of strategies to persist over time” (Ghemawat, 1991, p. 14). Commitments are choices made (Ghemawat, 1991) and as such, within the behavioral theory of the firm (Cyert & March, 1963), fall under the aspect of setting goals. As discussed, the goal—or commitment—within the current frame, is set to be the constant struggle to innovate in order to compete within the industry.

2.7.1 The Importance of Structure and Intent

In the past, inbound open innovation has often been unstructured and unintentional, guided by chance. Early on in the development of the open innovation concept, Chesbrough (2003a) outlines that the boundaries of the innovation process are permeable and that ideas can readily flow inside the company (and leave the company). However, the control over such processes is neglected in the general discussion of the concept. Focusing on the intentional
nature of structured inbound open innovation processes reflected in broadcast search, the current work strives to emphasize the importance of an intended strategy (Mintzberg, 1978) and suitable organizational structures to generate and capture such inbound knowledge flows. Drawing on the aggregate project planning (APP) framework (Christensen, 2000), the goal is to essentially reverse “the emergent strategy-making process” and thus making it an intentional, guided process. As Christensen (2000, p. 3) points out, “when a market is emerging, or undergoing radical change—a period in which emergent strategy processes need to predominate, the strategy-making process depicted in Exhibit 2 (replicated here in Figure 2) generally flows from right to left. Ideas for new products flow somewhat unpredictably into a company, and get filtered through the criteria employed in its resource allocation decisions. Those ideas and opportunities that get funded populate the firm’s new product portfolio. The stream of new products, processes and acquisitions that emerge from the development process define the firm’s de facto strategy” (Christensen, 2000, p. 3, emphasis added). Structures introduced through broadcast search systems are intended to guide this process and move it from a somewhat unpredictable, random process to one that still relies on chance at the individual search level but channels the search process so that the odds of detecting solutions are increased and unconstrained by up-front capital allocations. Notably, while the deliberant strategy model flows from left to right, the emergent strategy making process is depicted by Christensen (2000) as flowing from right to left.
2.7.2 Mechanics Underlying Broadcast Search

In essence, search is naturally local (Cyert & March, 1963), so in order to cover a large area of a given map or landscape (Levinthal, 1997; Gavetti & Levinthal, 2000), one approach would be to have many people that are positioned at various diverse points searching locally at the same time and subsequently choosing one of those solutions. Such an approach is underlying broadcast search and has been modeled as the effect of ‘crowdsourcing’ overcoming distant search (Afuah & Tucci, 2012). Building on the aspects outlined above, I now move into the discussion of my theoretical model.
3.0 THEORETICAL MODEL

My theoretical model builds on Cyert and March’s (1963) description of search expansion: “When search, using simple causal rules, is not immediately successful, we assume two developments. First, the organization uses increasingly complex (“distant”) search; second, the organization introduces a third search rule: (3) search in organizationally vulnerable areas.” (Cyert & March, 1963, p. 122). While previous literature on search has mainly focused on the first two aspects of search (Katila & Ahuja, 2002; Nelson & Winter, 1982; Stuart & Podolny, 1996), the extension of organizational search to broadcast search can be seen as a reflection of the latter. It is important to note that the idea of search in organizationally vulnerable areas was developed within a closed innovation mindset predominant at the time it was conceived. As such, although various forms of collaboration existed, the default setting for search expansion described by Cyert and March (1963) was restricted to search within the boundaries of the organization. The current work places the concept of organizationally vulnerable areas in an open innovation frame. In light of the recent focus on such open frames and the need to avoid the “strategic straightjacket” of closed innovation systems (Teece, 2007, p. 1322), it is necessary to broaden our basic theoretical framework to explain and predict outside the confines of current organizational structures.

Recognizing that Cyert and March (1963) focused on search internal to the firm, an ‘organizationally vulnerable area’ in my dissertation translates to the area which lies directly at the boundary of the organization, where the necessity arises to make part of the research agenda known to the public and maybe provide some of the internal knowledge base to the public to allow outside solvers a base on which to build solutions. This need for opening up some of the internal knowledge, whether through the question asked or by providing access to (previously)
proprietary knowledge, is reason to place such an approach into the latter of Cyert and March’s (1963) categories of search as it is a reflection of extreme search behavior. By offering outsiders a peek into the research agenda, firms allow competitors to gain potentially important knowledge, and as such make themselves vulnerable to competitive attacks. For example, using a multi-point competition frame (Karnani & Wernerfelt, 1985), such information could provide competitors with vital strategic information for launching an attack on the research trajectory (e.g., through preventive patenting or publishing). The vulnerability aspect then would also suggest that such an approach is generally only applied after the failure in other attempts, a common notion derived from open innovation case studies (Chesbrough, 2003a).

Newly developed search mechanisms do not, however, have to remain the exception. With the continued use and development of broadcast search, for organizations that are able to develop adequate structures and organizational routines, broadcast search might not remain in an organizationally vulnerable area and could become a common distant search alternative. As such, organizations that commonly use broadcast search and develop an expertise in that area will develop routines that allow them to benefit from broadcast search as a distant search alternative and potentially build competitive advantages in regards to cost structures and development times.

3.1 A Closer Look at ‘Organizationally Vulnerable Areas’

As stated above, the core basis for my theoretical model and my associated propositions is outlined by Cyert and March’s (1963) description of the organizational search process. Cyert and March (1963) outline organizational search behavior as an escalation process, based on a ‘simple-minded’ search function which expands from local into more ‘complex’ (and thus distant) search areas. These searches are driven into what Cyert and March (1963) call ‘organizationally
vulnerable areas’. The following extract from Cyert and March’s (1963) work explicates the idea of *search in organizationally vulnerable areas* and ties it directly to research.

“The motivation to search in vulnerable areas stems from two things. On the one hand, the existence of organizational slack will tend to lead search activity in the direction of slack parts of the organization. On the other hand, certain activities in the organization are more easily attacked than others, simply because of their power position in the system. One general phenomenon is the vulnerability of those activities in the organization for which the connection with major goals is difficult to calculate concretely (e.g., research in many firms). In either case, a solution consists in either absorbing slack or renegotiating the basic coalition agreement to the disadvantage of the weaker members of the coalition” (Cyert & March, 1963, p. 122).

From the above citation it can be inferred that the initial idea of Cyert and March (1963) seems to be that distant search within the organization is expanded into the areas of the organization that can be most easily exploited in terms of resource re-allocation (slack) and which are in positions most remote in terms of bottom line contributions. The term ‘organizationally vulnerable areas’ is never clearly defined by Cyert and March (1963) and the above paragraph is the only indication offered as to what the term refers to. Thus, its meaning leaves some room for speculation. Apparently, Cyert and March (1963) see organizationally vulnerable areas as a description of areas with a weak position within the organization when it comes to defending resources.

However, since no clear definition is offered, the above description of organizationally vulnerable areas not only leaves room for speculation and interpretation, it also raises some
interesting questions. Some questions immediately come to mind. What happens if there is neither slack to absorb, nor a weaker partner with whom one can negotiate? Does search stop if these conditions cannot be met? If the negotiation within the firm leads to the reallocation of resources, this should be considered just another form of slack, namely recoverable or potential slack. The other form of slack addressed by Cyert and March (1963) would be considered available slack. Is slack in the end the ultimate driver of search, or the defining variable in the course of search? Research is explicitly mentioned as an area of the organization with an unfavorable negotiation position. Does that mean that organizations who are not immediately, or at least through somewhat distant (but not too distant) search, successful in their search, will refrain from conducting research? Even though these are potential courses an organization can take when faced with search failure, I present an alternative view on how search will progress past the point of distant search. The view I present, interestingly enough, seems better aligned with the underlying assumptions of the behavioral theory of the firm than Cyert and March’s (1963) original conceptualization of slack-driven search in organizationally vulnerable areas. The true driver that I see working behind the search in my revised model becomes the pressure an organization faces. These pressures may be intensified by the organization not having adequate the slack resources to deal with the situation. Therefore, slack can, at best, be seen as taking on a moderating function, but I also expect to see a direct effect between the pressure an organization faces and its search behavior with. As such, a core proposition of this dissertation is that, within the search framework developed by Cyert and March (1963), pressure becomes the driver behind organizational search and its direction, rather than slack resources.

By drawing on the concept of organizational routines used in evolutionary economics frameworks (Nelson & Winter, 1982), instead of classifying areas as weak or strong in terms of
resource defendability, I consider past search behavior as an alternative force in guiding search. Specifically, I distinguish between routine and non-routine search behavior (Nelson & Winter, 1982). Such a classification leads to a depiction of organizational search behavior very closely aligned with Cyert and March’s (1963) model, yet the final step of the escalating process is clearly distinct from merely distant search in vulnerable areas within the organization. The integration or nesting of the concept of organizational routines within Cyert and March’s (1963) idea of simple-minded search leads to a two-by-two matrix with search distance on one axis and routine behavior on the other axis. Figure 3 reflects this combination and the arrows depict how organizational search is moving from quadrant to quadrant. Contrary to Cyert and March (1963), I do not view slack and weakness of position as the main driver (or motivator) of search direction, but rather previous experience and external pressure. In other words (distant) search will be conducted in routine ways unless failure of such routine search behavior leads to *ad hoc* problem solving (Nelson & Winter, 1982); in the current case this translates to new ways of searching. These new ways of searching would then be considered *non-routine distant search* approaches. At the same time, the overall process of moving through these subsequent steps of trying to solve the problem at hand becomes itself a routine that the organization employs—as such the search process itself is manifested in an *organizational search routine*.

Instead of talking about search in organizationally vulnerable areas, I will use the concept of non-routine distant search, which will be defined as search conducted in an area that is outside the current knowledge of the firm and uses an approach not commonly employed by the firm. For the purpose of this dissertation, the two concepts are congruent since non-routine distant search reflects search in organizationally vulnerable areas in an open innovation framework.
The different search alternatives in Figure 3 are categorized as they relate to the industry overall. For individual companies within the industry the 2x2 matrix might deviate. For example, individual firms might have little to no experience with M&As or alliances. If that is the case, these alternatives would be considered both distant and non-routine. This special case of a more closed company in terms of innovation processes is depicted in Figure 4. Overall, I expect to see more of these firms earlier in the industry life cycle.
In the following, I outline a model consistent with the above description that incorporates the need to innovate as a driver of firm search behavior. Subsequently, I develop my propositions based on this model, leading into the hypotheses which were tested using the methodology outlined in section 4 of this dissertation.

### 3.2 Broadcast Search as an Alternative Knowledge Sourcing Mechanism

Pressure to innovate (Villard, 1958; Williamson, 1965) is expected to lead companies to increase their R&D activities. A first response to increased need for innovation is an increase in
spending on internal R&D as a reflection of local search. As the effectiveness of purely internal R&D processes slows down, especially in regards to finding truly new, or breakthrough, innovations, firms start looking outside of their R&D departments for ideas. In order to broaden their search scope (Katila & Ahuja, 2002) employing more distant search, organizations start to engage in R&D alliances to leverage their knowledge and build on partners’ complementary knowledge. Firms also source knowledge that is available in markets for knowledge through in-licensing and they might acquire whole companies in order to internalize knowledge that exists in the market. Overall, this logic is reflected in Figure 5, where the individual steps are outlined based on the discussion above and the matrix outlined earlier.

**Figure 5: Model 1: Basic search steps**

* Licensing is not empirically tested in the model due to various confounding reasons for using licensing (such as proprietary but not new knowledge, i.e., not innovation).

The pressure to innovate can take many forms. Aside from general growth demands facing large, established organizations, in industries that are relying heavily on IP protection in the form of patents, organizations are often faced with the additional burden of having to replace revenue streams from products for which patent protection is running out. Examples of such
innovation intensive industries relying heavily on patent protection include the pharmaceutical industry (Bierly & Chakrabarti, 1996a), the industrial robotics industry (Katila & Ahuja, 2002), and the semi-conductor industry (Phene et al., 2012). As such, the anticipated loss of revenues due to patent expirations creates a mounting, measurable pressure for individual firms to innovate. Conversely, one could state that the attenuation of the patent-protected product base—a depletion of core resources in innovation based industries—reflects a future demand for the development of new patents and products. Organizations which have many patents close to expiration need to find ways to replace revenues from the associated products through the development of new products, and they are under time pressure to do so. My first proposition is thus that the pressure to innovate leads to the employment of routine search behavior, both local and distant. Formally, this translates to the following statement.

**Proposition 1:** Pressure to innovate leads to the employment of routine search behavior.

Failure with currently employed distant search approaches subsequently leads to considerations in terms of areas for search that have not previously been considered. In my model the appearance of broadcast search in industries that are highly protective about their knowledge and *ex ante* unlikely to publicly offer clues about their research intentions is explained by an increased pressure to innovate and a simultaneous failure of routine search behavior to alleviate these pressures. If routine search behavior does not sufficiently decrease the innovation pressure or the innovation pressure increases despite the intense use of routine search, organizations will experiment with alternative, non-routine search options. This innovation pressure is reflected in the need to replace current revenue streams stemming from
patent protected products and to stay competitive vis-à-vis rivals who might introduce new products to serve existing markets. This behavior is reflected in a simplified model in Figure 6.

**Figure 6: Model 2: Response to search failure**

The model does not distinguish between local and distant routine search for two reasons. One, my focus here is on the differentiation between routine and non-routine search, and as such the model strives for parsimony in other regards. Two, the model reflects reality in that distant search processes which have become routine for an organization might be employed almost as frequently as local search and not necessarily after local search has shown to be inferior. For individual projects, organizations might employ distant search instantly without considering local search first based on previous experience. Similarly, Cyert and March have made this point.
by stating that “the order in which various alternative solutions to a problem are considered will change as the organization experiences success or failure with alternatives” (Cyert & March, 1963, p. 124). For instance, a firm which has been successful using M&As might more readily revert to this approach rather than trying to first develop a compound internally. As such, local and distant routine search options can often be viewed as direct alternatives. The reflexive effect of the failure of routine search to alleviate innovation pressure is captured in Figure 6. As the description above has outlined, mounting pressure to innovate, which does not get resolved through routine search behavior, leads to experimentation with non-routine search alternative. In my conceptualization, this non-routine search is captured in more open approaches to innovation, operationalized in broadcast search. Formally, my second core proposition reads as follows:

**Proposition 2:** Failure to alleviate innovation pressure through routine search leads to the employment of non-routine distant search.

I would also like to note, that once broadcast search approaches are established, I expect a relative slow-down in the use of other external knowledge sourcing activities such as R&D alliances and M&As. While broadcast search is not likely to replace those two other activities completely, it should be considered a viable alternative in knowledge and innovation sourcing so that the pressure built up on using alliances and M&As will decrease after the installation of a functioning broadcast search system. As the application of the concept to pharmaceutical R&D is relatively young in comparison to the long development cycles of pharmaceutical R&D (DiMasi, Hansen, & Grabowski, 2003; Pisano, 2006), I do not expect to be able to find measurable outcomes at this point, so that the evaluation of outcomes is excluded from my
analysis. If measurable outcomes would be available, potential alternative DVs for an innovation outcome model would be the overall cost structure of the (R&D) organizations and development times for new products. However, as mentioned, due to the shift toward this approach being recent it is unlikely to be reflected in such measures at this point and therefore I do not measure outcomes in this dissertation.

3.2.1 A Model of R&D Decomposition and the Case of the Pharmaceutical Industry

Although in practice it is often difficult to distinguish where one ends and the other begins, Arrow’s (2000) distinction between research (R) and development (D) offers a coarse yet suitable starting point for a theoretical model that maps on to the inbound open innovation idea of a decomposable R&D process. According to Arrow’s (2000) conceptualization, research can be seen as a more general and exploratory activity, or as one that is characterized by higher uncertainty and associated with outcomes that hold lower commercialization prospects but higher scientific value (Banal-Estañol & Macho-Stadler, 2010), and separated from development, which is seen as being more application driven (Arrow, 2000; Banal-Estañol & Macho-Stadler, 2010). From an organizational level perspective, each step constitutes a separate investment decision (Arrow, 2000). The ability to separate those steps in the process is essential to being able to conduct research in one entity and transferring the results to another entity for further development into the final product. For the current study, the focus is on the research.

While the products themselves can be produced past the expiration of the patent, in the case of the pharmaceutical industry, sales will decrease due to falling prices for products that now can be produced by generic drug manufacturers. The pressure to develop breakthrough innovations able to function as replacements increases costs for internal R&D. This cost increase (DiMasi et al., 2003), and the inherent uncertainty of drug development, leads
companies to employ distant search using alternative ways to acquire knowledge that can be translated into new patents and products. Common avenues include R&D alliances/JVs, in-licensing, and M&As. All of these are routinely used in the pharmaceutical industry. As such, increased innovation pressure increases the need for distant search, drawing on these external sources of knowledge acquisition. The opportunities to cooperate with others, license compounds, or acquire start-ups that have researched promising breakthrough technologies are limited. There are usually only a few viable candidates for each, especially if corporations are looking in specific areas suitable to complement their current product portfolio. The limitations of current approaches have led companies to look into new approaches to drug development. One such approach that has somewhat recently evolved is reflected in broadcast search. Therefore, broadcast search is a potential answer to mounting innovation pressure. The establishment of broadcast search systems in turn should alleviate such innovation pressures.

A main focus of my study is on the contrast between the use of M&As for knowledge sourcing and broadcast search in the pharmaceutical industry. The M&A approach has been recognized as a common approach for structuring the financing of the R&D process (Arrow, 2000). However, it has also come under siege as a viable, sustainable model for R&D financing in drug development (Durand, Bruyaka, & Mangematin, 2008; Lazonick & Tulum, 2011; Pisano, 2006), mainly due to the long development cycles in pharmaceutical R&D which generally do not match up with temporal investor expectations of returns on venture capital investments (Pisano, 2006). Nonetheless, the model is heavily used in the pharmaceutical industry (Lazonick & Tulum, 2011). Spending on M&As in research intensive industries has become a major factor. However, a major disadvantage of M&As over internal research is that companies *ex ante* give up the right to determine the question to be asked and thus have no control over the direction of
research. Therefore, using M&As as a main source, companies cannot guide the development
direction early on and might suffer from small numbers bargaining problems (Williamson, 1973)
in terms of what is available for purchase in the market suitable to their knowledge base and area
of expertise as well as the price necessary to pay for promising start-ups over which multiple
corporations might compete. Similar to internal R&D, the use of an M&A approach has
however a very limited risk of knowledge leakage, which constitutes an eminent threat in more
open approaches to R&D. Table 5 compares some of the trade-offs of various knowledge
sourcing alternatives. Cost and control considerations are particularly important to keep in mind.

Table 5: Trade-offs between search approaches

<table>
<thead>
<tr>
<th>Search approach</th>
<th>Evaluation/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal R&amp;D</td>
<td>Full risk but full control, may take long time since company has to fund and administer full process</td>
</tr>
<tr>
<td>Alliances / JVs</td>
<td>Shared risk, but also shared control (compromising might be necessary). Knowledge can spill over to ‘partner’ but is relatively constrained. Shared appropriation. Similar time as internal R&amp;D since it covers again full process from start to finish.</td>
</tr>
<tr>
<td>In-Licensing</td>
<td>Decreased risk since patent/product is known. Can be costly and might not give exclusivity. Can speed up development problem but depends on the patents/products available. No control over what is being developed. Availability of patents/products is limited to what is available in the market (small numbers problem).</td>
</tr>
<tr>
<td>M&amp;As of start-ups</td>
<td>Decreased risk since initial successes are visible. Decreased time-line since start-up is taken over when considerable part of research is already done. Corporation might have to pay a high price for promising start-up/biotech firm. Many acquisitions turn out to be overpriced. Integration of the start-up might be costly or company could remain separate in which case knowledge does not transfer fully to parent (opportunity cost in terms of knowledge). No control over what is being developed prior to take-over. Availability of suitable acquisition targets might be limited (small numbers problem).</td>
</tr>
<tr>
<td>Broadcast Search</td>
<td>Risk of giving out proprietary information that is used elsewhere without the corporation profiting from it, especially if patents are put in public domain. Risk of knowledge leakage. Advantage is ex post compensation for solutions rather than payment of internal scientists (hire solution, not people). Also, some control over what is being developed and thus better fit and easier integration into internal R&amp;D. Might mitigate small numbers problems of M&amp;A and licensing, which are alternatives if solution already (knowingly) exists somewhere.</td>
</tr>
</tbody>
</table>

Source: Author’s own considerations.
3.2.2 Past Behavior and Path Dependence

Routine behavior in organizations (Nelson & Winter, 1982; Stene, 1940) is closely associated with path dependence (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010). In line with the ideas expressed above, the inherent openness and familiarity with external search approaches of organizations that have extensively relied on distant search in the past should make it easier for organizations to experiment with newly developed open approaches. Externally focused organizations are less worried about sharing knowledge or have systems in place that do not solely rely on secrecy in protecting their knowledge. Therefore, organizations which have been more active in employing alliances/JVs and M&As in the past are more likely to adopt broadcast search approaches.

**Proposition 3:** Under conditions of routine search failure, organizations that are more heavily engaged in routine distant search (as opposed to routine local search) are more likely to engage in non-routine distant search.

There are different sets of logic for each of the two distant routine search modes underlying this general prediction. First, in regards to alliances/JVs, firms that are routinely using alliances/JVs to a large degree are especially apt to sharing their knowledge with partners and, with the right structure in place, are more likely to share also with initially unknown partners. They are likely to have structures or systems in place that prevent from too much critical knowledge being spilled over. Second, as for organizations that routinely engage in M&As, it is likely that they have systems and routines in place to integrate externally acquired knowledge sets. Therefore, these companies should be able to transfer this capability to integrate
solutions offered by external solvers and should be more likely to experiment with broadcast search approaches. As such, the general proposition 3 translates into the following pair of sub-propositions.

**Proposition 3a:** Organizations that are more heavily engaged in alliances/JVs are more likely to engage in non-routine search.

**Proposition 3b:** Organizations that are more heavily engaged in M&As of start-ups are more likely to engage in non-routine search.

### 3.3 Summary of Propositions and Associated Hypotheses

For the purpose of testing the ideas underlying my propositions, I translated the propositions into hypotheses. Table 6 gives an overview of my propositions along with the associated hypotheses.
Table 6: Propositions and hypotheses

<table>
<thead>
<tr>
<th>P</th>
<th>Proposition</th>
<th>H</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pressure to innovate leads to the employment of routine search behavior.</td>
<td>1a</td>
<td>Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years, leads to increased R&amp;D spending by the focal organization.</td>
</tr>
<tr>
<td></td>
<td>1b</td>
<td>Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years, leads to an increase of alliance formations by the focal organization.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1c</td>
<td>Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years, leads to increased M&amp;A activity by the focal organization.</td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>Higher rivalry, reflected in an increasing number of new patents within a focal firm's core research area, leads to increased R&amp;D spending by the focal organization.</td>
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<td></td>
</tr>
<tr>
<td>2b</td>
<td>Higher rivalry, reflected in an increasing number of new patents within a focal firm's core research area, leads to an increase of alliance formations by the focal organization.</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>3a</td>
<td>Mounting resource depletion (relative increase in number of expiring patents) and mounting use of internal R&amp;D leads to adoption of broadcast search approach.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>3b</td>
<td>Mounting resource depletion (relative increase in number of expiring patents) and mounting use of alliances leads to adoption of broadcast search approach.</td>
<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>Under conditions of routine search failure, organizations that are more heavily engaged in routine distant search are more likely to engage in non-routine search.</td>
<td>5</td>
<td>Companies that use higher proportion of alliances AND M&amp;A over R&amp;D expenditures are more likely to engage in broadcast search.</td>
</tr>
<tr>
<td>3a</td>
<td>Organizations that are more heavily engaged in alliances/JVs are more likely to engage in non-routine search.</td>
<td>6a</td>
<td>Companies that use higher proportion of alliances over R&amp;D expenditures are more likely to engage in broadcast search.</td>
</tr>
<tr>
<td>3b</td>
<td>Organizations that are more heavily engaged in M&amp;As of start-ups are more likely to engage in non-routine search.</td>
<td>6b</td>
<td>Companies that use higher proportion of M&amp;A over R&amp;D expenditures are more likely to engage in broadcast search.</td>
</tr>
</tbody>
</table>
4.0 RESEARCH METHODOLOGY

This dissertation tested a behavioral theory of the firm perspective (Cyert & March, 1963) with a particular focus on inbound open innovation (Chesbrough et al., 2006; Chesbrough, 2003a; Dahlander & Gann, 2010) reflected in broadcast search (Jeppesen & Lakhani, 2010). I employed a multi-method and multi-sample approach (Scandura & Williams, 2000) using both primary data and large scale secondary data. The dissertation employed a triangulation approach (Scandura & Williams, 2000) using three pre-studies and two main studies to illuminate the phenomenon in question from different angles. The sensitivity of the data and potential secrecy surrounding the construct of interest for competitive reasons limited the viability of using a single approach. Also, due to the limited attention paid in past research to some of my core constructs there were no generally accepted measures readily available. My aim thus became to first understand aspects of the phenomenon in practice. While case studies are a common approach to achieve this, there are numerous examples of case studies describing the broadcast search approach (Birkinshaw & Crainer, 2009; Glaxo-Smith-Kline, 2010; MacCormack, Verganti, & Iansiti, 2001) and much of the literature on open innovation was founded on case study observations (Chesbrough, 2003a). Another case study would have only limited potential for substantially new insights. The interested reader is referred to these prior case descriptions as they are well suited to exemplify the approaches discussed in this dissertation. While case illustrations can offer detailed descriptions of the open innovation and broadcast search phenomena, they hold the common bias that they have been selected ex post as a result of certain behaviors. As such, cases are selected on the dependent variable of the model of interest and therefore are highly problematic to allow for making scientifically viable inferences and offer recommendations based on findings. From using only case studies, researchers cannot know
how many organizations face have been in similar situations and faced similar constraints, but
have made different choices. It is also possible that there are many organizations which have
taken the same direction as the successful cases under study but have failed to achieve equally
positive results as the winners. For these reasons, I decided to move beyond building on
individual cases to a more structured and less outcome-centered selection of observations. As
each and any research approach has unique limitations, my primary goal was to combine
uniquely different approaches with partial overlap and interconnections. I kept to one industry
with slight variations in the companies and timeframes covered. Restricting my research to one
industry limited the generalizability of findings across industries but had the advantage of
increased internal validity (Dess, Ireland, & Hitt, 1990), an aspect that in my view has received
limited attention in previous work concerned with different phenomena associated with research
employing an open innovation framework. Overall, this approach was beneficial to both ensure
higher levels of internal validity and increase the potential of extrapolating research findings for
designing future research studies on broader samples.

4.1. Multiple Study Purposes

Three pre-studies and two main studies with distinct methodologies were employed to
learn about the R&D related search behavior of pharmaceutical corporations outside their
corporate boundaries. Each study served a separate purpose in my overall quest to disentangle
the characteristics of these firms.

Pre-study A constituted a preliminary scanning of the pharmaceutical industry in regards
to the use of broadcast search. The purpose of this endeavor was to ensure that the
pharmaceutical industry employed broadcast search and communicated such activities in a way
that was detectable via secondary sources such as corporate websites and Factiva.
Pre-study B was an analysis of a specialized intermediary. The indirect approach offered an important advantage when conducting research on the pharmaceutical industry. Previous work on the pharmaceutical (or more precisely the biopharmaceutical) industry had shown that the organizations were highly secretive and selective about their corporate communications. To circumvent this issue, pre-study B looked at publicly available secondary data which could not be traced back to individual organizations, but which allowed to evaluate the use of broadcast search for the type of question which pharmaceutical R&D would be concerned with. As such, pre-study B was able to indirectly assess the viability and actual deployment of broadcast search for the pharmaceutical industry. This constitutes an important aspect for determining whether a broadcast search approach had merit for professional, large-scale use or whether such an approach should be deemed merely applicable to hobbyists (Jeppesen & Frederiksen, 2006; Poetz & Schreier, 2012). The high specificity of knowledge necessary to solve chemical or molecule related problems suggested that a reliance on professionals was essential for the pharmaceutical R&D. Therefore, in pre-study B I focused on gauging the feasibility and actual use of broadcast search in the pharmaceutical industry vis-à-vis other fields. The prevalent use of broadcast search specific to the industry of interest as an approach employed in practice was demonstrated and evaluated on a dataset collected from an intermediary firm for broadcast search, namely InnoCentive. From a scientific perspective, an important characteristic of this approach was that selection took place on the independent variable in that the industry was not pre-selected but rather a complete set of challenges was analyzed in regards to challenge characteristics.

In pre-study C, I collected evidence regarding the practical importance and prevalence of broadcast search approaches based on a survey conducted in conjunction with a spotlight
conference on the topic of interest. The data attained offered practitioners’ input on their perception of broadcast search and the open innovation phenomena specific to their situation and thus served as a particularly useful connector between practical challenges and theoretical research. The idea that organizations in the pharmaceutical industry are under pressure to innovate, a central theme to my thesis, has been recognized by practitioners (Agres, 2012). In order for organizations to act upon an external factor, this factor must not only exist, but has to be perceived as being important enough by an organization’s management in order to react to it (Hambrick, 1981). Judging the perceived importance of innovation pressure was at the same time important and challenging. A response to a call for a conference on the “Productivity Crisis” (Fleming Europe, 2012) of the pharmaceutical industry would be a strong indicator that there is an awareness of the pressure to innovate in the industry and that the issue is receiving attention (Ocasio, 1997, 2011). Aside from merely ensuring that factual pressure aligns with perceived pressure, the survey also allowed for collecting interesting insights into the use of broadcast search in pharmaceutical companies.

My first main study is an extension and replication of a cluster analysis on strategic knowledge groups conducted by Bierly and Chakrabarti (1996a). In constructing my replication I made ensure that my data, which was not always replicable from the same sources, would reflect the same constructs outlined and employed in the original study. The replication ensured that my data was largely comparable and most importantly that the samples were identical, although not all factors could be fully reconstructed. The replication of the sample then allowed me to use a non-hierarchical clustering technique (Ketchen & Shook, 1996) to extend the analysis. This study offered valuable insights leading into study two.
In my second study, I used a larger scale set of pharmaceutical firms to evaluate past developments and the current state of the US pharmaceutical industry in regards to search expansion. I utilized secondary data from different databases and publicly available sources to construct a dataset which was analyzed using econometrical empirical methods. Overall, the intention of the dissertation was to offer a thorough understanding of the type of organization likely to engage in broadcast search. An overview of the studies is outlined in Table 7.

4.2 Dissertation Focus

This dissertation employed a triangulation (Scandura & Williams, 2000) using several unique research approaches clustered around a single industry focus. I chose a single industry focus as this approach was the most conservative and straightforward with high internal validity to control for industry effects (Dess et al., 1990). Potential differences in the R&D process between industries, reflected for example in differences in R&D success rates (Stevens & Burley, 1997) also supported the use of a single industry sample. Restricting the dissertation to one industry did however mean that the generalizability of findings might be limited and it should be noted that it did not control for heterogeneity within the industry (Dess et al., 1990). However, the main concept chosen to operationalize my research topic was relatively young and unexplored and as such using a single industry approach aligns with the notion that a single industry context is an adequate starting point for examining contingency relationships (Ginsberg & Venkatraman, 1985). The within industry heterogeneity (Dess et al., 1990) was addressed in my dissertation design by building on prior work by Bierly and Chakrabarti (1996a) who used cluster analyses nested in a knowledge-based theory approach to separate the pharmaceutical into strategic knowledge groups. My model also considered general heterogeneity based on resources and strategies (Barney & Hoskisson, 1990) in determining competition between rivals.
Table 7: Overview of studies in this dissertation

<table>
<thead>
<tr>
<th>Study</th>
<th>Topic</th>
<th>Approach</th>
<th>Purpose</th>
<th>Population + Sample</th>
<th>Source</th>
<th>Measures</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-study A</td>
<td>Use of broadcast search by pharmaceutical companies</td>
<td>Preliminary web searches and Factiva search</td>
<td>Initial gauge of the possibility and usefulness of conducting a study on the use of broadcast search in the pharmaceutical industry.</td>
<td>Population = pharmaceutical industry Sample = pharmaceutical firms which communicated about broadcast search or were associated with it in the business press</td>
<td>Corporate websites, intermediaries, blogs, Factiva</td>
<td>Number of press publications associated with various search terms</td>
<td>The study is solely exploratory and only suggestive in regards to the adequacy of the industry.</td>
</tr>
<tr>
<td>Use of Intermediaries in the pharmaceutical industry</td>
<td></td>
<td></td>
<td>Offer a quantitative assessment of the adequacy of using the pharmaceutical industry. Study was designed to gauge the prevalence of use of broadcast search in the pharmaceutical industry. Provides a look into the involvement of solvers in the broadcast search process. Specific question addressed include: - Do the characteristics of pharma-related differ from other those of other challenges?</td>
<td>Population = question generally posed in broadcast search competition Sample = challenges collected from Innocentive.com in first half of 2012 N = 203, smaller for some analyses</td>
<td>Challenges posted on <a href="http://www.innocentive.com">www.innocentive.com</a></td>
<td>Challenge title for coding 'pharma-related' = 'Y', 'non-pharma' = 'N' Date challenge was posted Deadline closing date for the challenge Number of active solvers signed up for challenge Value of the award given to winning solution Type of challenge as per given categorization</td>
<td>Identification of seekers not possible. Coding of challenges would have benefitted from higher expertise in chemistry to better category chemical compounds. The collection of data could have been more consistent using an automated approach.</td>
</tr>
<tr>
<td>Pre-study B</td>
<td>Expert informants perspectives on the use of broadcast search in the pharmaceutical industry</td>
<td>Self-developed Survey distributed through Fleming Europe regarding</td>
<td>Access primary input from key personnel from pharmaceutical-related organizations interested in open innovation. Understand the type of organization interested in open innovation in general and the organization's use and importance of broadcast search in R&amp;D in particular.</td>
<td>Population = organizations interested in open innovation related to pharmaceutical R&amp;D Sample = organizations invited by Fleming Europe to attend a conference on &quot;Open Innovation in Pharmaceutical R&amp;D&quot; N = 4–14</td>
<td>Self-constructed survey administered by Fleming Europe to invited firms at around the time of a conference about &quot;Open Innovation in Pharmaceutical R&amp;D&quot;</td>
<td>Various measures - see survey reproduced in the appendix for details.</td>
<td>Lack of pre-test opportunity for the survey. Limited number of survey participants does not allow for a meaningful empirical investigation of the results.</td>
</tr>
<tr>
<td>Pre-study C</td>
<td>Corporate Communications of broadcast search in the pharmaceutical industry</td>
<td>Main study based on coding of firm communications</td>
<td>Empirically test my formal hypotheses. Understand and test the search behavior of organizations in regards to expanding search. Test whether organizations change their search behavior under pressure to innovate and which modes of search are being employed.</td>
<td>Population = US pharmaceutical corporations Sample = Set of organizations listed in Compustat under SIC code 2834 in 2011 N = 179 firms Nrestricted panel = 66 firms Npanel = up to 11,277 firm years (179 firms x 63 years) N[restricted panel] = up to 858 firm years (66 firms x 13 years)</td>
<td>Compustat Corporate communications: - Websites, - Annual reports, - Press articles, - Responses to email inquiry NBER database SDC database on alliances and M&amp;As</td>
<td>Broadcast search adoption (Dep Var.) Innovation pressure - Resource depleting Innovation pressure - Direct competition Internal R&amp;D R&amp;D intensity External collaborations Knowledge acquisitions through takeovers</td>
<td>Relative to the development time of drugs, the time between the potential change to incorporate broadcast search and outcomes was too short to measure. The decision to use broadcast search could only be estimated and could only be captured in a binary variable. The outcome data from the coding was positively skewed.</td>
</tr>
</tbody>
</table>

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I chose the US pharmaceutical industry as my field of study since it was well suited as a setting for my studies for various reasons. First, I was interested in understanding the effects of search expansion reflected in broadcast search for incumbent firms. The pharmaceutical industry as a capital intensive industry with long product development times (DiMasi et al., 2003; Pisano, 2006) consists largely of established, large corporations (Achilladelis & Antonakis, 2001), especially when considering public firms. By choosing to focus only on public companies I further sharpened this focus. Second, the high importance of knowledge protection and formal IP rights protection seemed to be a potential barrier to collaboration and openness. Seeing collaboration and openness becoming more of a routine task in the pharmaceutical industry warranted some attention and called for attempts to better understand the reasons and counter forces leading to these occurrences. Third, anecdotal evidence pointed to the pressure to innovate being very high in the pharmaceutical industry and a driver of strategic decision making in regards to R&D (Agres, 2012). Academic research on the costs of pharmaceutical R&D supported the idea of a steady increase of total drug development costs of over 800 million US dollar per drug along with total developments times surpassing the decade mark (DiMasi et al., 2003; Pisano, 2006). The costs had been shown to be closely correlated with the development times (DiMasi et al., 2003). In light of such staggering costs and commitments, much could be gained from finding ways for alleviating innovation pressure and decreasing innovation times. Incidentally, if we consider the Chesbrough’s (2006) general definition of open innovation addressed earlier, the compression of time is what theory on open innovation (and the inbound process in particular) suggests (Chesbrough et al., 2006). As such, I chose broadcast search as a reflection of open innovation and a primary indicator for expanding search culminating in search in organizationally vulnerable areas (Cyert & March, 1963). Recently, in line with these
concerns and along the same logic, a call for a practitioner conference made a similar connection by focusing on “open innovation” as an attempt to respond to the “Productivity Crisis” (Fleming Europe, 2012). The productivity crisis is a reflection of the pressure felt throughout the pharmaceutical industry in the form of an innovation gap (FitzGerald, 2008). Last but not least, a recent McKinsey Quarterly (Alexy & Reitzig, 2012) placed the pharmaceutical industry in the mid-range of industries in terms of risks of open innovation. Therefore, it reflected a middle ground in terms of likelihood that open innovation would occur (Alexy & Reitzig, 2012). Notably, though, the value of proprietary solutions was among the highest in the pharmaceutical industry (Alexy & Reitzig, 2012).

4.2 Study Descriptions

Search that extends beyond the simple idea of distant search has been categorized by Cyert and March (1963) as search in organizationally vulnerable areas. In other words, when search becomes more complex, it not only extends to areas that are more difficult to access and might be potentially new to the organization, but search spreads into areas that seem to be associated with the lowest immediate expected costs and repercussions. Within an open innovation framework for R&D activities, broadcast search fits this description and as such could be used by organizations which experience insufficient gains from their ad-hoc problem solving activities based on current organizational structures. The following studies were designed to outline and test this proposed process.

The measure to reflect search in organizationally vulnerable areas as a construct employed in my studies was the employment of broadcast search. Examining multiple firms, as opposed to using single case studies, had the advantage that I was able to employ a scientific process to start narrowing down the factors which lead firms to use broadcast search. This is a
critical first step in conducting future research to further deciphering the search expansion process.

In order to better understand the landscape of open innovation reflected in organizational communications, I conducted a series of three pre-studies. I started with semi-structured approaches before embarking on formal, scientifically structured data collection procedures.

4.2.1 Pre-study A: Web-searches and Preliminary Factiva Search to Evaluate Search Terms

Prior to designing my studies I conducted a preliminary search on the use of open innovation in various industries, and subsequently the pharmaceutical industry, using web-based sources. Aside from searching Google on the subject, reviewing specialized open innovation websites, looking at corporate websites employing broadcast search, and blogs on open innovation (e.g., http://blog.openinnovation.net/ by Joel West), I also used Factiva\(^{11}\) for a preliminary search on the topic. I had decided to use Factiva in my data collection process on the coverage of the subject in the popular business press. In order to determine and finalize the most suited search terms, I started by determining the number of results related to different search terms I had come across in my readings both on practitioner use and the academic literature. To further ensure that I was not missing any critical search term, I read many of the articles that were returned on my preliminary Factiva search on open innovation, broadcast search, and crowdsourcing to see if there were any synonyms used that I needed to incorporate later in my structured search on the pharmaceutical industry. To aid this process, Factiva offered a list of key terms that were related to one’s current search. I came across three terms that warranted further investigation as potential additions to my initial list of search terms. The term ‘open lab’ was used by an article that talked about Glaxo-Smith-Kline but was not found to be

\(^{11}\) Factiva© is a search engine for business news operated by Dow Jones & Company.
used anywhere else. The term ‘drug discovery platform’ was used in an article on Isis Pharmaceuticals but further investigation of the meaning of this term revealed that it was not referring to a broadcast search approach but rather an internal development technique. Last but not least, the term ‘innovation challenge’ was offered by Factiva’s related key term indicator tool and it turned out to be a viable search term for my purposes. Therefore, I adopted this search term in my final set of search terms.

As an indication of feasibility of my chosen approach, I conducted the following preliminary search in April of 2012. The purpose of this preliminary search was to garner an indication of the general prevalence of some core concepts in the popular business press to support the idea of conducting an analysis based on a larger scale data set where econometrics could be employed. A key question for being able to construct such a dataset was whether or not the vocabulary was developed clearly enough or whether there were too many nuances in the way corporations and the press verbalized similar concepts. Using Factiva, I determined the general press coverage of ‘open innovation’. The total number of hits returned by Factiva on a search on ‘open innovation’ without any further restrictions is 8463 (including duplicates) of which 7740 (including duplicates) are ‘publications’. A search on ‘open innovation’ which then was restricted to the ‘pharmaceuticals’ industry led to a total of 699 hits (including duplicates). A similar restriction of the ‘open innovation’ search on all industries to the term ‘drug discovery’, one of the most prevalent ‘keywords’ offered by Factiva to narrow down the search on ‘open innovation’, led to 411 total hits (or 242 unique ‘publications’). These numbers offered support that there was substantial press coverage on the topic regarding the industry of interest.

An alternative terminology used to describe the phenomenon is ‘crowdsourcing’ (Afuah & Tucci, 2012). Therefore, I also used this term to conduct a Factiva search. Using the term
‘crowdsourcing’ and then restricting to ‘pharmaceuticals’ industry brought up a total of 89 hits with 21 duplicates, for a total of 68 unique hits. This indicated that ‘open innovation’ is the more prevalent term in the pharmaceutical industry which led me to build on the literature accumulated on open innovation. For my analysis I did however review the results returned from all searches to more inclusively determine if companies were involved in such activity. Table 8 offers a summary of results from various combinations of search terms as of April 22, 2012. All numbers above are based on a Factiva searches conducted on April 10, 2012.

**Table 8: Preliminary Factiva search**

<table>
<thead>
<tr>
<th>Search Terms</th>
<th>Filters: Keyword (when available)</th>
<th>Industry</th>
<th>'Publications'</th>
<th>Identical Duplicates</th>
<th>Unique Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>open innovation</td>
<td>none</td>
<td>all</td>
<td>7796</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>open innovation</td>
<td>none</td>
<td>pharmaceuticals</td>
<td>526</td>
<td>150</td>
<td>216</td>
</tr>
<tr>
<td>open innovation</td>
<td>drug discovery</td>
<td>all</td>
<td>371</td>
<td>129</td>
<td>242</td>
</tr>
<tr>
<td>open innovation</td>
<td>drug discovery</td>
<td>pharmaceuticals</td>
<td>252</td>
<td>84</td>
<td>168</td>
</tr>
<tr>
<td>open innovation</td>
<td>drug development</td>
<td>all</td>
<td>540</td>
<td>143</td>
<td>397</td>
</tr>
<tr>
<td>open innovation</td>
<td>drug development</td>
<td>pharmaceuticals</td>
<td>304</td>
<td>85</td>
<td>219</td>
</tr>
<tr>
<td>crowdsourcing</td>
<td>none</td>
<td>all</td>
<td>5198</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>crowdsourcing</td>
<td>none</td>
<td>pharmaceuticals</td>
<td>69</td>
<td>21</td>
<td>48</td>
</tr>
<tr>
<td>crowdsourcing</td>
<td>crowdsourcing platform</td>
<td>all</td>
<td>1399</td>
<td>301</td>
<td>1098</td>
</tr>
<tr>
<td>crowdsourcing</td>
<td>crowdsourcing platform</td>
<td>pharmaceuticals</td>
<td>31</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>broadcast search</td>
<td>none</td>
<td>all</td>
<td>527</td>
<td>85</td>
<td>442</td>
</tr>
<tr>
<td>broadcast search</td>
<td>none</td>
<td>pharmaceuticals</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>prize competition</td>
<td>none</td>
<td>all</td>
<td>5488</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>prize competition</td>
<td>none</td>
<td>pharmaceuticals</td>
<td>37</td>
<td>1</td>
<td>36</td>
</tr>
</tbody>
</table>

* n/a = unable to determine due to Factiva error/restriction

In the described preliminary screening of Factiva to determine a rough estimate of the coverage of open innovation and related concepts in the popular press, I relied on the simple search on the topic. While conducting this preliminary screening I noticed that not all companies that were mentioned in the press articles were actually listed in the keyword list which generally was intended to include the companies being addressed in the article. In other words, using the
keyword list of companies offered by Factiva would not offer an inclusive coverage of all companies. Quite often, as it turned out, companies were not marked and as such they would not be picked up unless the company name was included as a search term. Therefore, in my structured search and coding on the coverage of organizations conducted later, I used an alternative approach, which was more time intensive but ensured that no coverage was overlooked. There, I used a free search and did a separate search with each combination of organization name and key search term. Details on the coding process are discussed in the description of Study 2.

4.2.2 Pre-study B: Intermediaries as Reflectors of the Phenomenon—InnoCentive Challenges

In an early description of the open innovation framework, Chesbrough predicted the formation of “specialized intermediaries that function as brokers or middlemen” (Chesbrough, 2003b, p. 40). As predicted, organizations have formed around business models focused on filling the position of an intermediary. One of the best known intermediaries and a pioneer in this regard is InnoCentive, Inc., which had been created and spun off by Eli Lilly. It has subsequently developed into a stand-alone, independent operation focused on administering broadcast searches for a wide variety of clients from various fields. There are various other organizations with similar offerings, such as Inno360, NineSigma, or Spigit, to name but a few. However, pre-study B focused on InnoCentive, mainly due to its early ties to the pharmaceutical industry and it being the most recognized intermediary both in practice and in research at the time of writing of this dissertation.

Before detailing the study and investigating the data, I briefly clarify and define a few idiosyncratic terms used by InnoCentive (https://www.innocentive.com/ accessed November 6, 2012). The term “solver” is used for people interested in or actually involved in finding a
solution to a stated problem. The stated problem itself is referred to as a “challenge” which is posted by a “seeker”—usually a company or organization of some sort. The monetary incentive for participating in the challenge solving process is referred to as “award” which can be “won”. In reference to the data collected from www.innocentive.com I adopted these terms in the following discussion.

4.2.2.1 Pre-study B—InnoCentive Challenges: Purpose and Goals

The purpose of pre-study B was to offer a quantitative assessment of the adequacy of choosing the pharmaceutical industry for the phenomenon of interest and to offer empirical support for this decision. Furthermore, the goal was to analyze systematically the use of questions relevant to organizations competing in the pharmaceutical industry and the viability of using broadcast search for solving such questions. Prior work also employing InnoCentive data had looked at the ability of broadcast search to solve scientific problems and had found that about one third (29.5%) of the submissions were solved through such a process, independent of the award value offered (Lakhani, Jeppesen, Lohse, & Panetta, 2007). The study also found a statistically significant (p < 0.01) but negative relationship between the days a problem was open and finding a solution to that problem—this correlation was however attributed to longer timeframes being associated with more complex problems (Lakhani et al., 2007). Notably, it was stated that many of the problems solved were problems that had not been solved in prior internal attempts by the seeker (Lakhani et al., 2007), supporting the notion that broadcast search was being employed after routine search attempts had failed. While the prior study was focused on the overall efficacy of broadcast search, the current study was focused on estimating the use of broadcast search in the pharmaceutical industry. As such, this study was designed to gauge the prevalence of the use of broadcast search in the pharmaceutical industry. Pre-study B was
intended to address questions referring to broadcast search structures in general and in the pharmaceutical industry in particular. It served as a starting point for my investigations by providing a peek into the involvement of solvers in the broadcast search process.

A specific question pre-study B aimed to answer was whether or not there were statistically meaningful differences between challenges posted by seekers from the pharmaceutical industry versus challenges posted by companies from other industries. Building on the prior work on a related sample (Lakhani et al., 2007), specific parameters on which the two groups might differ are the average award money offered in challenges, the average time a challenge is open to solvers, and the number of active solvers (those that signed up) per challenge. One aspect on which challenges might differ could be the number of solvers attempting to solve the problem. The high specificity of questions relating to pharmaceutical problems in terms of the necessary knowledge base required from solvers suggested that the number of solvers for pharma-related challenges could be lower than the comparison group. The hypothesis was that pharma-related questions are highly knowledge-specific and thus will attract only a small number of (specifically qualified) solvers. In addition, for all challenges as a whole or the separate groups, the number of active solvers could be a function of the average time a challenge was open to solvers or the value of the award that could be won. Based on prior work (Lakhani et al., 2007), however, there was reason to believe that no statistically significant differences existed between the groups in regards to the award money or in regards to the days the challenge was open. While Lakhani and colleagues (2007) had found a statistically significant effect of award value to a person actually submitting a winning solution, there were stronger effects stemming from intrinsic motivation and from free time of the solvers. I therefore did not put forth any predictions for these parameters.
From a scientific view, the design of this study had the advantage that it avoided the issue of potential survey bias and overcame industry secrecy issues. Also, the selection of the sample was not based on the number of pharmaceutical organizations using the InnoCentive platform, but instead the sample was inclusive of all challenges posted on www.innocentive.com during the timeframe under study.

4.2.2.2 Pre-study B—InnoCentive Challenges: Sample and Procedure

The population addressed by this study was the type of question that was generally posed by pharmaceutical firms in a broadcast search competition. To understand the type of question broad into broadcast search competitions by pharmaceutical and other organizations, pre-study B was conducted at the problem—or challenge—level. The sample for pre-study B was comprised of challenges collected over a six months time period from an intermediary (namely, InnoCentive, Inc.). I collected current data from InnoCentive’s website in the first half of 2012 to evaluate the extent to which this website was frequented for solving pharma-related challenges, such as medical related issues or searches for new or improved chemical compounds. The data I collected consisted of parameters that were available to anybody who visited the website and as such could be considered public knowledge. In order to more easily keep track of challenges, I registered as a solver and signed up for each individual project I found. This also had the added benefit that I was able to access more detailed descriptions of the challenges. For the analysis I constrained the data usage to that which was publicly available without having to enter any password restricted area. Having signed up for challenges meant, however, that I needed to deduct a count of one (1) from the number of active solvers for each challenge that was not already closed by the time I collected the information from the website. This was the case for all challenges for which a “posted” date is available. Since I was by definition not able to sign up
for challenges that had been closed by the time I collected the data, no such adjustment was necessary there. The sample I derived at using my approach consisted of all challenges that at some point during the first half of 2012 were listed on InnoCentive’s website, whether already closed prior to the first time I collected data or listed as a new challenge during this time. The overall set of observations could be viewed as a one-time snapshot of challenges for the first half of 2012 (and was employed in my analyses as such). Observations that were still open at my first collection point or opened during the six months period, and were subsequently closed before October 2012, offered more detailed data which allowed for an analysis of the effects of certain challenge parameters on the number of solvers signed up for each challenge.

Overall, I collected a total of 215 unique challenges that were listed on InnoCentive’s website at some point during the first half of 2012. The data were collected at six distinct times with irregular intervals during the first six months of 2012. The average time between collection points was 34 days with a maximum of 67 days between them. As such, challenges with very short cycle times, including the decision on who won the challenge, might have been omitted in the data. I expect this to be the exception as the minimum number of days between the posting date and the deadline was 29 days in my sample which did not include the time for the decision about the winner, during which time the challenge was still listed on the website. Additions to the data such as final counts of number of registered solvers per call were adjusted beyond the last collection point (7/10/2012) until the call was closed but no later than September 2012. Adjustments to the number of registered solvers were made at five points in time in addition to and beyond the data collection points, which were also used to update the data on registered users per challenge. These updates were made if the count of registered solvers was not the final
count when the data were downloaded. However, no further challenges were added past July 10th, 2012.

Of the 215 unique challenges I collected, five were dropped since they were so-called Brainstorm challenges, a newly introduced type of challenge that did not reflect the construct of interest in this dissertation. Seven more challenges were dropped since they had not been closed by September 9th, 2012 and will not have been closed before October 2012 or later. After these adjustments I was left with a total set of 203 unique challenges. Of these 203 unique challenges, I was not able to determine the exact time when the challenge was closed for 98 calls as they had been downloaded after closing of the challenge and they were merely listed as “under evaluation”. These were either challenges conducted in 2011 and before or challenges which were listed and closed between collection points and for which no award decision had been made yet. Therefore, they were still listed as “under evaluation” on InnoCentive’s website. Some of these challenges had been listed for months or even years. Similarly, I did not have information on the award value of 75 challenges as they had unique arrangements and the award amount was listed as “varies”. Some of my analyses of these data thus only employed a sub-sample of the 203 challenges.

There was no direct parameter provided by InnoCentive that would specify whether or not a challenge was posted by a pharmaceutical company. Therefore, I constructed an indicator variable called pharma-related which took the value of one (1) for challenges that could be related to R&D conducted by pharmaceutical companies and zero (0) for all other cases. To conduct this coding, I looked at each challenge headline individually to determine if it could be related to a problem submitted by a pharmaceutical company or could have implications for pharmaceutical companies’ R&D efforts. As such, most requests for chemical compounds were
included as *pharma-related* unless the chemical compound requested was clearly for non-
pharmaceutical products. Positive codings (i.e., =1) of *pharma-related* might have also included
challenges for the development of diagnostics and medical instruments. I excluded challenges
that were clearly not related to pharmaceutical development even if it was chemical related or for
chemical compounds. An example of a challenge that would be geared towards the development
of a chemical compound but not pharma-related would be a challenge requesting the
development of chemical components for detergents. However, *pharma-related* could still mean
that the challenge was de facto for food production, flora and fauna care, or beauty products if
this was not distinguishable from the challenge headline. While this might on the surface have
increased the number of actual challenges stemming from pharmaceutical companies, it reflected
the type of question that would typically be raised by pharmaceutical R&D.

4.2.2.3 Pre-study B—InnoCentive Challenges: Measures and Analyses

Available measures collected from InnoCentive’s website included the *challenge title*,
which was used for coding the challenges as *pharma-related* versus *non-pharma*. Furthermore, I
collected information on when the challenge was *posted*, the *deadline* of the challenge, the
number of *active solvers*, and the *award* value of the challenge. These terms were adopted from
InnoCentive. Several sample calls for challenges can be found in Appendix C. I also collected
the *type of challenge* under which a challenge was categorized by InnoCentive. The relevant
choices here included Ideation, Theoretical (IP Transfer), Theoretical (License), Reduction-to-
Practice (RTP), Computational, Novel Molecule Challenge (NMC), or Electronic Request for
Proposal (eRFP). InnoCentive distinguished between various types of challenges. These
challenges were organized in three main categories; (1) brainstorm challenges, (2) premium
challenges, and (3) grand challenges. For my analysis I focused on premium challenges as these
challenges best reflect the broadcast search concept described in this dissertation. Grand challenges, while similar in nature to premium challenges, were excluded mainly on the grounds that their timespan was longer than for premium challenges and most grand challenges in my dataset were still ongoing past the data collection timeframe. Grand challenges were also more flexible in that they might contain several steps, which would have complicated the theoretical conceptualization based on the blind variation and selective retention idea (Campbell, 1960) beyond the scope of the current work. Brainstorm challenges were excluded on the grounds that they did not reflect the construct of interest. Premium challenges were organized by InnoCentive into sub-groups per the definitions restated from www.innocentive.com in Appendix D.

4.2.2.4 Pre-study B—InnoCentive Challenges: Limitations

With very few exceptions, the data did not allow for an identification of the seeker. As such, I was not able to construct a larger dataset that included information on the seeker and thus allowed for a connection between the problem-level of the challenge and the organizational-level of the seeker. Such a connection would be very helpful in better understanding the type of organization conducting broadcast search. However, this information was proprietary and as such only available to InnoCentive.

Another limitation of this study lied in the coding of the challenges as pharma-related versus non-pharma, which was oftentimes not fully evident in the challenge title. Even going into the description of the challenge did not always allow for a more certain categorization without the specialized knowledge required to understand the meaning of applications of individual molecules. As this dissertation is focused on firm level strategic aspects, the author did not have the expertise for such a definitive distinction of chemical compounds.
The relatively long time between individual collection points in some instances was another limitation that might have led to omissions of some challenges (in case of very short cycle times). However, since the average times between pharma-related and non-pharma challenges were very similar, this is unlikely to have introduced a bias in either direction. More collection points would have been preferable and ideally the collection could have been conducted on a daily bases through an automated process employing some sort of web-crawler. Resource constraints in terms of researcher’s time warranted the approach taken for this study considering the low number of possible omissions and the low likelihood of introducing a bias in the data due to any potential omissions.

4.2.3 Pre-Study C: Survey of Specialists as Informants

Pre-study C is a self-developed survey administered through Fleming Europe, an East-European, Slovakia based organizer of innovation focused business conferences. While conducting the preliminary Factiva search for pre-study A, I came across an announcement of one of Fleming Europe’s conferences held in Amsterdam on the specific topic of open innovation in the pharmaceutical industry. I contacted Fleming Europe as the organizer of this conference titled “Solving the ‘Productivity Crisis’ – Open Innovation in Pharmaceutical R&D” to inquire about a potential research collaboration. The conference was held on April 26th & 27th, 2012 and included speakers from several, well known large pharmaceutical companies as evident by the conference schedule in Appendix E. While I was not able to participate in the conference due to time and monetary constraints, I was able to arrange with the organizers that a survey be sent to the proprietary mailing list used to invite participants to the venue. Due to the specificity of the conference and the limited access to people associated with open innovation approaches in the pharmaceutical industry this was an excellent opportunity to directly access key expertise.
4.2.3.1 Pre-study C—Survey of Informants: Purpose and Goals

The goal of pre-study C was to solicit input that would allow me to understand the type of organization interested in open innovation and specifically inquire about the engagement in broadcast search. Therefore, pre-study C was designed to access primary input from key personnel closely involved in open innovation and broadcast search for pharmaceutical R&D. My aim was to better understand the intentions and strategies behind pharmaceutical companies’ involvement in broadcast search. In the broader scheme of this dissertation, my aim was to access primary input which could complement my inquiries based on secondary data and explicate the relationship and connection between academia and practice. To make this connection, it was important for me to have some direct contact with decision makers involved with the subject of study to more fully understand and better be able to portray the practical meaning of the analyses’ findings in regards to the phenomenon. Getting access to people involved in the pharmaceutical and biotechnology industry is generally a difficult task as previous attempts have shown (Bruyaka, Zeitzmann, Chalamon, Wokutch, & Thakur, 2012), so I was very fortunate to have at least one, albeit limited, opportunity to receive some primary inside information on the practical application of the phenomenon. Employing a survey seemed to be the best method to accomplish this task as it allowed participants to voice their opinion as their busy time schedules permitted them. Overall, the survey’s general purpose was to offer supplemental support and ideas to my research studies rather than serving as a stand-alone analysis tool to answer my research questions.

4.2.3.2 Pre-study C—Survey of Informants: Sample and Procedure

The population of interest to which pre-study C refers is composed of organizations which are interested in the concept of open innovation in the pharmaceutical industry. A
representative sample of such a population consists of organizations which do not have to be engaged in broadcast search or even open innovation at this point, but must have indicated an interest in the topic. Organizations invited for participation in Fleming Europe’s conference are closely screened and reflect those criteria. The sample I was able to access was highly specific, yet diverse as evident by the data collected on the characteristics of the survey participants. At the same time, the sample was strongly limited in size due to the exclusivity of the mailing list, which again was reflected in the quality of survey respondents in terms of their executive positions. These factors placed some constrains on my research approach that needed to be overcome. The procedures outlined here refer to both the construction of the survey itself as well as the subsequent administering of the survey.

To construct my survey, I built on related materials and survey instruments. In doing so, I took great care to develop a valid instrument. The responses to the survey that resulted informed my subsequent studies and were useful in understanding more deeply the implications from my formal analyses of secondary data. The survey sent out by the conference organizers on my behalf served as a means to gather data on the understanding and use of broadcast search. To construct the survey, I reviewed and incorporated material used for previous surveys on innovation, both in general and on open innovation in particular. Since the survey was distributed in conjunction with a conference in Europe, I used the Oslo Manual (OECD/Statistical Office of the European Communities, 2005) which is the guiding source for the Community Innovation Survey (CIS). The CIS is the primary innovation gauge in Europe and is administered in 27 countries throughout Europe and select other countries (“Community Innovation Statistics,” n.d.). The Oslo Manual offers a section on ‘inbound diffusion’ which gives some guidance on designing questions to address questions on knowledge sourcing and
collaborations. The section is particularly useful for specialized surveys such as the current one and therefore I closely followed this guidance in designing the survey.

The most direct, somewhat equivalent counterpart to the CIS for the US is the Business R&D Innovation Survey (BRDIS) administered in the US through the Department of Commerce (“Business R&D and Innovation Survey (BRDIS) - nsf.gov,” n.d.). While there were no sample copies of the CIS available since these differ from country to country, the US Department of Commerce provides actual samples of their survey. Much of the BRDIS was not applicable for my survey since the BRDIS is an extensive measuring tool that is sent to organizations to be filled out by specialists in various areas, from finance to human resources and R&D. The level of detail requested in the BRDIS cannot be expected to be known ad hoc by all executives within an organization. Since my survey was being sent to executives in various positions, it would not have been adequate to ask such questions. An advantage of the BRDIS over my survey in terms of ensuring adequate response rates was that firms were required by law to participate in the BRDIS. My survey was purely voluntary in nature and as such relied on the goodwill of the people whose responses were sought. In outlining my survey and formulating my questions I relied on both the instructions from the Oslo Manual and the BRDIS sample surveys. The BRDIS consisted of seven (7) sections representing different specialty areas to be answered by different personnel within the organization with specialized knowledge and access to proprietary information. The questions in the specific areas were too detailed and required too much effort by the participants to be incorporated in a survey of voluntary nature. The survey samples were however helpful in determining the structure of my survey such as the inclusion of general questions describing the firm and the survey participant. In focusing on open innovation, beyond a general innovation focus of previous surveys, I also reviewed academic papers published by
Lichtenthaler (Lichtenthaler & Ernst, 2007, 2008, 2009; Lichtenthaler, Lichtenthaler, & Frishammar, 2009; Lichtenthaler, 2008b, 2010a, 2010b) which relied on surveys that had been conducted on the innovation appropriation (i.e., outbound) part of the open innovation concept. These publications listed many of the questions used so that I was able to reformulate them for my purpose of looking at the inbound open innovation concept, choosing the most relevant ones for my survey. Most notably, the 7-point Likert scale and the associated question structure were adopted from there. An exemplary comparison of questions used in my survey compared with their original version and source can be found in Table 9.

My survey was constructed in compliance with the Institutional Review Board for Research Involving Human Subjects (IRB). I went through the required IRB process for research involving human subjects and received clearance for distribution as documented by the memorandum regarding IRB number 12-340 reproduced in Appendix F. After constructing the survey and getting clearance for its distribution, the survey was administered electronically through Qualtrics online survey software (https://www.qualtrics.com/). To create awareness of the survey, it was announced in a conference reminder by Fleming Europe prior to its first distribution. Shortly before the conference, a link to the survey was sent out via email to Fleming Europe’s mailing list for the open innovation in pharmaceutical R&D conference. As a third step to entice invited recipients to participate, the survey was personally promoted at the conference by the conference organizers.
Pre-study C—Survey of Informants: Measures and Analyses

The survey employed in pre-study C was aimed at addressing questions related specifically to broadcast search. As such, the measures used were adapted from related surveys previously used. Importantly, the survey was intended to be relatively comprehensive yet the questions were intended to be general enough to be answered by executives with a general knowledge of their organization and with no need for extensive research on firm-level data. Questions referring to quantities were therefore kept more general and approximate. To streamline the survey process, a brief introduction was developed that explained the nature and
purpose of the survey and rather than requiring a separate consent form, informed consent was explicitly implied to satisfy IRB requirements. The survey was administered with the assurance of confidentiality to avoid biases in the data stemming from false or incomplete answers given for fear of retaliation. After inquiring about some general information about the organization and the person responding to the survey, a brief definition of the concept of interest—broadcast search—was offered. This was important for at least two reasons. One, while the conference to which survey participants were invited was on the subject of open innovation, my study is focused on broadcast search in particular, which is a more specific form of open innovation. Responses to the survey showed that this distinction was very important. Two, while there is in general a common understanding of what falls in the area of open innovation, the term is used at different levels of specificity in practice. Therefore, setting the boundaries of the broadcast search definition was intended to ensure that all respondents were answering the questions with the most homogeneous understanding of the concept of interest as possible. A copy of my full survey administered to conference participants is reproduced in Appendix G. All responses to the survey were collected around the time of the conference with the first respondent starting the survey on April 16th and the last respondent starting to answer the survey on May 8th, 2012.

4.2.3.4 Pre-study C—Survey of Informants: Limitations

A main limitation specific to the survey I developed was the lack of a pre-test opportunity. This was very unfortunate but unavoidable due to the specificity of the pool of participants. Attempts to overcome this limitation have been addressed in the procedure of the study.

Furthermore, the limited number of actual participants from this pool did not allow for a meaningful empirical investigation. The low number of respondents was not particularly surprising given the limited number and high level of potential respondents to start with. There
were only about 30 organizations that participated in the conference. This translates into a low number of people invited to the conference.

**4.2.4 Study 1: Strategic Knowledge Groups in the Pharmaceutical Industry**

To evaluate the importance of path dependence (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010), study 1 consisted of a replication and extension of Bierly and Chakrabarti’s (1996a) cluster analysis study on “generic knowledge strategies in the U.S. pharmaceutical industry”. Cluster analyses were used in Bierly and Chakrabarti’s (1996a) study to group organizations within the pharmaceutical industry along several knowledge based dimensions in order to investigate common behavior for firms with similar characteristics (Ketchen & Shook, 1996). Cluster analyses have been employed in strategic management research to identify groups of firms which are similar in some way since the 1970s (Ketchen & Shook, 1996). Cluster analysis allows for the inclusion of various dimensions on which ‘elements’ (i.e., companies) are compared and creates groupings for which within-group variance is minimized and between-group variance is maximized (Ketchen & Shook, 1996). Due to reliance on judgment by researchers that is essential to this approach, cluster analysis has been under siege by researchers (Barney & Hoskisson, 1990; A. D. Meyer, 1991; Thomas & Venkatraman, 1988) and as such its application and usefulness in strategy research has been doubtful (Ketchen & Shook, 1996). Accordingly, I conducted an in-depth investigation of the original study instead of blindly adopting the suggested clustering and applying it as a decision factor in the model. Ketchen and Shook (1996) offer a comprehensive assessment of the use of cluster analyses. More importantly for the current study, Ketchen and Shook (1996) provide useful advice on how to best employ cluster analyses and when such an approach is useful and what cautions and remedies need to be taken. Ketchen and Shook (1996) pointed out that
hierarchical algorithms, those that build on the data to construct the groups by adding or subtracting elements, are associated with certain issues. For one, selecting the best suited algorithm \textit{ex ante} is oftentimes impossible for researchers since they do not know the underlying structure of the data. This might be the case for Bierly & Chakrabarti’s (1996a) analysis since they use Ward’s method without considering that their data had unequal numbers of observations in each group and could potentially be driven by outliers, two aspects pointed to by Ketchen and Shook (1996). Two, hierarchical methods only make a single pass through the data to determine the clusters and thus no modification of cluster assignments is possible. Three, especially for small samples such as those often used in strategy research, such as the Bierly and Chakrabarti (1996a) study, outcomes would often change if elements were dropped from the sample (Jardine & Sibson, 1971). These factors led Ketchen and Shook (1996) to conclude that pure reliance on hierarchical methods could lead to validity issues. An alternative approach to using hierarchical methods is the use of non-hierarchical methods (Ketchen & Shook, 1996). Non-hierarchical clustering has the potential advantages that results are (1) less impacted by outliers and (2) optimized in terms of between-cluster heterogeneity and within-cluster homogeneity (Ketchen & Shook, 1996). Both of these advantages stem from the corrections achieved in the iterative process of determining clusters in non-hierarchical fashion (Ketchen & Shook, 1996). The obstacle of the non-hierarchical approach is that it is necessary to set \textit{ex ante} the number of groups. For the current dissertation, Bierly and Chakrabarti (1996a) provided a solid foundation which suggested that there are four meaningful groups in the pharmaceutical industry which seem to be consistent over time. There was movement of individual organizations between the groups over time, but the number of groups seemed adequately established (Bierly & Chakrabarti, 1996a). In the current dissertation I therefore use a non-hierarchical analysis approach using k-
means clustering. In essence, combined with Bierly and Chakrabarti’s (1996a) prior work, such a combination has been suggested (Hair, Anderson, Tatham, & Black, 1992; Ketchen & Shook, 1996; Milligan, 1980; Punj & Stewart, 1983). As such, my replication in this dissertation built on prior literature in two ways. On the one hand, it built on prior work by following a suggestion made in earlier research which suggested the use of a two-stage approach for cluster analyses (Ketchen & Shook, 1996). On the other hand, my replication study built directly on the findings from an earlier study of similar nature by using the findings of that study as the starting point for the current study.

4.2.4.1 Study 1—Strategic Knowledge Groups: Purpose and Goals

Building on prior work is essential for scientific progress and the generation of cumulative knowledge (Carlson & Hatfield, 2004; Hitt, Boyd, & Li, 2004). The replication of a study can serve as a first step for extending prior work and for constructing studies that show high validity within a stream of research. One purpose of study 1 was to function as a possible foundation for setting boundary conditions for future research. The results of study 1 were intended to form the basis for measures of knowledge strategies employed by firms. The replication of Bierly and Chakrabarti’s (1996a) study allowed me to address my research question more fully by testing the feasibility of using a previously used taxonomy in my study 2.

The use of strategic knowledge groups seemed particularly suitable for addressing the question of who engaged in broadcast search by determining if companies which engaged in broadcast search were associated with a particular common strategy, and if so, what the (dominant) generic knowledge strategy was for firms that engaged in broadcast search. As this dissertation was unable to address all of the elements outlined by Bierly and Chakrabarti (1996a) individually, it seemed useful to evaluate aggregated categorizations. Study 1 allowed me to
investigate the pharmaceutical industry using a previously employed taxonomy of firm knowledge strategies and examine if, as a group, organizations in different categories within this taxonomy differed in their use of broadcast search. Overall, study 1 had the dual purpose of extending prior work along the same parameters used in that work and informing my study 2 and the subsequent post-hoc analysis in terms of applying a taxonomy that had previously been established.

4.2.4.2 Study 1—Strategic Knowledge Groups: Sample and Procedure

The population to which study 1 relates is comprised of all R&D based organizations in the US pharmaceutical industry. For the replication and direct extension of the original study (Bierly & Chakrabarti, 1996a), I intended to use the exact same companies as the original study. Since the companies were individually listed in the original study (Bierly & Chakrabarti, 1996a), the main challenge was to find data sources which would allow me to collect the same data points as Bierly and Chakrabarti (1996a). Measures related to firm performance and R&D expenditures which relied on data collected from annual reports would be replaced by measures constructed from data collected through Compustat. I expected these numbers to be relatively comparable. Other data sources would likely be less comparable. Table 10 contrasts the sources used in the original study with the sources employed in constructing the variables for my replication.

In replicating Bierly and Chakrabarti (1996a) I was not able to draw from the same data sources as the original study. Instead I used data sources that would offer me information that would resemble the information used by Bierly and Chakrabarti (1996a) and mirror the constructs of interests as closely as possible. In other words, I focused on retaining the characteristics of the original study by focusing on replicating the constructs. In some instances,
I was able to directly access the same data as the original study from a different, secondary data source. For example, instead of directly collecting firm data from corporate reports, I employed Compustat to collect these types of data. Using Compustat data meant that I had to match the names listed by Bierly and Chakrabarti (1996a) with the correct listing in Compustat. This matching was done manually and for the most part was relatively straightforward. However, in a few incidences, the matching was complicated by changes in the historical listings of securities in Compustat and that Bierly & Chakrabarti (1996a) listed only generic (and sometimes abbreviated) names for the companies instead of the full official names.

In order to extend the study as far as possible, using NBER patent data as a substitute for CHI Research Inc.’s database, I employed data on patents granted rather than patents applied for. Also, Bierly and Chakrabarti (1996a, p. 127) talk about building on patents granted, and since I am building directly on their work, I am using ‘gyear’ in this study (even though I use ‘appyear’ in study 2 for the reasons outlined there). Using patents granted decreases the truncation generally found at the end of patent databases stemming from lags between patent applications, patent grantings, and the recording of these acts. I compared the mean values of the variables constructed on patent data for those using application year versus those using the grant year and there were no visible differences in their behavior in terms of changes in the mean level between groups and periods.

To construct my variables based on the data available, I made several adjustments to Bierly and Chakrabarti’s (1996a) data construction approaches. Before I address the differences I will briefly describe the construction of variables that I was able to reconstruct directly. Table 11 gives an overview of the variable means in the original study and the variable means of my replication attempt. As can be seen, the means of the variables which had been constructed from
corporate annual reports could be replicated from Compustat data. This constitutes a first, very important assertion that I was able to identify the correct set of firms in Compustat. Other variables were more difficult to approximate.
Table 10: Data sources for attempted replication of Bierly & Chakrabarti (1996)

<table>
<thead>
<tr>
<th>Knowledge Strategy (4 basic trade-offs)</th>
<th>Construct</th>
<th>Variable name (5 independent variables)</th>
<th>Var. type</th>
<th>In original defined / measured as</th>
<th>Original data (Bierly &amp; Chakrabarti, 1996)</th>
<th>Replication data (current study)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal learning</td>
<td>Financial performance</td>
<td>Return on sales (ROS)</td>
<td>DV</td>
<td>company annual reports &amp; 10-K forms</td>
<td>COMPUSSTAT database</td>
</tr>
<tr>
<td></td>
<td>Internal learning</td>
<td>Financial performance</td>
<td>Return on assets (ROA)</td>
<td>DV</td>
<td>company annual reports &amp; 10-K forms</td>
<td>COMPUSSTAT database</td>
</tr>
<tr>
<td></td>
<td>Internal learning</td>
<td>R&amp;D intensity (RDS)</td>
<td>IV</td>
<td>&quot;the ratio of annual R&amp;D dollars spent by the firm and the firm's total sales&quot;</td>
<td>company annual reports &amp; 10-K forms</td>
<td>COMPUSSTAT database</td>
</tr>
<tr>
<td></td>
<td>External learning</td>
<td>Scientific linkage (SCILINK)</td>
<td>IV</td>
<td>&quot;the average number of patent citations to the scientific literature&quot; - patent citations</td>
<td>patent data from CHI Research Inc. database</td>
<td>patent data from NBER databases</td>
</tr>
<tr>
<td></td>
<td>External learning</td>
<td>Scientific linkage (SCILINK)</td>
<td>IV</td>
<td>&quot;the average number of patent citations to the scientific literature&quot; - patent citations</td>
<td>patent data from CHI Research Inc. database</td>
<td>patent data from NBER databases</td>
</tr>
<tr>
<td></td>
<td>Firm's knowledge base</td>
<td>Knowledge dispersion index (DISP)</td>
<td>IV</td>
<td>&quot;technological distribution of a company's patents&quot; - patent data from CHI Research Inc. database</td>
<td>patent data from CHI Research Inc. database</td>
<td>patent data from NBER databases</td>
</tr>
<tr>
<td></td>
<td>Firm's knowledge base</td>
<td>Knowledge dispersion index (DISP)</td>
<td>IV</td>
<td>&quot;technological distribution of a company's patents&quot; - patent data from CHI Research Inc. database</td>
<td>patent data from CHI Research Inc. database</td>
<td>patent data from NBER databases</td>
</tr>
<tr>
<td></td>
<td>Learning speed</td>
<td>Technology cycle time (TCT)</td>
<td>IV</td>
<td>&quot;median age of the patents cited by a given firm's patents&quot;</td>
<td>patent data from CHI Research Inc. database</td>
<td>patent data from NBER databases</td>
</tr>
<tr>
<td></td>
<td>Learning radicalness</td>
<td>Radicalness (RAD)</td>
<td>IV</td>
<td>&quot;the ratio of New Chemical Entities (NCEs) and approved New Drug Applications to industry sources&quot;</td>
<td>FDA reports (plus undisclosed comparison to industry sources)</td>
<td>FDA database on drug applications</td>
</tr>
</tbody>
</table>

Analysis approach:
In Bierly & Chakrabarti (1996): "Cluster analyses, which were used to classify the firms into different groups based on their knowledge strategy, were carried out using the SPSS for Windows (1994) package. Specifically, we choose the Ward's hierarchical technique of clustering using squared Euclidean distances. All variables were standardized by using Z-scores so that variables with large units would not be overemphasized. The decision concerning how many clusters to use was guided by the agglomeration schedule, which displays the squared Euclidean distances between each case or group of cases combined to form a cluster for each step of the process. Cluster agglomeration is generally stopped when the increase between two adjacent steps becomes large. We stopped cluster agglomeration with four clusters for each of the 5-year time periods." (p. 127-128)
Table 11: Comparison of variable means between original study (Bierly & Chakrabarti, 1996) and replication (current study)

<table>
<thead>
<tr>
<th>Period I: 1977-81</th>
<th>KG1-Explorers</th>
<th>KG2-Explorers</th>
<th>KG3-Loners</th>
<th>KG4-Innovators</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>R1</td>
<td>R2</td>
<td>O</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>Original (O)</td>
<td>0.04</td>
<td>0.04</td>
<td>0.45</td>
<td>0.28</td>
<td>7.72</td>
</tr>
<tr>
<td>Replication (R)</td>
<td>0.78</td>
<td>4.05</td>
<td>0.76</td>
<td>6.67</td>
<td>8.23</td>
</tr>
<tr>
<td>KG1-Explorers</td>
<td>1.39</td>
<td>4.37</td>
<td>0.67</td>
<td>6.46</td>
<td>6.75</td>
</tr>
<tr>
<td>KG2-Explorers</td>
<td>0.50</td>
<td>4.30</td>
<td>0.70</td>
<td>13.28</td>
<td>10.13</td>
</tr>
<tr>
<td>KG3-Loners</td>
<td>0.08</td>
<td>0.08</td>
<td>1.22</td>
<td>5.34</td>
<td>6.90</td>
</tr>
<tr>
<td>KG4-Innovators</td>
<td>0.05</td>
<td>0.05</td>
<td>0.96</td>
<td>7.26</td>
<td>8.02</td>
</tr>
<tr>
<td>All groups</td>
<td>0.08</td>
<td>0.08</td>
<td>1.54</td>
<td>8.82</td>
<td>8.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period II: 1982-86</th>
<th>KG1-Explorers</th>
<th>KG2-Explorers</th>
<th>KG3-Loners</th>
<th>KG4-Innovators</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>R1</td>
<td>R2</td>
<td>O</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>Original (O)</td>
<td>0.09</td>
<td>0.09</td>
<td>1.52</td>
<td>7.72</td>
<td>7.12</td>
</tr>
<tr>
<td>Replication (R)</td>
<td>0.57</td>
<td>5.77</td>
<td>0.76</td>
<td>8.61</td>
<td>7.78</td>
</tr>
<tr>
<td>KG1-Explorers</td>
<td>0.65</td>
<td>5.45</td>
<td>0.75</td>
<td>11.23</td>
<td>9.41</td>
</tr>
<tr>
<td>KG2-Explorers</td>
<td>0.37</td>
<td>10.54</td>
<td>0.92</td>
<td>7.29</td>
<td>7.50</td>
</tr>
<tr>
<td>KG3-Loners</td>
<td>0.12</td>
<td>0.11</td>
<td>3.80</td>
<td>8.82</td>
<td>8.00</td>
</tr>
<tr>
<td>KG4-Innovators</td>
<td>0.08</td>
<td>0.08</td>
<td>1.54</td>
<td>8.82</td>
<td>8.00</td>
</tr>
<tr>
<td>All groups</td>
<td>0.08</td>
<td>0.08</td>
<td>1.54</td>
<td>8.82</td>
<td>8.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period III: 1987-91</th>
<th>KG1-Explorers</th>
<th>KG2-Explorers</th>
<th>KG3-Loners</th>
<th>KG4-Innovators</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>R1</td>
<td>R2</td>
<td>O</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>Original (O)</td>
<td>0.09</td>
<td>0.09</td>
<td>2.59</td>
<td>8.68</td>
<td>7.70</td>
</tr>
<tr>
<td>Replication (R)</td>
<td>0.76</td>
<td>7.76</td>
<td>0.83</td>
<td>8.68</td>
<td>8.68</td>
</tr>
<tr>
<td>KG1-Explorers</td>
<td>1.52</td>
<td>6.90</td>
<td>0.77</td>
<td>11.46</td>
<td>10.57</td>
</tr>
<tr>
<td>KG2-Explorers</td>
<td>1.03</td>
<td>6.59</td>
<td>0.80</td>
<td>8.69</td>
<td>7.08</td>
</tr>
<tr>
<td>KG3-Loners</td>
<td>0.13</td>
<td>0.13</td>
<td>3.80</td>
<td>9.11</td>
<td>8.30</td>
</tr>
<tr>
<td>KG4-Innovators</td>
<td>0.10</td>
<td>0.10</td>
<td>2.48</td>
<td>9.11</td>
<td>8.30</td>
</tr>
<tr>
<td>All groups</td>
<td>0.10</td>
<td>0.10</td>
<td>2.48</td>
<td>9.11</td>
<td>8.30</td>
</tr>
</tbody>
</table>

Table adopted from Bierly & Chakrabarti (1996, p. 129, Table 1 & Table 3).

Legend:

| SCILINK R1 | calculated based on the number of general patent links |
| SCILINK R2 | calculated as 1-'selfctub' (self citations upper bound from NBER data) |
| DISP R1    | calculated based on 'gyear' using the original formula given by Bierly & Chakrabarti |
| DISP R2    | calculated based on 'gyear' using the alternative formula described |
| TCT R1     | calculated based on my own calculation of a back lag |
| TCT R2     | calculated based on 'bckgtlag' (backwards citing lag from NBER) |
| RAD R1     | calculated based on FDA data |
| RAD R2     | calculated based on 'original' (originality measure from NBER) |
In the original study, Bierly and Chakrabarti (1996a) employed patent data supplied from a private source available for purchase from CHI Research, Inc. Despite several attempts\(^\text{12}\), I was unable to secure access to a copy of this data or a subset of it. Instead, I decided to revert back to publicly available patent data from the NBER patent data project (Hall, Jaffe, & Trajtenberg, 2001). The NBER data is available to researchers at no cost and has been extensively used in the strategic management literature. The major drawback of using the NBER patent data (Hall et al., 2001) in the current context was that it did not include a key variable used in constructing SCILINK in the original study (Bierly & Chakrabarti, 1996a). Furthermore, I used data provided by the US Food and Drug Administration (FDA) which should be very similar to the data used by Bierly and Chakrabarti (1996a) but which turned out to be quite different. Potentially, the database had been updated to be more complete than the data which Bierly and Chakrabarti (1996a) were able to collect from other FDA sources.

Building on Bierly and Chakrabarti (1996a), I followed Ketchen and Shook’s (1996) advice of employing a two-stage approach, taking Bierly and Chakrabarti’s (1996a) study as the hierarchical analysis part determining the number of groups and constructing a non-hierarchical follow-up study. Bierly and Chakrabarti (1996a) had outlined four groups which they termed (1) ‘explorers’, (2) ‘exploiters’, (3) ‘loners’, and (4) ‘innovators’ arrived from cluster analyses of the pharmaceutical industry. Confidence in the number of groups was supported by the consistency over three timeframes with varying numbers of firms in the sample (Bierly & Chakrabarti, 1996a). Building on this categorization would allow me to extrapolate these categories and evaluate the strategies of the companies in my sample for study 2. I first conducted a replication of Bierly and Chakrabarti’s (1996a) data based on the constructs outlined and then extended the

\(^{12}\) I conducted a Google web search which however did not return a webpage indicating that the data is still available for purchase. Other attempts to secure a copy of the data were equally unsuccessful.
clusters using non-hierarchical (k-means) cluster analysis up to the year 2001. This approach was a first step in bridging the sample used in study 1 and the sample used in study 2. Study 1 by itself offered interesting insights in regards to Bierly and Chakrabarti’s (1996a) sample, in addition to attempting to provide a taxonomy which could be applied in study 2.

An important aspect of the replication of Bierly and Chakrabarti’s (1996a) study on strategic knowledge groups in the US pharmaceutical industry was the correct matching of the set of firms to data available to me. Starting with the set of firm names offered by Bierly and Chakrabarti (1996a), I manually looked for these names in the complete list of firm names covered by Compustat. For most of the names, matching was relatively easy as the names were more or less unique. Some companies, however, were harder to track and there were instances where company names would not be unique or identical. Oftentimes, false positives could be ruled out based on the industry they were in, as indicated by their SIC code, if that industry was not even remotely related to the pharmaceutical industry or pharmaceutical related R&D. In a few instances matching was not possible at first. For example, “American Home Prod.” as it was labeled in Bierly and Chakrabarti (1996a) had now changed its name through corporate restructuring to “Wyeth” and since the GVKEY in Compustat had not been changed as it was still considered the same security, all information relating to the former company name “American Home Prod.” was now listed in Compustat under “Wyeth”. By tracking the development of companies between 1977 and current through Google searches and Wikipedia entries, I was able to positively match all company names to Compustat data.

A similar matching procedure needed to be employed between the studies company names (Bierly & Chakrabarti, 1996a) and the FDA list of drug applicants. For this matching, a list of all drug applicants was created and manually compared to the list of Compustat names
generated in the first matching. For matches, I was able to associate a GVKEY with the drug applicant and thus match FDA data with my main dataset. An overview with the full list of company matches is provided in Table 12 (with data not covering the full timeframe marked in bold font).

Table 12: Match between companies from Bierly & Chakrabarti (1996) with Compustat

<table>
<thead>
<tr>
<th>No. (1996)</th>
<th>Bierly &amp; Chakrabarti</th>
<th>COMPUSTAT name</th>
<th>SIC code</th>
<th>GVKEY</th>
<th>Timeframe of data used in B&amp;C study</th>
<th>Timeframe for which Compustat data was available</th>
</tr>
</thead>
</table>

4.2.4.3 Study I—Strategic Knowledge groups: Measures and Analyses

In order for my replication to be useful and comparable, I needed to ensure that I was working with data on the correct companies. Since I only had brief company names I needed to match those names with information available to me through the sources depicted in Table 10. Creating variables from the data collected from Compustat which, as far as I was able to assess based on the data provided by Bierly and Chakrabarti (1996a), would match the characteristics of
the data collected from annual reports in Bierly & Chakrabarti’s (1996a) original study, was a
litmus test of my matching. As Table 11 asserts, the mean values of the Compustat based
variables are equal within rounding error to the means offered by Bierly & Chakrabarti (1996a).
Data collected from Compustat should be the same as data collected from annual reports.
However, due to M&As of the focal companies occurred in the meantime, it was not certain that
the information offered by Compustat would still be pure enough to reflect the focal
organizations, since the level of analysis which Compustat is concerned with is that of the
security (i.e., stock market listing) while the research study is conducted at the firm level.

Bierly and Chakrabarti (1996a) integrated several knowledge spectra into their generic
knowledge strategies. Bierly and Chakrabarti’s (1996a) knowledge strategies were built on four
basic trade-offs requiring managers to make strategic decisions. Among these were internal
versus external learning, incremental versus radical learning, learning speed, and the breadth of
the knowledge base (Bierly & Chakrabarti, 1996a). To reflect these dimensions, Bierly &
Chakrabarti (1996a) offered several constructs with associated measures on which they base their
cluster analysis. The selection of variables has been noted as potentially being the most
important step in cluster analyses (Ketchen & Shook, 1996). The variables selected by (Bierly &
Chakrabarti, 1996a) were based on theoretical logic and as such their approach would
appropriately be categorized as employing a deductive approach in selecting variables for
inclusion in the model (Ketchen & Shook, 1996) but not making *ex ante* predictions on the
number and nature of groups. A closer look at the variables used was thus warranted and I will
outline how I constructed my variables. The variable descriptions offered by Bierly and
Chakrabarti (1996a) were sometimes a bit brief so that assumptions had to be made in
constructing some of the variables.
There were two outcome variables which both served as reflections of financial performance. The variables were return on sales (ROS) and return on assets (ROA). Initially these measures had been based on data collected directly from annual reports. In my replication I used Compustat data and calculated ROS as the fraction of net income (ni) over sales (sale) and analogue constructed ROA as the fraction of net income (ni) over total assets (at). The four strategic trade-offs extracted from the review of the related literature were reflected in five independent variables (Bierly & Chakrabarti, 1996a). R&D intensity (RDS) was another measure based on information from corporate annual reports which in my replication was constructed based on Compustat data as the simple fraction of R&D expenditures (xrd) over total sales (sale). As can be seen from the comparison of means in Table 11, these variables were recreated successfully and the litmus test that the correct set of companies was being considered was passed.

Next, I attempted to replicate the science linkage variable (SCILINK) which was based on patent citation information. Unfortunately, I was not able to secure access to the same dataset of patents used in the original study. While Bierly & Chakrabarti (1996a) used the database provided by CHI Research Inc., I had access to NBER’s patent database (Hall et al., 2001). While the NBER database (Hall et al., 2001) probably is at least as complete and accurate, it does not offer a specific parameter employed in Bierly & Chakrabarti (1996a), namely the count of links to the scientific literature for each patent. I attempted to create a similar measure employing the number of links to other patents. However, as is evident by the dispersion between means in Table 11 this approach failed to generate a good replication proxy.

Also based on patent data was the creation of a knowledge dispersion index (DISP) in the original study to reflect the breadth of knowledge a firm holds (Bierly & Chakrabarti, 1996a).
The dispersion index was specified in the original study as follows (Bierly & Chakrabarti, 1996a):

\[
DISP = -1 / \ln N \sum_{i=1}^{N} (f_i * \ln f_i)
\]

where \( f_i \) = the fraction of patents in \( i \)th category.

However, the resulting dispersion index based on my data was indicating opposite behavior to the results presented by Bierly and Chakrabarti (1996a). I thus corrected the specification of the formula to be as follows which led to means for the dispersion index which were larger in absolute values but behaved similar in regards to the groupings to the means of the index specified in the original study\textsuperscript{13}:

\[
DISP = -1 * \ln N \sum_{i=1}^{N} (f_i * \ln f_i)
\]

where \( f_i \) = the fraction of patents in \( i \)th category. Unless the -1 operator is used as a multiplicator rather than being placed in the nominator, the formula is corrected twice for negative log normal values stemming from values smaller than 1, once by the negative sign of the -1 operator and once by placing the formula in the denominator. After correcting the formula, the construction of the dispersion index was relatively straight forward, despite a rather scarce description of the variable. I used the variable \textit{nclass} provided in the NBER database (Hall et al., 2001) as my grouping variable for patent categories.

Another patent-based variable was technology cycle time (TCT) which measured the “median age of the patents cited by a given firm’s patents” (Bierly & Chakrabarti, 1996a, p. 127). Again, I had to rely on a different dataset as the original study. In reconstructing this variable, I

\textsuperscript{13}I assume that there is some sort of misspecification which is reflected in a printing error rather than a substantial error as it seem that Bierly and Chakrabarti (1996) used a specification other than the one presented.
used the older version of the NBER dataset (Hall et al., 2001) which contains all USPTO patent data up to 1999 and merged every patent with the patents it had cited using statistical software by Stata. From this merged set of data I extracted the date of the cited patent now linked to the focal patent. In the next step I collapsed the data so that each focal patent would only be listed once, linked to the median age of patents cited by the focal patent.

The last independent variable I attempted to replicate was based on data provided by the US Food and Drug Administration (FDA). Bierly & Chakrabarti (1996a) in the original study collected the data from FDA reports. Nowadays, these data can be downloaded from the FDA website and characteristics of variable constructed from this data should be comparable. However, the description provided by (Bierly & Chakrabarti, 1996a) was again somewhat confusing so that it was hard to ensure adequate replication. The confusion here stemmed from the discussion of New Chemical Entities (NCEs) versus New Molecular Entity (NMEs) without explicitly stating which adjustments to the FDA data, if any, were made based on the SCRIPT [sic] [recte SCRIP] magazine terminology and “other industry sources” (Bierly & Chakrabarti, 1996a, pp. 127–128). Since I did not have access to the individual FDA reports to which Bierly and Chakrabarti (1996a) refer and could not retrace their adjustments, I employed the information from the FDA database at face value. In doing so, I used the definition of and data of NME instead of NCE, which according to Bierly and Chakrabarti (1996a, p. 127) should be very close. I constructed the measure of incremental versus radical learning (RAD) as the fraction of NMEs over New Drug Approvals (NDAs), both provided by the FDA.

In a related article building on the same dataset, Bierly and Chakrabarti (1996b) are a little more explicit about the construction of their variables and specify that they constructed aggregate measures for the five year intervals by taking the average value of the annual values.
In my analysis I assumed that the same logic and approach was taken in their cluster analysis study. In the study of determinants of technology cycle times, Bierly & Chakrabarti (1996b) also specified the firm years for which data was available to them in their study. In my replication I constrained my data accordingly.

In their analyses, Bierly & Chakrabarti (1996a) use standardized values. They do not, however, provide an explanation for this decision. Since there are tradeoffs between the use of standardized and unstandardized values (Ketchen & Shook, 1996), Ketchen and Shook (1996) suggest the use of both and validity investigations if they diverge. Following Bierly & Chakrabarti (1996a), I ran my analyses with standardized variables but provide means and other descriptions in unstandardized form.

4.2.4.4 Study 1—Strategic Knowledge Groups: Limitations

I was unable to access the same data sources and collect the same data points that had been used by Bierly and Chakrabarti (1996a). I intended to overcome this by using sources that would offer me information that was as similar to the information used in the original study as possible as outlined in Table 10.

4.2.5 Study 2: Corporate Communications and Broadcast Search

The second main study of this dissertation was an empirical investigation which employed a larger set of firms to test the individual steps of my model. I constructed a sample of current organizations in the pharmaceutical industry and employed a series of steps to arrive at a valid sample of organizations which are engaged in broadcast search or refrain from it currently.
4.2.5.1 Study 2—Corporate Communications: Purpose and Goals

The primary purpose of study 2 was to empirically test the hypotheses formally stated in Table 6. These hypotheses will also be listed individually in the discussion of the results in Chapter 5. Creating a single industry sample and relying on the scientific method, I employed secondary data collected from a variety of sources.

4.2.5.2 Study 2—Corporate Communications: Sample and Procedure

The population to which study 2 relates consists of all US pharmaceutical corporations. The sample on which my analyses in this study were based consisted of all publicly traded US pharmaceutical companies listed on Compustat under SIC code 2834 in 2011. As outlined above, in this dissertation I focused on a single industry. To construct my sample for study 2, I started from a set of all publicly traded pharmaceutical companies in the United States (all companies with primary SIC code 2834) listed in Compustat with filings for fiscal year 2011. This approach gave me a total set of 179 companies that were active at the end of 2011. Since my coding was based on current information collected from active operations in 2012 it was essential that my sample only included currently active firms. Using the primary industry of a company is a common approach in constructing single industry samples (Bettis & Mahajan, 1985; Dess et al., 1990; Keats & Hitt, 1988). The primary industry is generally associated with the largest portion of revenue (Rumelt, 1974) and it reflects the firm’s core business and heritage (Dess et al., 1990; Galbraith & Kazanjian, 1986). It is seen as being most applicable for corporate level analyses (Dess et al., 1990).

To arrive at a valid sample for study 2, I used several approaches to distinguish between pharmaceutical companies that were engaged in broadcast search and those that were not. Specifically, I looked at four different indicators to determine if an organization seemed to be
engaged in broadcast search. These indicators were derived from (a) corporate websites, (b) corporate annual reports, (c) public press articles, and (d) company responses to direct inquiry about the subject matter. Table 13 outlines the four sources which I relied upon in my search.

Table 13: Sources employed to identify broadcast search

<table>
<thead>
<tr>
<th>Measure</th>
<th>Source</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast search</td>
<td>Factiva</td>
<td>Search terms were used to find incidents which were then content coded as to their relevance</td>
</tr>
<tr>
<td>Broadcast search</td>
<td>Company website</td>
<td>Websites were screened via search terms and relevant sections content coded</td>
</tr>
<tr>
<td>Broadcast search</td>
<td>Annual report</td>
<td>Annual reports were screened via search terms and relevant sections content coded</td>
</tr>
<tr>
<td>Broadcast search</td>
<td>Email</td>
<td>Emails were sent to companies to inquire about ‘Open Innovation’ contact person</td>
</tr>
</tbody>
</table>

If companies had established a dedicated website or are otherwise involved in broadcast search it should be noted in press releases and reflected in popular press articles. Since broadcast search relies on publicity, it was highly likely that companies would make sure that new systems be made public through press announcements or advertisements on their corporate websites. Therefore, I was confident that the combination of these approaches offered an adequately reliable estimate on the involvement of individual firms in broadcast search. As a first step I reviewed each company’s website and content analyzed relevant sections to determine if there was any indication of broadcast search. In a second step, if available I reviewed the latest corporate annual report in a similar fashion for any indication of broadcast search. To determine relevant sections for my content analyses of the websites and annual reports, I used search terms which included “open innovation”, “broadcast search”, “crowdsourcing”, “prize competition”, and “innovation challenge”. Upon finding those indicators I reviewed the relevant section on the
website or the relevant section in the report and coded whether or not it qualified as broadcast search.

After the review of corporate websites and annual reports, in a third step, I conducted an in-depth Factiva search to identify companies that are actively involved in broadcast search. I was primarily interested here in broadcast search systems that were initiated by the pharmaceutical companies themselves but I also considered companies to be involved in broadcast search if they were found to employ third party approaches using intermediaries. The use of intermediaries was less likely to be picked up in my analysis since the call initiator is not necessarily made public and may in fact strategically have chosen to remain anonymous. In as much as I was able to identify an organization’s use of third party intermediaries, such approaches were included as a reflection of using broadcast search and the organizations employing intermediaries were coded as employing broadcast search. An indicator variable was constructed taking on the value of 1 for companies that were found to be using broadcast search and 0 for those that did not show signs of broadcast search. For coding purposes I downloaded all articles found through the Factiva search and organized these articles by organization and search term. This allowed for a focused coding by subsequent coders for validity purposes as any additional coders would not have to go through the mechanic task of finding the articles in a separate search on the search terms in Factiva.

In order to validate the set of companies I had determined to be involved in broadcast search, I trained two additional coders to analyze the content of the websites, annual reports, and articles that I had found. One of the coders was a graduate student in my department who was involved in technology research and was familiar with the ideas of open innovation and broadcast search. The other coder was an undergraduate work study student who was
specifically trained to complete the coding task. Unfortunately, the undergraduate student turned out to be unreliable in that he did neither send in any coded material nor responded to an email correspondence after the training session. Therefore, I was left with one additional coder. After the coding was completed by the graduate student coder, I met with him to talk about coding mismatches between his coding and mine. Mismatches then were resolved through discussion.

The fourth and final step in my coding procedure constituted sending out an email to each company in the total set of US pharmaceutical companies asking for the contact information of the person in charge of their ‘open innovation processes’. The necessary contact information was collected from the company websites. The body of this email can be found in Appendix H. A copy of the corresponding IRB approval letter for conducting this inquiry (IRB number 12-731) is attached in Appendix I. In cases where I was unable to collect an email address from the company website, I used the company’s web contact form and copied the text into the ‘comment’ field. The request was sent out around September 6th, 2012 for the first time. The procedure was repeated on or around October 1st, 2012 with the requests sent being indicated as a reminder to those organizations where no personal response had been received. However, the response by companies was less than satisfactory so that, despite repeated attempts, it was not possible to get a large number of valid responses. Only a very limited number of companies actually responded to my inquiry personally. I received a total of about 10 useful responses from both rounds of inquiry. Appendix J offers an overview of typical responses received. Oftentimes, only a standard answer was given or the inquiry was ignored altogether, which was the case for the majority of firms. In many cases, the automatic response indicated that a person would be in contact with me at a later point but no follow-up by the organizations was undertaken. Reasons for this behavior could be that the pharmaceutical industry is a highly secretive industry and the
limited time of potential respondents which have been voiced as potential reasons for non-
response in the pharmaceutical industry (Bruyaka et al., 2012). A response by one of the
corporations contacted supported this notion by stating: “Unfortunately, we do not provide
proprietary information on manufacturing, advertising, market share, competition, pricing,
strategic planning or sales information by operating unit, geographic area or product category.
We also cannot provide the names of our employees” (large US pharmaceutical corporation).

I investigated the potential to purchase a detailed industry specific list of direct contacts
to whom the email could have been addressed. However, uncertainty of receiving better
responses with this approach along with prohibitively high costs for purchasing the list, factored
against this approach. For the emails sent out to companies which did get returned, I reviewed
the responses and coded whether it qualified for ‘open innovation processes’ or only constituted
a generic response to the email. Some of the emails clearly stated that they were not involved in
the described open innovation approach and some stated that the study was not applicable to
them. Such answers were coded as 0. Importantly, the responses I received, although limited,
did not contradict my otherwise established coding so that I felt confident that the classification
within the sample was valid even without the primary validation from the organizations in the
sample.

The combination of these coding approaches resulted in a set of companies that had
active corporate processes for broadcast search. I expected that a small but growing number of
pharmaceutical companies were using broadcast search approaches. Using the coding
procedures outlined above, accordingly, I identified 10 out of 179 companies that explicitly used
such an approach. Examples of findings from the overall coding process leading to one firm
being coded as employing broadcast search (Lilly = 1) and one firm being coded as not employing broadcast search (Celgene = 0) are presented in Table 14.

Table 14: Example comparison of companies

<table>
<thead>
<tr>
<th></th>
<th>Lilly (example of broadcast search engaged)</th>
<th>Celgene (example of no broadcast search)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factiva</td>
<td>In a release, the Company said that the new platform, titled Open Innovation Drug Discovery, is supported by a new website available at openinnovation.Lilly.com. It builds on the success of Lilly's Phenotypic Drug Discovery Initiative (PD2) that was launched in 2009 to facilitate research on molecules around the world that have the potential to ultimately be developed into medicines.</td>
<td>no mentioning of any of the search terms (open innovation, broadcast search, crowdsourcing, or prize competition)</td>
</tr>
<tr>
<td>Website</td>
<td>Separate broadcast search website, but no mention of it on corporate website</td>
<td>[Internal process outlined] Drug Discovery: Celgene Target Identification and Drug Discovery Capabilities Celgene has developed target-identification and drug-discovery technology platforms that enable the Company to proceed rapidly from target identification and validation through lead identification and optimization.</td>
</tr>
<tr>
<td>Annual Report</td>
<td>DISCOVERY: Accessing molecules through open innovation Marta Piñeiro-Núñez, Ph.D., director, open innovation drug discovery, builds relationships with academic scientists. We’re opening the door for accessing promising molecules around the world with an innovative approach to collaborating with scientists in academia and small biotech companies. In 2009, we launched the Lilly Phenotypic Drug Discovery Initiative, known as “PD2,” and we expanded the program in 2011 under the banner of Open Innovation Drug Discovery.</td>
<td>no mentioning of any of the search terms (open innovation, broadcast search, crowdsourcing, or prize competition)</td>
</tr>
<tr>
<td>Email</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

In addition to hand collected information, I used data from three separate databases. First, I used Standard and Poor’s Compustat database (Compustat) accessed through Wharton Research Data Services (https://wrds-web.wharton.upenn.edu/wrds/) to determine a set of publicly traded companies whose core business focus was on the US pharmaceutical industry. Compustat was also used to collect information on R&D spending which was used as a proxy for local search. Furthermore, Compustat was used to collect data on certain control variables. Second, I collected patent data using the datasets and procedures collected by the National Bureau of Economic Research (NBER) Patent Data Project (Hall et al., 2001) in the most recent
version which included patent data up to the year 2006. Third, I employed Thompson Reuter’s SDC Platinum database (SDC) to collect data on alliances and M&As.

The earliest I expected to see a recorded use of broadcast search was the year 2003 when the open innovation concept was first formally introduced (Chesbrough, 2003a). Even though a reflection of the concept might have been used before (Trott & Hartmann, 2009), 2003 constituted the first time it had been employed under the terminology used in my search approach. The data sources employed are depicted in Figure 7.

To construct the dataset for my analyses from these sources, I started from the set of all firms listed in Compustat with primary SIC code 2834 with filings for fiscal year 2011. Relevant parameters that I collected from Compustat were data on the organization’s name (conm), the GVKEY (gvkey), the Cusip number (cusip), the fiscal year (fyear), total assets (at), number of employees (emp), net income (ni), net sales (sale), and R&D expenditures (xrd). Combined with my coding results derived from the coding procedure outlined earlier, this dataset constituted my base dataset which I merged with data from other sources.
After establishing a set of US pharmaceutical companies that were involved in broadcast search at the time of my study, I combined my coded data with secondary data on patents from the NBER Patent Data Project (Hall et al., 2001) and secondary data on alliances and M&As from SDC. Since I had started out from a set of companies collected from Compustat, I used Compustat data as my starting point for my data merging procedures. As the first step in this process, I merged data from the NBER patent data project (Hall et al., 2001) with my dataset. Merging of these two data sources was not as straightforward as it might seem at first. The NBER patent data project website (https://sites.google.com/site/patentdataproject/), however, offered a matching procedure that was developed based on standardized names which allowed
users to match Compustat data with patent data based on the GVKEY provided by Compustat (Hall et al., 2001). The approach used a dynamic match between patent assignee names reflecting the organization that was at any given point in time associated with a specific security, which was the unit of analysis Compustat data was concerned with. The available patent data in the NBER datasets covered the years 1976 to 2006 and included 3,209,376 unique patents according to the data description offered (Hall et al., 2001).

Second, I supplemented my dataset with data on R&D alliances and M&As from Thomson Reuters’ SDC Platinum database. This database was considered to be the “world’s foremost financial transaction database” according to Thomson Reuters’ website (http://thomsonreuters.com/, accessed 09/17/2012) and has been commonly used in previous literature on alliances and M&As. De facto, the alliance data and the M&A data were in two separate databases and needed to be merged with my base database individually. These data were used as the source for the variables reflecting routine search in my model, gauging the development of R&D alliances and takeovers of start-up organizations through M&As. I expected both of these indicators to generally increase over time, due in turn to an increased pressure to quickly innovate. As for in-licensing, another common external knowledge sourcing mechanism, I did not empirically evaluate the effects of licensing since there are particular confounding issues with licensing, such as the use of licensing to cover and integrate previous knowledge which may not constitute an innovation, and cross-licensing as a means to accommodate existing patent protection. A meaningful distinction of the various reasons for using in-licensing would have been beyond the scope of the current work and as such licensing was not considered in the analyses. After having matched my initial dataset based on Compustat with the patent data provided by NBER, the matching of the resultant dataset with data provided
by SDC was more straightforward. Both datasets included the CUSIP number (Standard and Poor’s security identifier) for the organization as a unique identifier. Since the Compustat to NBER data match had already accounted for changes of ownership, CUSIP numbers could be matched directly after they were converted into a common 6-digit format.

4.2.5.3 Study 2—Corporate Communications: Measures and Analyses

The merging procedure outlined in the previous section resulted in a panel dataset consisting of combined data from Compustat, NBER, and SDC databases. In addition, the ultimate outcome variable (broadcast search adoption) which was a reflection of search in organizationally vulnerable areas, was included in the dataset for the year 2012. The panel data were used in study 2, which was employed to predict change in search behavior over time and estimated the likelihood of broadcast search adoption by the end of the time covered in the data based on past behavior. The overall panel covered the years 1950 to 2011 whereby certain variables were restricted by data available in the individual databases so that the most complete and valid panel data was available for the timeframe 1990 to 2005.

4.2.5.3.1 Dependent Variable

The dependent variable for my full model, broadcast search adoption, was a binary variable indicating the adoption of a broadcast search strategy. Broadcast search was a reflection of the concept of non-routine distant search (or search in organizationally vulnerable areas) in my model. Companies that had started using broadcast search, either through their own broadcast search system or through intermediaries, were assigned a value of 1; those organizations for which there was no indication of the adoption of such a strategy were assigned a value of 0. In order to determine whether or not a company had adopted broadcast search processes, I employed the mechanisms outlined earlier.
4.2.5.3.2 Independent Variables

To operationalize my independent construct, *innovation pressure*, I used two separate reflections of this notion. One was the idea that innovation pressure could stem from the depletion of resources and the other one was that innovation pressure could stem from an increase in competition. Each of these two notions of innovation pressure was operationalized in a couple different ways. The independent variables employed to reflect innovation pressure were based on patent data collected from the NBER patent database (Hall et al., 2001).

The first measure was a reflection of *resource depletion*, measuring the fraction of patents an organization held that was due to expire within the next subsequent five years from the focal year. I calculated the number of patents expiring within the next five years out of the total patent base of an organization. *Resource Depletion* was reflected by the need to replace patents that are soon running out. To construct this independent variable I collected patent data for all of the companies in my dataset and determined the percent of patents that would be losing protection approximately within the next five years from the focal year. I expected this pressure to increase over time and to be generally high in recent years.

The second measure served as a proxy for a firm’s innovation pressure stemming from *direct competition*. To construct this measure I utilized the patent classification codes in order to determine a firm’s core knowledge base. In a second step, the year over year change in number of new patents in a firm’s core area was determined to evaluate whether rival pressures were increasing or decreasing. *Direct Competition* was reflected by the patenting strengths of competitors which were holding patents that were in direct competition with the focal organization. Using *nclass* as the classification for patent groupings and direct competition, I eliminated any data with classification nclass = 1 (‘** Classification Undetermined’).
4.2.5.3.3 Variables to measure routine search

There are three distinct search modes that I measured as reflections of the use of routine search. One of which was measuring a local routine search mode, \textit{R&D intensity}, and two of which were measuring distant routine search modes, \textit{alliances} and \textit{M&As}. R&D intensity was captured by a firm’s R&D spending based on data collected from Compustat. The number of alliances and M&As in which a company engaged was collected from the SDC database. The data were collected on a yearly basis. For the number of alliances I calculated the number of current alliances, defined as alliances formed in the last 4 years and included both the current alliances and total alliance experience in the regression model. Analogue to this approach, for M&As I calculated the number of recent M&As defined as those conducted in the last 4 years prior to the focal year and included the total number of M&As conducted as a measure of M&A experience in the regression model. An overview of the measures is offered in Table 15. Their construction is outlined in a flow chart in Figure 8.
Table 15: Constructs, measures, variables, and regression model

<table>
<thead>
<tr>
<th>Construct</th>
<th>Measured by</th>
<th>Variable(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>innovation pressure - resource depletion</td>
<td><strong>Total</strong> number of patents expiring in the next 5 years.</td>
<td>Patents expiring</td>
</tr>
<tr>
<td></td>
<td><strong>Relative</strong> number of patents expiring in the next 5 years.</td>
<td>Patents expiring &amp; patents held</td>
</tr>
<tr>
<td>innovation pressure - direct competition</td>
<td><strong>Number of patents</strong> by other firms in the same nclass in the last 5 years as the primary nclass of the focal firm.</td>
<td>Number of patents by other firms in primary nclass</td>
</tr>
<tr>
<td>Internal R&amp;D</td>
<td><strong>Total</strong> spending on R&amp;D.</td>
<td>US dollar amount spent on R&amp;D in the current year.</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td><strong>Relative</strong> spending on R&amp;D based on sales.</td>
<td>R&amp;D spending (xrd) &amp; total sales (sale).</td>
</tr>
<tr>
<td>External collaborations</td>
<td><strong>Number of alliances</strong> formed in the last 4 years.</td>
<td>Cumulative number of alliances formed in the past 3 years.</td>
</tr>
<tr>
<td>Knowledge acquisition through takeovers</td>
<td><strong>Number of M&amp;As</strong> engaged in over the last 4 years.</td>
<td>Cumulative number of M&amp;As executed in the past 5 years.</td>
</tr>
<tr>
<td>Adoption of broadcast search</td>
<td><strong>Indicator</strong> whether or not firm had adopted broadcast search by 2012</td>
<td>Indicator on broadcast search adoption by 2012</td>
</tr>
</tbody>
</table>
Figure 8: Flow chart of variable constructions and coding

Study II: Corporate communications about broadcast search

Collect set of firms active in SIC 2834 in 2011

Collect press articles from Factiva

Content analyze press articles

Does it reflect broadcast search?

Yes

code as "1" = engaged in broadcast search

No

code as "0" = not engaged in broadcast search

Collect infromation on firms' patents

Collect infromation on firms' alliances and M&As

Collect set of firms active in SIC 2834 in 2011

Collect public communications from organizations

Content analyze corporate websites

Does it reflect broadcast search?

Yes

code as "1" = engaged in broadcast search

No

code as "0" = not engaged in broadcast search

Content analyze corporate annual reports

Does it reflect broadcast search?

Yes

code as "1" = engaged in broadcast search

No

code as "0" = not engaged in broadcast search

Collect email addresses from corporate websites

Send email to corporations

Collect and review email responses

Does it reflect broadcast search?

Yes

code as "1" = engaged in broadcast search

No

code as "0" = not engaged in broadcast search

Collect infromation on firms' patents

Collect infromation on firms' alliances and M&As

Merge all collected information in one dataset

Combine coding counting as "engaged in broadcast search" if any indication was found (any coding = "1")
My overall study design was based on a pre-post design with the year 2003 as the dividing year. I started out with a detailed examination of the position in which organizations in the pharmaceutical industry were in leading up to the year 2002. Rather than just examining a single year, I looked at time series data covering a 13 year time span. This allowed me to better understand the corporations’ positions and allowed for considerations of path dependencies (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010).

In the analysis I took a pre-post approach around the year 2003, the year the open innovation concept, from which the broadcast search approach as a recognized alternative originates, had first become widely discussed based on Chesbrough’s (2003a) popular treatment of the topic. The overall design of the study is depicted in Figure 9. The idea of open innovation had spread rapidly shortly thereafter (Dahlander & Gann, 2010). In my analyses the year 2003 was therefore considered a watershed in the use of open innovation approaches. While there have certainly been open approaches prior to Chesbrough’s (2003a) articulation of it, the particular broadcast search approach did not seem to have a meaningful presence in the pharmaceutical industry prior to 2003. On the flipside, it was not possible to determine exactly when, after 2003, the approach was adopted by individual organizations. It was only possible to determine with some degree of certainty which companies had adopted this approach by 2012. As such, I restricted my data to determine organizational characteristics of the pre broadcast search era to the years 1990-2002. This restriction had two major advantages. First, I covered a time-span of 13 years prior to the watershed event which was roughly equivalent to the time elapsed since the inflection point (2003 to current year are 10 years). These time estimates were also similar to the time the R&D process takes for developing a new drug (DiMasi et al., 2003; Pisano, 2006). Second, the time between 1990 and 2002 was a time for which the data at hand
was most reliable (Schilling, 2009b). While the data collected from NBER extended to the year 2006, there were truncation effects for the later years due to delays between the application of a patent and the subsequent granting of the patent. Since patents were only recorded after they have been granted, and there can be a substantial delay between application and grant date (Hall et al., 2001), the NBER patent data showed an artificial drop in applications in the later years. By restricting my observations to exclude the last four years of NBER patent data (Hall et al., 2001), this truncation was minimized and the data should overall have been more reliable.

Figure 9: Overall pre-post design of study 2

As for the statistical methodologies applied, I relied on two primary approaches. For the panel data, I used panel data regression. All analyses were conducted using Stata 11.1 for Windows. As such, the commands used for the panel data regression analyses were all taken
from the “xt” family within Stata. Although Stata offers xtprobit regression capability, I purposely designed my study to be able to use a simple probit regression analysis. The interpretability of results of a standard probit regression is in itself limited so that a complication in regards to the data by using panel data probit regression would not have increased the usefulness of the study. The trade-off was of course that the chosen design had lower power over a full panel data design. However, the available data did not allow me to construct a full panel across all years since I did not have a time-variant measure for broadcast search involvement. Hypotheses groups 1 and 2 could have been tested on a larger panel since data was available for more years. However, the integrity of the overall research design would have been undermined if a more exclusive panel would have been employed to test the hypotheses 1 and 2 since the independent variables would not have reflected the organizations’ pure “pre” position in regards to the publicity of the open innovation concept. Possible lessons stimulated by the explication of the open innovation mindset could have confounded the independent variables if the study would not have been strictly confined to the time constraints of a pre-post model.

4.2.5.4 Study 2—Corporate Communications: Limitations

The time at which the study was conducted should be considered relatively early in the life cycle of the broadcast search approach in the area of investigation. Changing a search strategy in a knowledge intensive industry such as the pharmaceutical industry is a major strategic decision and not one that is easily reversed. Therefore, it may take some time until a large number of organizations adopt a new approach. As my data reflected, only a small number of pharmaceutical corporations had adopted a broadcast search approach. In addition, development times for pharmaceutical research are long (DiMasi et al., 2003; Pisano, 2006) and thus, returns stemming from strategic changes are quite remote in terms of time. It may take up
to a decade or more to see results from strategic changes and therefore the current investigation may not show the expected results even if they are under way. As the development of a new drug generally takes over 10 years (DiMasi et al., 2003; Pisano, 2006), organizational effects from strategic change will also take time. It may thus be a few more years before we can estimate the benefits or negative effects of choosing a more open approach to research in the pharmaceutical industry. The high uncertainty of the research process in itself as well as the general uncertainty within the industry did however allow for experimentation of individual players in the industry.
5.0 ANALYSIS

I present findings and discuss main implications from my studies. After describing the findings individually, I discuss overall implications and interpretations from my analyses.

5.1. Results from Pre-study A: Web-searches and Factiva Screening

The results for pre-study A have immediately been addressed in Chapter 4 of this dissertation since they were crucial to all subsequent investigations. Therefore, the discussion of results commences with pre-study B.

5.2 Results from Pre-study B: Intermediaries Reflecting the Phenomenon—InnoCentive

5.2.1 Pre-study B—InnoCentive Challenges: Results / Findings:

Building on the initial theoretical focus on the innovation process as an integral part of this dissertation, pre-study B analyzed problem-level data collected from www.innocentive.com. I employed this data to test for the existence of innovation pressure within the industry. The underlying hypothesis in this test was that I expected to see high levels of usage of the broadcast search to solve pharma-related challenges. As such, it reflected a combined view of propositions 1 and 2, in that innovation pressure eventually leads to non-routine distant search if it would not get resolved.

Contrasting the number of challenges that were potentially relevant for pharmaceuticals (e.g., drug development, chemical components) to requests for solutions related to other areas (e.g., equipment engineering), I found that more than half (110/203 or 54%) of the challenges were potentially pharmaceutical related. This was an impressive number considering the variety of fields using this approach, ranging from engineering over physics and math to business and
entrepreneurship. It should be noted that InnoCentive was a spin-off of a pharmaceutical company, Eli Lilly, yet from its presentation in the media, InnoCentive at this point seemed by no means in their approach limited or focused on the pharmaceutical industry.

To evaluate the potential to generalize based on the findings from studying the pharmaceutical industry, I tested the uniqueness of pharma-related challenges with regards to a few key parameters (Lakhani et al., 2007). In my analysis I looked at the difference of average number of solvers per challenge between challenges that were pharma-related and those that were not. The sample showed a statistically significant difference ($p < 0.001$) between the number of solvers signed up for pharma-related challenges and those challenges that were not pharma-related. This was potentially a result of the highly specialized knowledge necessary for solving pharma-related challenges and served as support for the idea that challenges in the pharmaceutical industry rely on professionals rather than hobbyists as do many crowdsourcing approaches in other fields (Jeppesen & Frederiksen, 2006; Poetz & Schreier, 2012). The data did not suggest that there were any meaningful differences between the groups in terms of the number of days a challenge was open for solvers to respond or the amount of award money offered as incentive for participation. This aligned with similar findings of earlier research on data collected from InnoCentive (Lakhani et al., 2007). In an analysis of data collected between 2001 and 2005, Lakhani and colleagues (2007) reported no significant correlation between the award value and the solvability of a problem. Table 16 gives an overview of the results from my analysis. It also offers descriptive statistics of the different types of challenges used by InnoCentive.
One might expect that the number of potential solvers could be affected by the number of days a challenge was open or by the value of the award. Since there was no significant difference between pharma-related and other challenges, I used the full set of challenges to test for these effects. I also tested the two groups separately since the number of solvers varied across the two groups. Employing a simple regression analysis [ordinary least squares (OLS) analysis] using Stata, I did not find support for these expectations. The results of this analysis are summarized in Table 17.

Table 16: InnoCentive Challenges—Pharma-related versus non-pharma

<table>
<thead>
<tr>
<th></th>
<th>Group 1: Pharma-related (1)</th>
<th>Group 2: Non-pharma (0)</th>
<th>Total</th>
<th>Comparison of differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean (SD)</td>
<td>n</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Total challenges</td>
<td>110</td>
<td>93 (226.78)</td>
<td>93</td>
<td>516.44 (392.45)</td>
</tr>
<tr>
<td>Number of solvers</td>
<td>110</td>
<td>195.85 (226.78)</td>
<td>93</td>
<td>516.44 (392.45)</td>
</tr>
<tr>
<td>Number of days challenge was open</td>
<td>59</td>
<td>55.05 (70.16)</td>
<td>46</td>
<td>54.91 (18.87)</td>
</tr>
<tr>
<td>Amount of award (USD)</td>
<td>49</td>
<td>28938.78 (25105.74)</td>
<td>79</td>
<td>22544.3 (18261.31)</td>
</tr>
<tr>
<td>Type of challenge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideation</td>
<td>14</td>
<td>54.2%</td>
<td>32</td>
<td>45.8%</td>
</tr>
<tr>
<td>Theoretical (IP Transfer)</td>
<td>12</td>
<td>22%</td>
<td>34</td>
<td>16.7%</td>
</tr>
<tr>
<td>Theoretical (License)</td>
<td>7</td>
<td>17%</td>
<td>24</td>
<td>11.8%</td>
</tr>
<tr>
<td>Reduction-to-Practice (RTP)</td>
<td>75</td>
<td>15%</td>
<td>90</td>
<td>44.3%</td>
</tr>
<tr>
<td>Computational</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td>Novel Molecule Challenge (NMC)</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td>Electronic Request for Proposal (eRFP)</td>
<td>2</td>
<td>7%</td>
<td>9</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

Pearson chi2(4) = 55.8975  p < 0.001
Fisher's exact: p < 0.001

I calculated t-scores to establish the significance of the differences between two independent groups' average values. Significance is calculated using a two-tailed test. I use 'unequal' specification in Stata since I assume that my unpaired data do not have equal variances. Numbers in brackets reflect standard deviations. I conducted a χ² test to evaluate whether the groups differ in terms of the challenges employed. I also conducted a Fisher's exact test to confirm the results of the χ² test since some of group values were n < 5.
### Table 17: Innovation Challenges—Effects on Number of Solvers

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days</td>
<td>0.602</td>
<td>-0.275</td>
<td>3.264</td>
<td>-0.0883</td>
<td>4.114</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.03)</td>
<td>(-0.43)</td>
<td>(1.04)</td>
<td>(-0.14)</td>
<td>(1.18)</td>
<td></td>
</tr>
<tr>
<td>award</td>
<td>0.000114</td>
<td>0.00292</td>
<td>0.000531</td>
<td>0.00248</td>
<td>-0.00134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.92)</td>
<td>(0.14)</td>
<td>(0.64)</td>
<td>(-0.27)</td>
<td></td>
</tr>
<tr>
<td>pharmarelated</td>
<td>54.61</td>
<td>-160.9</td>
<td>9.141</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(-0.93)</td>
<td>(0.04)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day * pharmarelated</td>
<td>-3.527</td>
<td>-4.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.09)</td>
<td>(-1.23)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>award * pharmarelated</td>
<td>0.000652</td>
<td>0.00435</td>
<td>-0.09</td>
<td>-0.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>268.3***</td>
<td>467.2***</td>
<td>419.8***</td>
<td>324.1*</td>
<td>472.1***</td>
<td>316.4</td>
</tr>
<tr>
<td></td>
<td>(6.00)</td>
<td>(10.94)</td>
<td>(4.76)</td>
<td>(2.02)</td>
<td>(4.66)</td>
<td>(1.95)</td>
</tr>
<tr>
<td>N</td>
<td>105</td>
<td>128</td>
<td>59</td>
<td>59</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>t statistics in parentheses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* p&lt;0.05, ** p&lt;0.01, *** p&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.2.2 Pre-study B—InnoCentive Challenges: Interpretations / Implications:

The findings from study one suggest that neither the number of days a challenge is open nor the award value meaningfully affect the interest in a challenge. These findings generally align with earlier analyses of InnoCentive data regarding the solvability of problems (Lakhani et al., 2007). Another potential explanation fitting the observed pattern was that the self-selection was mostly driven by the knowledge base of the solver, rather than the monetary incentive or availability window. Since InnoCentive sent emails to potential solvers whenever a new challenge was posted which was similar to a solver’s interests as determined by challenges this solver had previously been engaged in, the vast majority of interested solvers might sign up...
quickly after the challenge is first posted. This would explain the lack of significant difference with regard to the effects of the timeframe a challenge was open on the number of solvers interested in a challenge. As per the lack of significant findings regarding the importance of the award value, this might suggest that solvers were motivated by more than merely the monetary award. These non-monetary factors were also stressed by InnoCentive itself as there were various non-pecuniary incentives for participating in challenges listed on the InnoCentive website, such as “make a positive impact”, “exercise your brain”, and “promote yourself” in addition to “earn awards” (https://www.innocentive.com/ accessed 10/11/2012).

5.3 Results from Pre-study C: Survey of Specialists as Informants

The purpose of pre-study C was to obtain direct input by organizations interested in open innovation and to test for the discrepancies between theory and practice apparent in the interchangeable use of the term *open innovation* for broadcast search mechanisms often witnessed in firms’ communications. To achieve this direct contact, pre-study C was comprised of an online survey which was sent out to invited key personnel from organizations related to the pharmaceutical industry (primarily pharmaceutical companies). The survey was constructed by myself and distributed by the organizer of a conference on open innovation in pharmaceutical R&D, Fleming Europe.

5.3.1 Pre-study C—Survey of Informants: Results / Findings:

Overall, 39 people have viewed the survey of which about 10 respondents went through the full survey with about 5 respondents answering close to all questions. Results of the survey are shown in Appendix K and Appendix L. Some of the early questions were answered by up to 14 participants. The high drop-out rate might indicate that the survey was a bit lengthy for the high caliber respondents taking part in the conference. However, the answers collected offer
some direct insights into organizations’ involvement in broadcast search activities and as such the survey was very valuable to this research. Specifically, out of the up to 14 participants that offered answers to at least some of the questions, 12 provided a company name and 11 provided personal names (both of which are kept confidential). Interestingly, the survey participants were equally divided as taking part or not taking part in the conference. The participants were generally in specialized or senior management functions as was evident by job titles such as Medical Director, Country Manager, Manager Open Innovation, Market Access Manager / Director, Business Developer, Director [...] Core Facility, Executive Chairman, Head of Business Development, President, Senior V.P. & Global Head – Medical Affairs, Head Innovation & External Collaboration Chemical R&D, or Senior Manager – Tenders, Pricing and Reimbursement Strategy. About 2/3 (8 out of 13 or 61.5%) of the companies who responded were publicly held companies with a wide spread of institutional structures, most of them in multinational corporations. Factors that I had outlined as being important were reflected in the type of respondents who answered the survey. The vast majority of participants came from the pharmaceutical industry with only a few from other industries (there seemed to be some hospitals in the sample) but no participants indicated that their companies were biotechnology firms. This aligned with and gave credence to my chosen sample for this dissertation and study 2 in particular which was restrained to the core pharmaceutical industry. The size of the companies which participated was also quite diverse, ranging from 10-49 employees at the low end to corporations with more than 25000 employees. The majority of participants came from large organizations with generally more than 5000 employees (10 out of 14 or 71.4%) and only 3 small and medium-sized enterprises (SMEs) with less than 500 (in fact less than 250) employees. This again supported the adequacy of my chosen sample focusing on large, complex
organizations. Also, most respondents (9 out of 12 or 75%) viewed “open innovation” as a broader concept than just “broadcast search”. This indicated that there was an understanding in practice that was closer aligned to the understanding in the theoretical literature which in general was not always reflected in the written communication about open innovation distributed by companies. It also showed how important it was to clarify the meaning of open innovation or in this case broadcast search through a clear definition. In regard to the importance of the definition I would like to note that one respondent directly criticized the interchangeable use of the terms open innovation and broadcast search: “Again, I do not believe in this definition of "broadcast search" - 'Open Innovation' means a lot more than this kind of narrow understanding.” (anonymous survey respondent, 2012 - large European publicly held corporation). I agree with this statement in regards to the differences between the terms and hope that the current dissertation helps to show how important a clear definition is in this regard. I strive to offer clarification regarding the terminology by outlining and explicating how broadcast search falls into the area of open innovation. Overall, the survey suggested that broadcast search was used in companies to a very small extent, often as a supplement to more mainstream types of innovation. This was supported by small numbers of innovations and new products stemming from broadcast search activities, the small or non-existent budgets for broadcast search as well as commentary feedback received from the organizations. For example, participants commented that they “use broadcast searches in order to complement [their] existing portfolio of problem solving practices” (large European publicly traded organization) or “use broadcast search in a semi-internal format in order to allow both external researchers we communicate with and our [...] equivalent to a Medical Advisory Board, to understand what areas we prioritize in our search for new project candidates” (medium-sized European privately
Others noted that they “currently do not use broadcast search” (large European privately held organization) or that they “do not believe to benefit from this "broadcast search" with [their] existing business model (B2B, supplier) [and that within Chemical R&D [they] rather prefer 1-1 solutions with dedicated problem solvers with which [they] have made good experiences” (large European publicly held organization). As per my general notion that the use of broadcast search affects the use of co-operations with established firms or the number of M&As, or the number of R&D projects in general, the survey did not offer support in this regard. Respondents unanimously agreed that there was no change on these parameters coinciding with their use of broadcast search. Additional results from the survey can be found in Appendix K for general questions and Appendix L covering questions employing a 7-point Likert scale for ratings. As an incentive to participate in the survey, respondents were promised access to this dissertation upon its completion.

5.3.2 Pre-study C—Survey of Informants: Interpretations / Implications:

The qualitative analysis of survey responses in pre-study C indicated that the pharmaceutical industry was well suited as a study setting. There seemed to be genuine interest in the topic by specialized and senior management of organizations reflecting the type of organization portrayed in my theoretical development. The results of pre-study C also lent support to the hypothesis that broadcast search was considered exploratory search. As expected, it was not employed by everybody, even when drawing from a sample of organizations that have indicated an interest in the open innovation concept. It also became evident that broadcast search in many instances was currently primarily used only as a side option to complement other approaches. However, pre-study C also showed that broadcast search was indeed seen as a viable option alongside other search alternatives. Organizations seemed to seriously consider
broadcast search as a research approach. Latter comments by participants on the applicability of the concept to their business model supported the notion that broadcast search (and thus certain types of open innovation) would not be equally beneficial to all organizations, reverberated most pointedly in the statement by one manager that they “do not believe to benefit from this "broadcast search" with [their] existing business model (B2B, supplier) [and that w]ithin Chemical R&D [they] rather prefer 1-1 solutions with dedicated problem solvers with which [they] have made good experiences” (large European publicly held organization). This was strong support for the concerns I raised in the discussion on the open innovation concept in regards to its sometimes broadly applied recommendations, such as the general implication that “firms can and should use external and internal ideas” Chesbrough (2003a, p. xxiv italics added, 2006). Premature generalizations in regards to its applicability and usefulness to all firms should be avoided.

5.4 Results from Study 1: Strategic Knowledge Groups in the Pharmaceutical Industry

Before moving into my econometric investigation of the pharmaceutical industry in regards to the firms’ search behaviors, I conducted an investigation of a possible pre-condition to the theory—a study of one relevant boundary condition, namely a firm’s strategic knowledge position within the industry. In doing so, I built on prior work on strategic knowledge groups in the pharmaceutical industry (Bierly & Chakrabarti, 1996a) and extended this work both in regards to the timeframe and the sample under investigation. A detailed understanding of the pre environment of the industry would allow for a closer inspection of the post environment by focusing on factors which had shown to define the clusters of interest. As such, study 1 was positioned as a pre-cursor to study 2 but also served as a stand-alone investigation of within-industry groupings. As for the latter, the study’s premise was to test if there were specific groups
which seemed more likely to engage in broadcast search. Included herein was the consideration of an alternative explanation to the idea that search in organizationally vulnerable areas would necessarily have to be based on pressure. An alternative explanation to the theory based on organizational pressures outlined throughout this dissertation, would be the idea of entrepreneurial vision (Kuratko, Ireland, & Hornsby, 2001; Shirley, 1989). Through entrepreneurial vision and foresight, organizations take entrepreneurial actions, defined as “any newly fashioned behaviors through which companies exploit opportunities others have not noticed or aggressively pursued” (Kuratko et al., 2001, p. 60). If indeed, firms used an entrepreneurial strategy to act (Kuratko et al., 2001; Shirley, 1989), rather than being driven by external and internal pressures to react, this would suggest a pro-active approach to search behavior in regards to corporate R&D. Such a visionary perspective would suggest that firms that have been more aggressive in pursuing new paths in the past would also be more aggressive in employing broadcast search. Keeping in mind that the behavioral theory of the firm as outlined by Cyert and March (1963) and the theory outlined in this dissertation are concerned with complex organizations, there are potentially differences along the complexity of organizations which are reflective on firm behavior. The expectation for study 1 was therefore that there were distinct groups within the industry which differed based on their categorization in strategic knowledge groups and that certain groups would be more likely to engage in broadcast search regardless of innovation pressure. Differences among strategic knowledge groups could then inform further research in regards to the distinguishing factors.

5.4.1 Study 1—Strategic Knowledge Groups: Results / Findings:

The replication and extension of Bierly and Chakrabarti’s (1996a) cluster analyses were helpful to gain a detailed understanding of the industry structure prior to the incubation of
broadcast search as a potential knowledge sourcing alternative for pharmaceutical R&D. The study’s extension showed that not all firms in the industry were equally likely to engage in broadcast search but rather, that differences existed alongside the knowledge strategy parameters identified by Bierly and Chakrabarti (1996a) on which organizations were grouped. Table 18 shows the grouping results of the non-hierarchical re-analyses and time extension of Bierly and Chakrabarti’s (1996a) original set of firms. To capture the constructs of interest put forth in the original study (Bierly & Chakrabarti, 1996a), the data sources and measures used were those that were outlined in Chapter 4.

Furthermore, Table 18 reflects the position of each firm in regards to the original knowledge group. As can be seen, there was quite some discrepancy between the grouping in my replication and the original study (Bierly & Chakrabarti, 1996a). This stemmed from three sources: one, being the use of substitute measures for the constructs; two, being the use of different methodologies (Ward’s method versus k-means method); and three, being omission of individual firms as also noted in Table 18. Examining Table 21, we can see that the use of hierarchical versus non-hierarchical methods can have quite an effect on the groupings. In addition, it has been noted that groupings in cluster analyses are sensitive to the omission of individual elements (Jardine & Sibson, 1971; Ketchen & Shook, 1996) which in turn was supported in a comparison of the clusters generated in Table 19 and Table 20.
Table 18: Knowledge group memberships

<table>
<thead>
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<th>Period: 1977-81</th>
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<th>KG B</th>
<th>Original KG</th>
<th>KG C</th>
<th>Original KG</th>
<th>KG D</th>
<th>Original KG</th>
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</tr>
</thead>
</table>
| Johnson & Johnson | 1    |             | Abbott | 1           | AH Robins | 1           | ICN | 2           | American Home Prod.
| Rorer           | 1    |             | American Cyanamid | 1   | Carter Wallace | 3         |         | Home Prod.      |
| Schering-Plough | 1    |             | Bristol Myers | 2   | Forest        | 3           |         | Marion         |
|                |      |             | Lilly    | 4           | Sterling | 1           |      | Upjohn        |
|                |      |             | Pfizer   | 1           |         |             |      |               |
|                |      |             | SmithKline Beckman | 4 |         |             |      |               |
|                |      |             | Squibb   | 2           |         |             |      |               |
|                |      |             | Syntax   | 3           |         |             |      |               |

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<th>KG B</th>
<th>Original KG</th>
<th>KG C</th>
<th>Original KG</th>
<th>KG D</th>
<th>Original KG</th>
<th>not placed</th>
</tr>
</thead>
</table>
| Squibb          | 2    |             | Abbott | 1           | Lilly | 4           | Forest | 3           | American Home Prod.
|                 |      |             | American Cyanamid | 2   | Merck       | 1           | ICN | 3           | Home Prod.      |
|                 |      |             | Bristol Myers | 2   | Pfizer      | 1           |         | Marion         |
|                 |      |             | Carter Wallace | 3 | Schering-Plough | 2           |         | Upjohn        |
|                 |      |             | Johnson & Johnson | 2 | SmithKline Beckman | 2           |         |               |
|                 |      |             | Rorer    | 2           | Syntax  | 1           |       |               |
|                 |      |             | Sterling  | 2           |         |             |       |               |
|                 |      |             | Warner Lambert | 2 |         |             |       |               |

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<th>KG C</th>
<th>Original KG</th>
<th>KG B</th>
<th>Original KG</th>
<th>KG D</th>
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<td>1</td>
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<td>Lilly</td>
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<td>Carter Wallace</td>
<td>3</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Johnson &amp; Johnson</td>
<td>2</td>
<td>Forest</td>
<td>3</td>
<td>Syntax</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pfizer</td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Warner Lambert</td>
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<tbody>
<tr>
<td>American Cyanamid</td>
<td></td>
<td></td>
<td>Abbott</td>
<td></td>
<td>Warner Lambert</td>
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<td>Schering-Plough</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Carter Wallace</td>
<td></td>
<td>Forest</td>
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<td>Lilly</td>
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<tr>
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<td>Johnson &amp; Johnson</td>
<td></td>
<td>American Home Prod.</td>
<td></td>
<td>Pfizer</td>
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<th>KG B</th>
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</thead>
<tbody>
<tr>
<td>Carter Wallace</td>
<td></td>
<td></td>
<td>Merck</td>
<td></td>
<td>Lilly</td>
<td></td>
<td>Pfizer</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td>American Home Prod.</td>
<td></td>
<td>Schering-Plough</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Johnson &amp; Johnson</td>
<td></td>
<td></td>
<td></td>
<td>Warner Lambert</td>
<td></td>
</tr>
</tbody>
</table>

Select groupings of firms that seem to form a core group over time are marked in color.
Firms that are found to group have the same color. Lighter color is used for periods in which firms join or leave a core group.
The comparison of the original study (Bierly & Chakrabarti, 1996a) with the results of a non-hierarchical analysis using 4 groups as determined by Bierly and Chakrabarti (1996a) and shown in Table 18, offered some interesting results. In a general sense it exemplified that a replication is not always easily achieved, even if the set of firms and the sources of information are known. More specifically, when comparing the groupings, it became obvious that there was not a complete overlap of groups. I intentionally labeled the knowledge groups in the replication KG A through KG D in order not to confuse that the knowledge group numbers are actually referring to the same labeling (i.e., ‘Explorers’, etc.). The groups in the replication differed and as such I refrained from labeling them. What was noticeable, though, was that just like in the original study, some firms were changing groups from period to period while other firms remained in one group over time. It should be noted, though, that the periods were considered to be independent and as such one group label for one period might not be the same group label for another period. Comparing the outcomes of the replication to the original, it could be noticed that within the groups there were certain firms that could be found together over time. Just to illustrate, American Cyanamid and Abbott were together in one group for periods 1 through 4 (American Cyanamid is not present in period 5), although they change groups twice. At the same time, they diverge into different groups (KG 1 and KG2, respectively) in Bierly and Chakrabarti’s (1996a) original classification. To aid the reader, a graphical comparison of the group memberships of individual companies in the separate periods can be found in Table 18. This visualization depicts two important aspects one can extract from the replication. One, the groups created by Bierly and Chakrabarti (1996a) through hierarchical cluster analyses were not identical to the groups formed in the replication study using non-hierarchical cluster analyses using the number of groups found by Bierly and Chakrabarti (1996a). Two, despite not finding
the exact same groups, one could observe sets of firms which seemed to exhibit consistently similar patterns along the chosen parameters. In the replication, these patterns could be observed as consisting beyond the time of the original study, although the integrity of the groups was significantly challenged by the low number of firms from the original set still present in periods 4 and 5. For those firms that remained together in groupings over time, in terms of their knowledge strategies, these companies seemed to be similar. Capturing these similarities in the form of defined strategic knowledge groups did however seem to be more challenging than suggested by Bierly and Chakrabarti (1996a). The comparison between the studies showed that while companies seemed to be more or less similar to each other, the exact placement in groups differed. This could potentially stem from the omission of just a few of the organizations due to unavailability of data. Cluster analysis is reliant on the number of companies in the sample and the distribution among groups is sensitive to omissions of individual firms (Jardine & Sibson, 1971; Ketchen & Shook, 1996). This was important in two regards. First, the divergence between the clusters found in my replication and the clusters found in Bierly and Chakrabarti’s (1996a) study may have been due to the omission of individual firms for which I had missing data. Second, the number of companies in my last period of observation, period V, was very low with only 9 organizations left from the original starting point of 21 organizations. These 9 observations were forced to be distributed in 4 categories. Even if one assumes for a moment that Bierly and Chakrabarti’s (1996a) findings were correct, and there were 4 distinct knowledge strategies which are stable over time, it was well possible that certain strategies are de facto not represented in this set of 9 firms and as such the distribution into four groups would paint a distorted picture.
To overcome the issues stemming from the lack of observations for periods 4 and 5 in the original set of firms, I conducted further analyses using a sample comprised of all publicly traded US pharmaceutical organizations in existence in 2011 for which relevant data were available for the years of interest. By starting from a set of companies in existence in 2011 as opposed to starting from 1977 as the base year, I ensured that there would be more organizations available for later periods of investigation and that the companies in the sample would be relevant to the overall dissertation structure. After all, I was interested in strategic knowledge groups to the extent it was impacting knowledge sourcing behavior. Using a consistent set of companies was in line with the approach taken by Bierly and Chakrabarti’s (1996a) except that in my case the ‘survival’ was backwards, leaving me with fewer companies for earlier years. Looking at my groupings formed based on the set of companies used by Bierly and Chakrabarti (1996a), depicted in Table 19, and contrasting those groupings with the ones formed based on the analyses using the SIC code 2834 sample shown in Table 20, offered some striking results. The markings in Table 20 revealed that with the broader industry perspective, the differences between firms in the Bierly and Chakrabarti (1996a) sample seemed to be less pronounced. All of the firms for which data were available to trace in both samples, would eventually be found in one common group. Bierly and Chakrabarti (1996a) selected their set of companies on the premises that these were pharmaceutical organizations which “(a) primarily produce brand ethical drugs (no generic drug producers were included), (b) are U.S. publicly owned companies, and (c) have pharmaceutical sales account for a substantial portion of company sales” (Bierly & Chakrabarti, 1996a, p. 126). To account for restriction (a), I conducted a sensitivity test with a sample restricted to organizations with a minimum of 5 patents granted throughout their lifetime and a minimum R&D expenditure of 1 percent of total assets in 2011. Restrictions (b) and (c)
were implied to be met by default using Compustat data and SIC code 2834. Notably, this group (KG C in the non-hierarchical cluster analyses for period 5 using the SIC code 2834 set of firms) was also the one which included firms that eventually engaged in broadcast search. As such, a closer look at this group was warranted.

The individual group averages for the parameters used in the various analyses are provided in Table 21. As can be seen in terms of the characteristics of the firms in group KG C of my last cluster analysis, there were distinguishing factors separating this group from the other three groups in the k-means cluster analysis of the SIC code 2834 sample in period 5. Specifically, the group of interest was considerable lower in regards to R&D intensity (RDS) but was highest on return on sales (ROS) and return on assets (ROA). For period 5, only this group was profitable on average based on ROA, indicating that the industry as a whole was struggling at this point in time. An advantage of these factors being relevant was that the replication along them was most precise in terms of replicating the measures among all of the constructs replicated. Another distinguishing factor was the breadth of the firms’ knowledge bases captured in the knowledge dispersion index (DISP), which was considerably higher for this group compared to all others. Based on those characteristics I specified this group of organizations as the “successfully dispersed” firms.

My theory, in line with the assumptions of the behavioral theory of the firm (Cyert & March, 1963), was constructed to apply to complex organizations. The considerably higher dispersion index found for the organizations to which my theory seemed to apply, supported my theoretical view in terms of higher complexity being reflected in a broader knowledge base. Importantly, this finding was not the result of a predetermined restriction on size. At the same time, the higher average profitability level of firms within this group indicated that slack
(Bourgeois, 1981; Cyert & March, 1963; Daniel, Lohrke, Fornaciari, & Turner Jr., 2004) could potentially play a role in driving the search behavior. On the surface, these findings lent support to the alternative explanation of entrepreneurial vision (Kuratko et al., 2001; Shirley, 1989) briefly outlined above. Notably, though, not all firms within the group of successfully dispersed ones engaged in broadcast search and as such the question remains as to whether there exists a relationship between organizational pressure, particularly within a subgroup of more complex organizations, and the adjustment of search behavior. Being dispersed and successful, therefore, seemed to be a necessary but not sufficient condition for broadcast search engagement. As such, it would be in line with path dependency arguments put forth earlier (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010), which would not just suggest a continued use of routine practices (Nelson & Winter, 1982; Stene, 1940), but also experimentation with new approaches, potentially enabled by slack resources (Bourgeois, 1981; Cyert & March, 1963; Daniel et al., 2004) stemming from higher profitability. The aspect of group membership will be further investigated in a post-hoc analysis to study 2.

Since most relevant firms seemed to fall into one group, I tested whether a separation into two groups would again place all or most relevant organizations in one group and other organizations in a second group. I focused my attention on period 5 as this was the period of interest for further investigations. The grouping results are presented in Table 22. In a first step, I conducted a two-group non-hierarchical k-means clustering procedures using all seven parameters. This placed all organizations which had comprised KG C for period 5 using k-means clustering within the same group with a few additional groups. In a second step, I investigated in the same fashion whether the use of only the Compustat based measures—ROS, ROA, and RDS—would suffice to achieve similar groupings. The results are presented in the
middle section in Table 22 which shows that the classification along these parameters was unsuccessful. In a third step, I included the Compustat based measures and the dispersion index DISP. As can be seen from Table 22, this approach clearly separated the core group of former KG C into one group and placed the rest of the organizations in the other groups with only a few former KG C group members now included in the second group. The extensive change between groupings stemming from the inclusion of DISP led me to test DISP individually, under omission of the Compustat based measures. Table 22 shows that the grouping results remained the same whether or not Compustat based measures were included. Therefore, DISP could be determined as a driver of the groupings. Focusing on DISP for establishing groupings seemed to be the most parsimonious approach and as such DISP was used as the group defining factor for the post hoc analysis. Aside from the empirical finding that DISP was the defining grouping factor, DISP could also be seen as a theoretically founded logical choice as it reflected a broad knowledge base which might be necessary in order to be able to generate value from external ideas and to incorporate external ideas into internal processes. In this regard, Bierly and Chakrabarti (1996a) argued for a better ability to combine knowledge (Henderson & Cockburn, 1994; Kogut & Zander, 1992) which is essential to valuing external knowledge as a critical component for innovation. In the post hoc analysis to study 2, I therefore hypothesized group membership as a necessary but not sufficient condition to engage in broadcast search.
Table 19: Replications using Bierly and Chakrabarti’s original set of firms

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>KG A</td>
<td>KG B</td>
<td>KG C</td>
</tr>
<tr>
<td>CARTER-WALLACE INC</td>
<td>ABBOTT LABORATORIES</td>
<td>LILLY (EU) &amp; CO</td>
</tr>
<tr>
<td>FOREST LABORATORIES - CL A</td>
<td>AMERICAN CYANAMID CO</td>
<td>MERCK &amp; CO</td>
</tr>
<tr>
<td>ION PHARMACEUTICALS - OLD</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>SCHERING-PLOUGH</td>
</tr>
<tr>
<td>ROBINS (A.H.) CO</td>
<td>PFIZER INC</td>
<td>SMITHKLINE-BECKMAN-CORP</td>
</tr>
<tr>
<td>WARNER-LAMBERT CO</td>
<td>STERLING DRUG INC</td>
<td>SYNTAX CORP</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Period II: 1982-86</th>
<th>KG A</th>
<th>KG B</th>
<th>KG C</th>
<th>KG D</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABBOTT LABORATORIES</td>
<td>FOREST LABORATORIES - CL A</td>
<td>LILLY (EU) &amp; CO</td>
<td>ICN PHARMACEUTICALS - OLD</td>
<td>MARION MERRELL DOW INC</td>
</tr>
<tr>
<td>AMERICAN CYANAMID CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>PFIZER INC</td>
<td>SCHERING-PLOUGH</td>
<td>WARNER-LAMBERT CO</td>
</tr>
<tr>
<td>BRISTOL-MYERS-SQUIBB CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>RHONE-POULENC RORER</td>
<td>SYNTAX CORP</td>
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<tr>
<td>JOHNSON &amp; JOHNSON</td>
<td>PHARMACEUTICALS - OLD</td>
<td>WARNER-LAMBERT CO</td>
<td>SYNTAX CORP</td>
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</tr>
<tr>
<td>RHONE-POULENC RORER</td>
<td>WARNER-LAMBERT CO</td>
<td>SYNTAX CORP</td>
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</table>

<table>
<thead>
<tr>
<th>Period III: 1987-91</th>
<th>KG A</th>
<th>KG B</th>
<th>KG C</th>
<th>KG D</th>
</tr>
</thead>
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<tr>
<td>FOREST LABORATORIES - CL A</td>
<td>CARTER-WALLACE INC</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>PFIZER INC</td>
<td>WYETH</td>
</tr>
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<td>JOHNSON &amp; JOHNSON</td>
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<td>PHARMACEUTICALS - OLD</td>
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<td>WARNER-LAMBERT CO</td>
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<td>JOHNSON &amp; JOHNSON</td>
<td>PHARMACEUTICALS - OLD</td>
<td>WARNER-LAMBERT CO</td>
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<th>KG C</th>
<th>KG D</th>
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<td>AMERICAN CYANAMID CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>WYETH</td>
<td>SYNTAX CORP</td>
</tr>
<tr>
<td>AMERICAN CYANAMID CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>SCHERING-PLOUGH</td>
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<tr>
<td>AMERICAN CYANAMID CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>WYETH</td>
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</table>

NOTE: For ease of comparison, I use Compustat labels to refer to the organizations.
Table 20: Extensions using SIC code 2834 set of firms from Compustat

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<tr>
<th>Period I: 1977-81</th>
<th>Hierarchical extension SIC 2834 set of firms (words)</th>
<th>Non-hierarchical (k-means) extension SIC 2834 set of firms</th>
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<td>KG B</td>
<td>KG C</td>
</tr>
<tr>
<td>BAYER CORP</td>
<td>ABBOTT LABORATORIES</td>
<td></td>
</tr>
<tr>
<td>MERCK &amp; CO</td>
<td>BRISTOL-MyERS SQUARE CO</td>
<td></td>
</tr>
<tr>
<td>LILLY (EU) &amp; CO</td>
<td>JOHNSON &amp; JOHNSON</td>
<td></td>
</tr>
<tr>
<td>PFEIZER INC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Period II: 1982-86

| KG A              | KG B                                                 | KG C | KG D |
| MYLAN INC         | ELAN CORP PLC                                        |       |      |
| BAYER CORP        | ABBOTT LABORATORIES                                  |       |      |
| MEDICIS PHARMACEUTICALS - CL A | JOHNSON & JOHNSON                                      |       |      |
| PFEIZER INC       |                                                     |       |      |

Period III: 1987-91

| KG A              | KG B                                                 | KG C | KG D |
| EXEL CORP         | BAYER CORP                                           |       |      |
| GRAXOSMITHLTHE PLC | ABBOTT LABORATORIES                                  |       |      |
| NOVO NORDISK A/S  | JOHNSON & JOHNSON                                    |       |      |
| TEVA PHARMACEUTICALS | THERAGENICS CORP                                     |       |      |
| UNITED-GUARDIAN INC |                                                      |       |      |

Period IV: 1992-96

| KG A              | KG B                                                 | KG C | KG D |
| ABBOTT LABORATORIES | ACCESS PHARMACEUTICALS INC                           |       |      |
| BAYER CORP        | BRISTOL-MyERS SQUARE CO                              |       |      |
| MERCK & CO        | AMYN PHARMACEUTICALS INC                             |       |      |
| LILLY (EU) & CO   | COLUMBIA LABORATORIES INC                            |       |      |
| PFEIZER INC       | DUSA PHARMACEUTICALS INC                             |       |      |
| ROCH Holdings AG  | ENSPHIRE TECHNOLOGIES INC                            |       |      |
| NATURES SUNSHINE PHROX INC |                                                     |       |      |
| LEAGACORP - CL A |                                                       |       |      |
| COLUMBIA LABORATORIES INC |                                                      |       |      |
| MYLAN INC         | PFEIZER INC                                          |       |      |

Period V: 1997-2001

| KG A              | KG B                                                 | KG C | KG D |
| ABBOTT LABORATORIES | ACCESS PHARMACEUTICALS INC                           |       |      |
| BAYER CORP        | BRISTOL-MyERS SQUARE CO                              |       |      |
| MERCK & CO        | AVANIR PHARMACEUTICALS INC                           |       |      |
| NOVARTIS AG       | COLUMBIA LABORATORIES INC                            |       |      |
| TEVA PHARMACEUTICALS | VITEX PHARMACEUTICALS INC                           |       |      |

NOTE: I use Compustat labels to refer to the organizations. Marked firms are found in Bierly and Chakrabarti's sample.
Table 21: Means of replications and extensions of Bierly and Chakrabarti’s cluster analyses using different samples

<table>
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<tr>
<td></td>
<td>RDS SCL DISP TCT RAD ROS ROA N</td>
<td>RDS SCL DISP TCT RAD ROS ROA N</td>
<td>RDS SCL DISP TCT RAD ROS ROA N</td>
<td>RDS SCL DISP TCT RAD ROS ROA N</td>
<td>RDS SCL DISP TCT RAD ROS ROA N</td>
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Period I: 1982-86

<table>
<thead>
<tr>
<th>KG 1 / KG A</th>
<th>KG 2 / KG B</th>
<th>KG 3 / KG C</th>
<th>KG 3 / KG C</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.84 0.45 6.67 0.18 0.09 0.09 9</td>
<td>0.71 0.95 8.88 0.28 0.04 0.04 4</td>
<td>0.84 8.87 7.39 0.33 0.11 0.12 3</td>
<td>0.10 0.00 12.74 0.74 0.05 0.09 1</td>
<td>0.08 0.66 8.00 6.40 0.26 0.15 0.14 2</td>
</tr>
<tr>
<td>0.75 0.89 7.92 0.76 0.00 0.08 4</td>
<td>0.68 7.76 6.13 0.29 0.11 0.11 9</td>
<td>0.07 6.87 5.77 0.31 0.13 0.12 2</td>
<td>0.01 1.00 0.00 12.74 0.74 0.05 0.09 1</td>
<td></td>
</tr>
<tr>
<td>0.56 0.12 13.28 0.08 0.06 0.06 3</td>
<td>0.71 6.56 6.29 0.29 0.15 0.14 5</td>
<td>0.05 7.71 3.66 0.26 0.06 0.07 5</td>
<td>0.16 6.73 3.66 0.26 0.10 0.11 1</td>
<td>0.05 8.01 8.35 0.03 0.08 0.12 1</td>
</tr>
</tbody>
</table>

Period II: 1977-81

<table>
<thead>
<tr>
<th>KG 1 / KG A</th>
<th>KG 2 / KG B</th>
<th>KG 3 / KG C</th>
<th>KG 3 / KG C</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 0.72 6.70 0.19 0.09 0.10 21</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 0.72 6.70 0.19 0.09 0.10 21</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
</tr>
</tbody>
</table>

Period III: 1987-91

<table>
<thead>
<tr>
<th>KG 1 / KG A</th>
<th>KG 2 / KG B</th>
<th>KG 3 / KG C</th>
<th>KG 3 / KG C</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
</tr>
</tbody>
</table>

Period IV: 1992-96

<table>
<thead>
<tr>
<th>KG 1 / KG A</th>
<th>KG 2 / KG B</th>
<th>KG 3 / KG C</th>
<th>KG 3 / KG C</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
</tr>
</tbody>
</table>

Period V: 1997-2001

<table>
<thead>
<tr>
<th>KG 1 / KG A</th>
<th>KG 2 / KG B</th>
<th>KG 3 / KG C</th>
<th>KG 3 / KG C</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
<td>0.85 0.72 6.70 0.19 0.09 0.10 18</td>
<td>0.85 7.20 7.17 0.20 0.09 0.10 18</td>
</tr>
</tbody>
</table>

Table adapted from Bierly & Chakrabarti (1996, p. 129, Table 1 & Table 5).
Note: Groups in replications/extensions are in no particular order.
SIC = SIC LINK
5.4.2 Study 1—Strategic Knowledge Groups: Interpretations / Implications:

My current replication and extension of Bierly and Chakrabarti (1996a) has several implications. First, based on the lack of fully coherent overlap between the original study on strategic knowledge strategies of pharmaceutical companies conducted by Bierly and Chakrabarti (1996a) and my replication with a ten year extension, it was not possible to determine exact groupings that would be fully stable over time. Furthermore, the use of a separate, yet related sample indicated that groups were equally unstable across samples. In particular, the groupings determined by Bierly and Chakrabarti (1996a) eventually submerged in a single group when employing a larger sample. This indicated the existence of a nested structure in terms of similarities and differences within the industry. At the same time, the contrasting of various approaches indicated that there were organizations which tend to cluster and remain more closely aligned over time and across samples, even if an exact determination of groupings was difficult to achieve. Most notably, a clearly distinguishable group emerged, which I labeled “successfully dispersed”. This group was exclusive in that it included all organizations which were part of both samples, the original sample used by Bierly and Chakrabarti (1996a) and the sample based on SIC code 2834 which I had created. It should be noted, though, that due to missing data and reverse survival effects the sample size was lower in study 1 than in study 2.

Second, the variables employed by Bierly and Chakrabarti (1996a) reflected important constructs to consider in terms of strategic foci of R&D based organizations. While these variables could not all be incorporated in the current dissertation, the cluster analyses pointed to the most relevant of these factors in terms of distinguishing the group of successfully dispersed
companies. These factors were RDS, ROS/ROA, and DISP, as noted earlier. Further investigation revealed that the driving factor for determining groups was DISP.

Throughout the analyses, it became apparent that the sensitivity of cluster analyses to the total number of elements and inclusion or omission of individual elements (Jardine & Sibson, 1971; Ketchen & Shook, 1996) was an important factor. The increasing drop in numbers towards the end of the replication study based on the original set of companies chosen by Bierly and Chakrabarti (1996a) along with the omission of a few of the original firms, seemed to be a factor in the shifts between the original and the replication. Therefore, groupings based on a higher number of elements should offer more confidence in the findings. The extension to a separate, yet related, sample was able to overcome some of these issues and offer insights regarding the position of industry in the pre broadcast search era of the industry.

A major finding of the replication attempt in study 1 was that the use of previously constructed taxonomies needs to be employed with caution. It became obvious that in the current case the blind acceptance of taxonomies even for related samples would have been misleading. As such, study 1, although seemingly extensive, was very important to ensure the integrity of study 2 by not employing a taxonomy whose underlying differentiation vanished in the scope of a broader industry sample.
Table 22: K-means clustering in 2 groups using different sets of parameters

<table>
<thead>
<tr>
<th>Period V: 1997-2001</th>
<th>KG X</th>
<th>KG Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABBOTT LABORATORIES</td>
<td>ACCESS PHARMACEUTICALS INC</td>
<td>COLUMBIA LABORATORIES INC</td>
</tr>
<tr>
<td>BOSTON SCIENTIFIC CORP</td>
<td>AVANIR PHARMACEUTICALS INC</td>
<td>CURIS INC</td>
</tr>
<tr>
<td>COLUMBIA LABORATORIES INC</td>
<td>DUSA PHARMACEUTICALS INC</td>
<td>ELAN PHARMACEUTICALS INC</td>
</tr>
<tr>
<td>GIANT PHARMACEUTICALS INC</td>
<td>EMPIRE PHARMACEUTICALS INC</td>
<td>EMPIRE PHARMACEUTICALS INC</td>
</tr>
<tr>
<td>LILLY ELI &amp; CO</td>
<td>PHARMON INC</td>
<td>PHARYNX INC</td>
</tr>
<tr>
<td>MERCK &amp; CO</td>
<td>MYLAN INC</td>
<td>VIVUS INC</td>
</tr>
<tr>
<td>NOVARTIS AG</td>
<td>ONO PHARMACEUTICALS INC</td>
<td>TITAN PHARMACEUTICALS INC</td>
</tr>
<tr>
<td>PFEIZER INC</td>
<td>PHARMON INC</td>
<td>TITAN PHARMACEUTICALS INC</td>
</tr>
<tr>
<td>SCHLECHTEN PHARMACEUTICALS INC</td>
<td>SCHLECHTEN PHARMACEUTICALS INC</td>
<td>SCHLECHTEN PHARMACEUTICALS INC</td>
</tr>
<tr>
<td>TEVA PHARMACEUTICALS</td>
<td>TEVA PHARMACEUTICALS</td>
<td>TEVA PHARMACEUTICALS</td>
</tr>
</tbody>
</table>

Non-hierarchical (k-means) extension SIC 2834 set of firms distributed in 2 groups

Grouping based on ALL parameters

Grouping based on Compustat based measures

Grouping based on Compustat based measures and DISP

Grouping based on DISP (by itself)
5.5 Results from Study 2: Corporate Communications and Broadcast Search

In my second main study, I employed an econometric approach analyzing secondary data collected from a variety of public and private sources. Study 2 was positioned to test all hypotheses outlined in my theoretical development. Therefore, in the following, I will present empirical findings retaining to each hypothesis individually.

5.5.1 Study 2—Corporate Communications: Results / Findings:

The sample data used for my analyses in study 2 were comprised of data from various secondary sources. The ultimate dependent variable, broadcast search adoption, was constructed through the coding scheme detailed in chapter 4. Before going into the findings of the analyses a closer look at the characteristics of the data is warranted and I will briefly address restrictions to the data that I have employed to ensure that the final sample functioned as an adequate reflection of the types of organization addressed and outlined in the theoretical model. In a first step I will address the unrestricted data. Table 23 outlines some characteristics of this data for key variables. Table 24 gives an overview of the labels used for the individual constructs and the constructions of the measures.

Table 23: Descriptive statistics of unrestricted data – sample variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Observations</th>
<th>Firms</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>year</td>
<td>1950</td>
<td>2011</td>
<td>N = 11098</td>
<td>n = 179</td>
<td>T = 62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>broadcast_search2012</td>
<td>0.06</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
<td>N = 11098</td>
<td>n = 179</td>
<td>T = 62</td>
</tr>
<tr>
<td>patcount</td>
<td>3.38</td>
<td>23.80</td>
<td>0</td>
<td>431</td>
<td>N = 10203</td>
<td>n = 179</td>
<td>T = 57</td>
</tr>
<tr>
<td>allicount</td>
<td>0.22</td>
<td>1.10</td>
<td>0</td>
<td>17</td>
<td>N = 6265</td>
<td>n = 179</td>
<td>T = 35</td>
</tr>
<tr>
<td>ma_count</td>
<td>0.15</td>
<td>0.74</td>
<td>0</td>
<td>14</td>
<td>N = 6086</td>
<td>n = 179</td>
<td>T = 34</td>
</tr>
<tr>
<td>xrd</td>
<td>345.94</td>
<td>1224.83</td>
<td>0.000</td>
<td>12183.000</td>
<td>N = 2673</td>
<td>n = 174</td>
<td>T-bar = 15.3621</td>
</tr>
<tr>
<td>emp</td>
<td>8.88</td>
<td>21.40</td>
<td>0.000</td>
<td>123.686</td>
<td>N = 2603</td>
<td>n = 177</td>
<td>T-bar = 14.7062</td>
</tr>
</tbody>
</table>
### Table 24: Explanation of the labels used to reflect the individual constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>Label</th>
<th>How constructed</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-routine distant search</td>
<td>broadcast_search2012</td>
<td>Binary coding (0/1)</td>
<td>Public corporate information and popular press</td>
</tr>
<tr>
<td>Patenting experience</td>
<td>patcount</td>
<td>total number of patents per firm year</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Experience with alliances</td>
<td>allicount</td>
<td>count of total alliances per firm year</td>
<td>SDC alliance database</td>
</tr>
<tr>
<td>Experience with M&amp;As</td>
<td>ma_count</td>
<td>count of total M&amp;As per firm year</td>
<td>SDC M&amp;A database</td>
</tr>
<tr>
<td>Local search / Internal R&amp;D</td>
<td>xrd</td>
<td>R&amp;D expenditures (xrd) taken from database</td>
<td>Compustat database</td>
</tr>
<tr>
<td>Organizational size</td>
<td>emp</td>
<td>Number of employees (emp) taken from database</td>
<td>Compustat database</td>
</tr>
<tr>
<td>Acquisition activity</td>
<td>acq</td>
<td>Cash outflow for acquisitions per year (acq)</td>
<td>Compustat database</td>
</tr>
<tr>
<td>Firm’s technological focus</td>
<td>avg_firm_5yr_pats_prime_nc</td>
<td>Average number of patents by focal firm in primary nclass in the last 5 years</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Overall competitiveness of a technology space</td>
<td>avg_tot_5yr_pats_prime_nc</td>
<td>Average number of total patents in primary nclass in the last 5 years</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Innovation pressure - direct competition</td>
<td>avg_Syr_competitor_pats_prime_nc</td>
<td>Average number of patents by other firms in primary nclass in the last 5 years</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Innovation pressure - resource depletion</td>
<td>patsexpire_5yr</td>
<td>Number of patents expiring in the next 5 years (appyear &gt;= t-19 &amp; &lt;= t-15)</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Intellectual property stock</td>
<td>pats_active</td>
<td>count of patents per firm with appyear &gt;= t-19 &amp; &lt;= t = pats_expire / pats_active</td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Innovation pressure - resource depletion</td>
<td>pctexpire_5yr</td>
<td></td>
<td>NBER patent database</td>
</tr>
<tr>
<td>Current distant search activity - alliances</td>
<td>allicurrent</td>
<td>Number of alliances a firm engaged in during the last 4 years</td>
<td>SDC alliance database</td>
</tr>
<tr>
<td>Total distant search activity - alliances</td>
<td>allitotal</td>
<td>Total number of alliances a firm engaged in = allicurrent / allitotal</td>
<td>SDC alliance database</td>
</tr>
<tr>
<td>Relative recency of distant search activity - alliances</td>
<td>pctallicurrent</td>
<td></td>
<td>SDC alliance database</td>
</tr>
<tr>
<td>Current distant search activity - M&amp;As</td>
<td>ma_recent</td>
<td>Number of M&amp;As a firm engaged in over the last 4 years</td>
<td>SDC M&amp;A database</td>
</tr>
<tr>
<td>Total distant search activity - M&amp;As</td>
<td>ma_total</td>
<td>Total number of M&amp;As a firm engaged in = ma_recent / ma_total</td>
<td>SDC M&amp;A database</td>
</tr>
<tr>
<td>Relative recency of distant search activity - M&amp;As</td>
<td>pctma_current</td>
<td></td>
<td>SDC M&amp;A database</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>RDS</td>
<td>Analogue Bierly &amp; Chakrabarti: ratio of xrd /sales</td>
<td>Compustat database</td>
</tr>
</tbody>
</table>
Overall, I constructed a panel dataset starting from the 179 pharmaceutical firms active in 2011 listed in Compustat under primary SIC code 2834 for the years 1950 to 2011. This panel provided and N of 11,098 observations based on 62 years of data for each of the 179 firms. It was, however, necessary to substantially constrain this dataset to ensure that (a) only years would be considered for which adequate, valid observations were available and that (b) firms within the panel would reflect the type of organization to which the theory applied.

Accordingly, I first restricted the panel data (a) to include only the years 1990 to 2002. The reason to restrict my analysis timeframe to these years was based both on theory and on the data which were available through the NBER and SDC databases. In a review of various alliance databases, Schilling (2009b) concluded that the SDC alliance data was most reliable from 1990 onwards. My surface review of the data supported this observation as it seemed as if prior to 1990 the number of alliances drops sharply. For the M&A data collected from SDC, the data past 1990 also seemed to be adequate, although Schilling’s (2009b) review only applied to the alliance data. In order to keep the individual analyses comparable, I decided to restrict all data to 1990 and later. The upper bound of my sample timeframe—2002—is based on theoretical arguments more so than on data validity restrictions. Schilling (2009b) looks at the timeframe 1990-2005 so that this time span in regards to validity is best verified. The more current data in the SDC database seems to be generally more complete so that this would not necessitate a restriction on the upper bound. Notably, though, there is a restriction stemming from the NBER patent database. The current version of the NBER data ends in 2006. Therefore, no patents are included that have been granted after 2006. Since I used the application year as my year of reference, there was a time lag in which applicants had submitted an application but if the patent had not been granted yet, the application year would not be included in the data. This
data limitation was however superseded by my study design which constrained the need for a panel dataset to the years prior to 2003. Thus, I omitted the last four years of NBER data, automatically avoiding a truncation stemming from this lag. As a precaution, when using a single year, I used the year 2001 as my base year for the probit regression models to ensure that the data was clearly pre 2003 data.

The second restriction I undertook was in regards to the characteristics of the organization. I restricted the data (b) to account for the theoretical focus on incumbent, innovation oriented firms. I purposely did not restrict on size, although there is potentially a correlation between my restrictions and the average size of a firm. This, however, reflected the idea that incumbent firms would generally be larger than start-up firms. As such a restriction on size would not have been unreasonable. My restrictions were focused on the innovation behavior of firm. Specifically, I simultaneously restricted on the level of R&D spending and the number of a firm’s patents. I excluded all firms with an R&D budget for 2011 which was less than 1 percent of the organizations total assets\(^\text{14}\). I also excluded all firms with no or very limited patenting experience, measured as having a total of less than 5 patents in their portfolio. I consider these estimates to be conservative restrictions which nonetheless ensured that the organizations at least indicated a desire and ability to compete based on innovation. While this approach decreased the power and degrees of freedom in my sample, it more closely aligned the data with the conceptual ideas underlying my hypotheses. Descriptive statistics of the restricted data are summarized in Table 25. Zero order correlations between the variables are presented in Table 26 for the year 2001. The year 2001 was used as the base year on which the probit

\(^{14}\)Although Bierly and Chakrabarti (1996a) use R&D expenditures over sales as the ratio of R&D intensity, I base my value here on assets in order not disadvantage firms that have not yet had research success which is reflected in sales but which are nonetheless research focused.
regressions were conducted for statistical tests referring to hypotheses which made predictions on the engagement in broadcast search as the dichotomous outcome variable.

Table 25: Variables included in restricted panel with descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Observations</th>
<th>Firms</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>year</td>
<td></td>
<td></td>
<td>1990</td>
<td>2002</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>ID_hz</td>
<td>95.67</td>
<td>50.91</td>
<td>1</td>
<td>178</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>broadcast_search2012</td>
<td>0.12</td>
<td>0.33</td>
<td>0</td>
<td>1</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>patcount</td>
<td>26.36</td>
<td>67.73</td>
<td>0</td>
<td>431</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>allcount</td>
<td>0.90</td>
<td>2.27</td>
<td>0</td>
<td>17</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>ma_count</td>
<td>0.36</td>
<td>1.06</td>
<td>0</td>
<td>8</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
<td>xrd</td>
<td>366.42</td>
<td>836.61</td>
<td>0</td>
<td>5176</td>
<td>N = 663</td>
<td>n = 66</td>
<td>T-bar = 10.0455</td>
</tr>
<tr>
<td>emp</td>
<td>11.68</td>
<td>24.15</td>
<td>0.004</td>
<td>116.178</td>
<td>N = 620</td>
<td>n = 62</td>
<td>T-bar = 10</td>
</tr>
<tr>
<td>aqc</td>
<td>111.86</td>
<td>761.36</td>
<td>-19.611</td>
<td>10767.87</td>
<td>N = 614</td>
<td>n = 66</td>
<td>T-bar = 9.30303</td>
</tr>
<tr>
<td>at</td>
<td>3937.90</td>
<td>9220.10</td>
<td>0.084</td>
<td>47561.2</td>
<td>N = 663</td>
<td>n = 66</td>
<td>T-bar = 10.0455</td>
</tr>
<tr>
<td>ni</td>
<td>483.32</td>
<td>1301.76</td>
<td>-3615.1</td>
<td>9126</td>
<td>N = 663</td>
<td>n = 66</td>
<td>T-bar = 10.0455</td>
</tr>
<tr>
<td>sale</td>
<td>2967.57</td>
<td>7053.87</td>
<td>0</td>
<td>51790.3</td>
<td>N = 663</td>
<td>n = 66</td>
<td>T-bar = 10.0455</td>
</tr>
<tr>
<td>act</td>
<td>1878.87</td>
<td>4477.70</td>
<td>0.072</td>
<td>27107.35</td>
<td>N = 660</td>
<td>n = 65</td>
<td>T-bar = 10.1538</td>
</tr>
<tr>
<td>lct</td>
<td>1135.61</td>
<td>2688.57</td>
<td>0.084</td>
<td>18555</td>
<td>N = 660</td>
<td>n = 65</td>
<td>T-bar = 10.1538</td>
</tr>
<tr>
<td>avg_firm_5yr_pats_prime_nc</td>
<td>70.47</td>
<td>163.78</td>
<td>1</td>
<td>1182.2</td>
<td>N = 787</td>
<td>n = 66</td>
<td>T-bar = 11.9242</td>
</tr>
<tr>
<td>avg_tot_5yr_pats_prime_nc</td>
<td>2403.80</td>
<td>1110.75</td>
<td>84.2</td>
<td>4903</td>
<td>N = 787</td>
<td>n = 66</td>
<td>T-bar = 11.9242</td>
</tr>
<tr>
<td>avg_5yr_competitor_pats_prime_nc</td>
<td>2333.33</td>
<td>1087.97</td>
<td>82.39999</td>
<td>4901</td>
<td>N = 787</td>
<td>n = 66</td>
<td>T-bar = 11.9242</td>
</tr>
<tr>
<td>patsexpire_5yr</td>
<td>41.37</td>
<td>146.54</td>
<td>0</td>
<td>1019</td>
<td>N = 858</td>
<td>n = 66</td>
<td>T = 13</td>
</tr>
<tr>
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Correlations are statistically significant (p < .05, two-tailed) for df=60 at .25
In the following I describe how I went through my analyses for each hypothesis. For all analyses I report the estimates using a 1-year, 5-year, and 8-year lag. There is little doubt that there is a delay between the R&D input and the expected outcome (DiMasi et al., 2003; Pisano, 2006). The exact time span for an adequate lag, however, is more ambiguous so that I decided to offer 3 separate lag estimates. The correct delay in ongoing R&D is likely to be somewhere within this range. Overall, the use of a lag seemed warranted since I used time-variant panel data for most of my analyses and the long development time inherent in pharmaceutical R&D (DiMasi et al., 2003; Pisano, 2006) suggested a substantial time lag between the input of R&D efforts and outputs, whether measured in the form of IP rights or financial results.

The importance of path dependencies (Arthur, 1989; David, 1985; Gruber, 2010; Vergne & Durand, 2010) is usually not well covered in regression analyses. I thus led off with rich general descriptions of the industry prior to 2003 which was accompanied by regression analyses on panel data (xt-regression) for the years 1990 to 2002. After establishing the situation of the industry and examining potential differences between organizations which later engaged in broadcast search and those which refrained from it, I conducted a formal probit regression analysis between the year 2001 and the outcome achieved by the year 2012 in the form of broadcast search engagement. Restrictions on the organizations meeting the requirements to be considered incumbent, research oriented firms, reduced my sample to 66 firms of which 8 showed indications to be engaged in broadcast search at some point between 2003 and 2012.

Before presenting the results from the statistical analyses, a brief visualization of the positions of organizations which later engaged in broadcast search versus organizations which up to 2012 had refrained from engaging in broadcast search, was conducted to offer an overview of the data. The following graphs present differences between the two groups of organizations
which decided to engage or not engage in broadcast search. The graphs are constructed based on the restricted set of 66 organizations with a minimum R&D spending of 1% of total assets and a patent base of at least 5 patents.

Figure 10: Comparison of average R&D expenditures

Figure 10 shows the different average amounts of R&D expenditures per year for firms that by 2012 had engaged in broadcast search (1) and those that had not engaged in it (0). The average R&D expenditures are substantially higher for those firms that engaged in broadcast search versus those that did not. This was likely a reflection of a generally larger size of firms that engaged in broadcast search within the sample. Figure 11 supports this conjecture. Nonetheless, both graphs in Figure 10 indicate a rise in R&D expenditures over time with a
reversal of direction towards the end for firms not engaged in broadcast search (0) and an expedited increase for firms later engaged in broadcast search (1).

**Figure 11: Comparison of average firm size**
Keeping in mind that the average firm size differs, Figure 12 depicts the average number of alliances over time in which firms had been engaged in during the last 4 years relative to the focal year. The number of alliances was higher on average for firms that eventually engaged in broadcast search. The starting point for both graphs was relatively close which could however stem from truncation effects due to data limitations. It had been suggested that the SDC alliance data is incomplete and therefore not valid prior to 1990 (Schilling, 2009b) so that the first few years may be constructed from partially incomplete data. I therefore ignore the initial upward trend in the number of alliances. Notably, though, for both types of firms the average number of alliances engaged in seemed to decrease towards the end of the timeframe under consideration.
Contrary to the potential drop in the use of alliances, the graphs on recently conducted M&As, displayed in Figure 13, did not suggest a drop in the number of M&As conducted. However, it did seem to be leveling off for organizations not later engaged in broadcast search and the curve for organizations who later engage in broadcast search seemed to be growing slightly at a very moderate, almost flat, growth rate. The strong growth in the first part of the 1990s shown in the graphs was again potentially a reflection of data truncation effects and as such was ignored.
Figure 14: Comparison of competition pressure

Figure 14 depicts the competition pressure as reflected by the number of patents applied for in the same technology category as the category in which the focal firm applied for the most patents in a given year. As can be seen from the graph it seems as if the pressure was slightly higher for firms which later engaged in broadcast search, although the levels seem to converge towards the end. Due to the way the competition was measure here (number of total patents in the nclass(es) a focal firm primarily patented – number of patents in that nclass by the focal company), the graph could also be seen as an indication that firms which did not later engage in broadcast search were moving into more mainstream technology areas. Since firms that did not later engage in broadcast search were on average smaller, as shown in Figure 11, this could be an artifact of smaller firms moving into more mainstream research areas. This in itself constitutes an interesting research question potentially to be addressed elsewhere.
The pressure stemming from resource depletion as reflected in the expiration of patents, is shown in Figure 15. As can be seen, there were higher numbers of patents expiring for firms which later engaged in broadcast search than those which did not. However, much of this could be again attributable to the size effects reflected in Figure 11. Again, the sharp increase in the beginning of the curves could be an artifact of the data, considering that the NBER data (Hall et al., 2001) looks at patents between the years 1976 and 2006 based on the year the patent was granted. I employed a time frame of $t$ to $t-19$ to construct the patent base at any given year so that 1990 would refer back up to the year 1971. The truncation is however minimized by using the application year which is often prior to the grant year. In the NBER data (Hall et al., 2001), individual application years go back up to 1901. A small truncation effect is however to be expected for the first 3-4 years of the graphs.
Figure 11 had shown that there were differences in average size between organizations which in the time between 2003 and 2012 conducted broadcast search those which did not. These differences have been inherent in the previous graphs. Due to these large differences in average size between the groups, I decided to further investigate the relationships graphically. To do so, it was best to look at percentages in regards to organizations’ actual pressures and search behavior in the pre-period. The following graphs offer comparisons based on size adjusted ratios between organizations subsequently engaged in broadcast search and organizations refraining from such search.

**Figure 16: Comparison of percent patents expiring**

As can be seen from Figure 16, differences in terms of patent expirations do not seem to be restricted to total numbers. The average resource depletion pressure measured as a percentage of patents expiring short term seems to be higher for those companies which subsequently
engaged in broadcast search. Notably, however, the trend was declining towards the end of the covered time span, yet not the same relative level of patents expiring had been reached by the engagers as that for those of non-engagers. Combining this with the notion that the engagers were much larger on average, this translated into very high amounts in terms of lost sales on the horizon.

**Figure 17: Comparison of percent of current alliances**

The graphs in Figure 17 paint a rather interesting picture in regards to the relative number of alliances an organization had been engaged in recently. Aside from the truncation effect in the early 1990s, in relative terms, organizations which were later engaged in broadcast search seemed to have slightly fewer alliances that are recent.
The relative number of M&As being recent as compared to all M&As conducted by an organization seemed to be roughly at the same level for firms later engaging in broadcast search and those which did not engage in broadcast search according to Figure 18. However, the volatility of this measure seemed to be greater for non-engagers, whereas the engagers showed a clear consistent increase in the recency of M&A engagements.
In the original model of search in organizationally vulnerable areas, Cyert and March (1963) argued that search was conducted in the areas which offer slack. As such, organizational slack is an alternative driver to the pressure arguments outlined in this dissertation. It is therefore warranted to take a look at slack as an alternative, viable option to the theory offered in this dissertation. Figure 19 offers a brief look at slack—here in the form of available slack, which is the most readily accessible type of financial slack. I used the current ratio to measure available slack since it is the most commonly used measure for available slack (Daniel et al., 2004). The graphs in Figure 19 point to interesting avenues in terms of future research associated with the issues at hand. As outlined in the theoretical section of this dissertation, Cyert and March (1963) built their idea of search in organizationally vulnerable areas on the idea of the availability of slack. The graphical comparison in Figure 19, however, did not support the
idea that higher slack should lead to search in organizationally vulnerable areas, reflected in my study as broadcast search engagement.

As per the statistical analyses in study 4, the general consensus on the use of control variables in econometric analyses is that control variables are included in the base model and the variables specified in the model are included afterwards. While the intention behind this approach is to construct a conservative model, there has been recent concern about this technique in terms of the ability to arrive at the desired outcome of statistical control and the potential for unintentional alterations of the interpretation of results (Breaugh, 2006; Carlson & Wu, 2012; Spector & Brannick, 2011). It has been recommended to only include variables which are included in the hypotheses (Spector & Brannick, 2011). In either case, recent research on the use of statistical control variables suggests that the inclusion of control variables should be done cautiously (Carlson & Wu, 2012; Spector & Brannick, 2011). In a middle ground between traditional procedure and the recommendation “when in doubt, leave them out” (Carlson & Wu, 2012, p. 413), I restricted the use of control variables to a common indicator of size, namely number of employees. The use of control variables in my dissertation is a response to potential issues of multicollinearity which can arise when including extensive sets of control variables (Spector & Brannick, 2011) and resulting concerns of reduced interpretability (Becker, 2005). A control variable approximating the size of an organization is included in my regression analyses to account for size-dependent characteristics of the organizations under study. I follow Carlson and colleagues (Carlson & Kunkel, 2011; Carlson & Wu, 2012; Carlson, Zeitzmann, & Flynn, 2012) approach in entering the meaningful variables first and adding my control variable last. For transparency and comparison purposes I present the controls also individually in a separate
model where appropriate so that a traditional comparison starting from an examination of just the control variables is also possible.

All analyses are conducted for the restricted set of companies which have a minimum R&D budget in 2011 of 1 percent of their total assets and which hold at least 5 patents. Panel data is used for the analyses of the predictions put forth in Hypotheses 1 and 2. For all panel data analyses, the set of independent variables in the regression starts at year 1990 for all models unless otherwise noted.

Each analysis for Hypothesis 1 shows three models. The analyses for each Hypothesis are conducted similar. For each analysis, Model 1 uses a 1-year lag of the panel data regression on the dependent variable, Model 2 uses a 5-year lag, and Model 3 employs an 8-year lag.

5.5.1.1 Hypothesis 1a

“Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years, leads to increased R&D spending by the focal organization.”

Table 27 outlines the results of the regression of patents expiring on R&D spending. For all three different time lags (1 year in Model 1, 5 years in Model 2, and 8 years in Model 3) there is a statistically significant relationship between the number of patents expiring and the R&D expenditures of the organization. Also, the total knowledge base reflected in the number of patents currently active (less than 20 years since application) and the size of the organization reflected in the number of employees, exhibit statistically significant relationships with the R&D expenditures.
Table 27: Panel regression of resource depletion on research activity

<table>
<thead>
<tr>
<th></th>
<th>R&amp;D expenditures (xrd)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 1-year time lag</td>
<td>Model 2 5-year time lag</td>
<td>Model 3 8-year time lag</td>
</tr>
<tr>
<td></td>
<td>coef se</td>
<td>coef se</td>
<td>coef se</td>
</tr>
<tr>
<td>Number of patents expiring in the next 5 years</td>
<td>1.002** 0.505</td>
<td>2.657*** 0.677</td>
<td>1.746** 0.790</td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>0.810*** 0.119</td>
<td>1.401*** 0.159</td>
<td>2.205*** 0.186</td>
</tr>
<tr>
<td>Number of employees</td>
<td>48.907*** 3.346</td>
<td>44.835*** 4.483</td>
<td>19.865*** 5.234</td>
</tr>
<tr>
<td>_cons</td>
<td>-487.563*** 41.729</td>
<td>-471.567*** 55.909</td>
<td>-172.294*** 65.276</td>
</tr>
<tr>
<td>N</td>
<td>620</td>
<td>620</td>
<td>620</td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.2 Hypothesis 1b

“Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years, leads to an increase of alliance formations by the focal organization.”

Table 27 outlines the results of the panel regression of patents expiring on the number of alliance formed for a 1-year, 5-year, and 8-year time lag. The regression coefficient was only statistically significant for the 1-year time lag model which might indicate that alliances were used as a short-term remedy against the loss of critical resources reflected in IP protection. The analyses conducted on a set restricted to only R&D alliances for which results are presented in Table 27: Panel regression of resource depletion on indicated similar yet slightly stronger results, despite a decreased sample size.

Table 28: Panel regression of resource depletion on distant search (alliances)

<table>
<thead>
<tr>
<th></th>
<th>Number of total alliances in focal year</th>
<th>Number of R&amp;D alliances in focal year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 1-year time lag</td>
<td>Model 2 5-year time lag</td>
</tr>
<tr>
<td></td>
<td>coef se</td>
<td>coef se</td>
</tr>
<tr>
<td>Number of patents expiring in the next 5 years</td>
<td>0.004*** 0.002</td>
<td>-0.001 0.002</td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>0.004*** 0.000</td>
<td>-0.002*** 0.000</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.096*** 0.010</td>
<td>0.054*** 0.011</td>
</tr>
<tr>
<td>_cons</td>
<td>1.356*** 0.131</td>
<td>1.429*** 0.131</td>
</tr>
<tr>
<td>N</td>
<td>620</td>
<td>620</td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1
5.5.1.3 Hypothesis 1c

“Higher resource depletion, reflected in a higher relative number of patents expiring within the next five years leads to increased M&A activity by the focal organization.”

Table 29 outlines the results of the panel regression of patents expiring on the M&A activity of firms for a 1-year, 5-year, and 8-year time lag. In the short term, there is a positive statistically significant (p < .05) relationship between number of patents expiring and the number of M&As an organization subsequently engaged in. With an extended time lag this coefficient becomes negative for a 5-year lag but remains significant (p < .05) and eventually remains negative but non-significant for the 8-year lag. For the 1-year and 5-year lags, the knowledge base reflected in the number of patents active, is negative and statistically significant (p < .05 and p < .1, respectively), indicating that there are potentially fewer M&As conducted by firms with higher knowledge bases. The coefficients are generally very small. However, the monetary values of acquisitions are generally quite large which would translate into small effects having large impacts in practice.

Table 29: Panel regression of resource depletion on distant search (M&As)

<table>
<thead>
<tr>
<th>Number of total M&amp;As conducted in focal year</th>
<th>Number of patents expiring in the next 5 years</th>
<th>Number of active patents held</th>
<th>Number of employees</th>
<th>_cons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
</tr>
<tr>
<td>Model_1 1-year time lag</td>
<td>0.002**</td>
<td>0.001</td>
<td>-0.002**</td>
<td>0.001</td>
</tr>
<tr>
<td>Model_2 5-year time lag</td>
<td>-0.000**</td>
<td>0.000</td>
<td>-0.000*</td>
<td>0.000</td>
</tr>
<tr>
<td>Model_3 8-year time lag</td>
<td>0.013**</td>
<td>0.006</td>
<td>0.034***</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>_cons</td>
<td>0.405***</td>
<td>0.078</td>
<td>0.426***</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>620</td>
<td>620</td>
<td>620</td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

The consideration of monetary outflow is reflected in an alternative investigation for Hypothesis 1c which I conducted based on a measure of acquisition expenditures. The measure
was collected from the Compustat database. As can be seen in Table 30, the coefficients here are larger, as expected. For Models 1 and 2, respectively reflecting a 1-year and 5-year time lag in the regression, there is a statistically significant (p < .01 and p < .05, respectively) positive effect of the number of patents expiring on the expenditures for acquisitions. The change in the direction of the coefficient between Model 1 and Model 2 raises some curiosity.

Table 30: Panel regression of resource depletion on distant search expenditures

<table>
<thead>
<tr>
<th></th>
<th>Acquisition expenditures (aqc)</th>
<th>Value (USD) of M&amp;As in focal year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model_1</td>
<td>Model_2</td>
</tr>
<tr>
<td></td>
<td>1-year time lag</td>
<td>5-year time lag</td>
</tr>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
</tr>
<tr>
<td>Number of patents expiring in the next 5 years</td>
<td>3.645***</td>
<td>1.171</td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>-0.277</td>
<td>0.225</td>
</tr>
<tr>
<td>Number of employees</td>
<td>-13.51**</td>
<td>5.99**</td>
</tr>
<tr>
<td>cons</td>
<td>179.16**</td>
<td>65.93**</td>
</tr>
<tr>
<td>N</td>
<td>570</td>
<td>581</td>
</tr>
</tbody>
</table>

The comparison between models in Table 30 is particularly interesting in that the significant relationships in Model 1 and Model 2, which seemed to diminish with a larger time lag, indicating that the use of acquisitions might reflect a short term solution to the resource depletion problem. Additionally, the stronger coefficients on the financial measures versus the mere count measures of the number of acquisitions suggest that companies under resource depletion pressure will spend more per acquisition. There are two complementary explanations for this finding. One, companies might pay a premium (Laamanen, 2007) to ensure that they are able to secure the purchase of an acquisition. Two, organizations might acquire more valuable targets which either have a higher patent stock or a more advanced R&D pipeline with soon expected successes. In addition to the Compustat based measure of acquisition related expenditures, I also constructed a measure of M&A expenditures based on information provided on M&A values provided in the SDC database. The results are presented in Table 30 and for the
5-year time lag support the notion of a statistically significant positive relationship (p < .05), again under consideration of a smaller sample.

5.5.1.4 Hypothesis 2a

“Higher rivalry, reflected in an increasing number of new patents within a focal firm's core research area, leads to increased R&D spending by the focal organization.”

Table 31 outlines the results of the panel regression of competition measured by the density of patenting in a focal firm’s core area of research on R&D spending for a 1-year, 5-year, and 8-year time lag. Throughout all three models, there is a positive relationship (p < .01) between the average number of patents from competitors in the primary area of research reflected in the focal firms patenting behavior. This relationship becomes stronger the greater the time lag chosen, as indicated by a rising coefficient for this relationship.

Table 31: Panel regression of direct competition on research activity

<table>
<thead>
<tr>
<th></th>
<th>R&amp;D expenditures (xrd)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-year time lag</td>
<td>5-year time lag</td>
<td>8-year time lag</td>
<td></td>
</tr>
<tr>
<td>Average number of competing patents in primary patent class</td>
<td>0.082***</td>
<td>0.027</td>
<td>0.160***</td>
<td>0.038</td>
<td>0.229***</td>
</tr>
<tr>
<td>Number of employees</td>
<td>61.905***</td>
<td>3.251</td>
<td>68.023***</td>
<td>4.596</td>
<td>55.044***</td>
</tr>
<tr>
<td>_cons</td>
<td>-512.014***</td>
<td>75.590</td>
<td>-472.647***</td>
<td>106.860</td>
<td>-194.995</td>
</tr>
<tr>
<td>N</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td></td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.5 Hypothesis 2b

“Higher rivalry, reflected in an increasing number of new patents within a focal firm's core research area, leads to an increase of alliance formations by the focal organization.”

Table 32 outlines the results of the panel regression of competitive pressure on organizations’ involvement in alliances for a 1-year, 5-year, and 8-year time lag. This effect was
found to be statistically significant (min. p < .05) and negative for all three models using a self-constructed measure of competition based on the number of patents filed by other organizations within the core technology area of the focal organization, determined by its patenting behavior. Contrary to my theory, this would suggest that higher competitive pressure would lead to less engagement in alliances. However, since I do not control for the size of the technology area, this might be a spurious finding.

Table 32: Panel regression of direct competition on distant search (alliances)

<table>
<thead>
<tr>
<th>Number of total alliances in focal year</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-year time lag</td>
<td>5-year time lag</td>
<td>8-year time lag</td>
</tr>
<tr>
<td>Average number of competing patents in primary patent class</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.0003***</td>
<td>0.000</td>
<td>-0.0002***</td>
</tr>
<tr>
<td>_cons</td>
<td>1.604***</td>
<td>0.242</td>
<td>1.666***</td>
</tr>
<tr>
<td>N</td>
<td>550</td>
<td>550</td>
<td>550</td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

To follow up on this, I constructed another measure of competition based on patents. Building on a prior Competition Index of patenting at the country level (Banerjee, Gupta, & Garg, 2000), I constructed a similar index for firm competition. Specifically, this index was constructed as follows. Banerjee and colleagues’ (2000) formula for the country competition index was

\[ C_C = \left( \frac{C_Y}{R_Y} \right) \left( \frac{R_{D-Y}}{W_{D-Y}} \right) \]

where, \( C_Y \) = Number of patents in the country in 1982-1984,

\( R_Y \) = Number of patents in the rest of the world in 1982-1984,

\( R_{D-Y} \) = Number of patents in the rest of the world in 1985-93,

and \( W_{D-Y} \) = Number of patents in the world in 1985-93.
I translated this equation to the firm level to construct an index based on a focal year as outlined by the following fraction:

\[ F_C = \frac{\sum_{t-5}^{t} F_Y}{\sum_{t-5}^{t} R_Y} \left/ \frac{\sum_{t+5}^{t+1} R_Y}{\sum_{t+5}^{t+1} T_Y} \right. \]

Where, \( t \) denominates the focal year,

FC = Firm Competition index,

FY = Number of patents in applied for by the focal firm in its primary nclass or the average of primary nclasses if tied,

RY = Number of patents by the rest of patentees in the focal nclass,

and TY = Number of total patents in the focal firm’s primary nclass.

The result from the analysis employing this revised measure are presented in Table 33. As reflected in the results shown in Table 33, the negative correlation found by the previous regression was confirmed. The zero order correlations listed in Table 26 indicate that the two variables are not correlated, since for the year 2001 the zero order correlation is 0.00 between the two variables. Therefore, the negative correlation between competition and the number of alliances seemed well supported. This indicated that there were fewer alliances in more competitive environments. Firms might potentially substitute alliances with other search approaches in highly competitive situations.
Table 33: Panel regression of Firm Competition Index on distant search (alliances)

<table>
<thead>
<tr>
<th></th>
<th>Number of total alliances in focal year</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 1-year time lag</td>
<td>Model 2 5-year time lag</td>
<td>Model 3 8-year time lag</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.037***</td>
<td>0.011</td>
<td>0.009</td>
<td>0.010</td>
<td>-0.006</td>
</tr>
<tr>
<td>_cons</td>
<td>1.175***</td>
<td>0.166</td>
<td>1.275***</td>
<td>0.159</td>
<td>1.294***</td>
</tr>
<tr>
<td>N</td>
<td>517</td>
<td>517</td>
<td>517</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.6 Hypothesis 2c

“Higher rivalry, reflected in an increasing number of new patents within a focal firm’s core research area, leads to increased M&A activity by the focal organization.”

Table 34 outlines the results of the panel regression of competition measured by the density of patenting in a focal firm’s core area of research on the number of M&As conducted using a 1-year, 5-year, and 8-year time lag. There are no statistically significant results found for this variable. Regressing this measure of competition on the acquisition expenditures incurred by the organizations does not lead to statistically significant results either as shown in Table 34.

Table 34: Panel regression of direct competition on distant search (M&As + aqc)

<table>
<thead>
<tr>
<th></th>
<th>Number of total M&amp;As conducted in focal year</th>
<th>Acquisition expenditures (aqc)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 1-year time lag</td>
<td>Model 2 5-year time lag</td>
<td>Model 3 8-year time lag</td>
<td>Model 4 1-year time lag</td>
<td>Model 5 5-year time lag</td>
<td>Model 6 8-year time lag</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
</tr>
<tr>
<td>Average number of competing patents in primary patent class</td>
<td>0.00004</td>
<td>0.000</td>
<td>-0.00004</td>
<td>0.000</td>
<td>0.0001</td>
<td>0.000</td>
<td>0.017</td>
<td>0.044</td>
<td>-0.018</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.006</td>
<td>0.006</td>
<td>0.024***</td>
<td>0.005</td>
<td>0.045***</td>
<td>0.007</td>
<td>-15.45</td>
<td>5.63</td>
<td>18.08</td>
</tr>
<tr>
<td>_cons</td>
<td>0.381***</td>
<td>0.132</td>
<td>0.399***</td>
<td>0.126</td>
<td>-0.043</td>
<td>0.166</td>
<td>252.40</td>
<td>121.60</td>
<td>122.80</td>
</tr>
<tr>
<td>N</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>508</td>
<td>515</td>
<td>521</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

Substituting the competition measure with the Firm Competition index (compindex) generated for Hypothesis 2b, led to statistically significant findings of a positive relationship (p
< .01) between competition and the number of M&As an organization conducts for the 5-year lagged model as shown in Table 35.

Table 35: Panel regression of Firm Competition Index on distant search (M&As)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-year time lag</td>
<td>5-year time lag</td>
<td>8-year time lag</td>
</tr>
<tr>
<td>Firm Competition Index</td>
<td>-7.262</td>
<td>13.600***</td>
<td>13.600***</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.009</td>
<td>0.020***</td>
<td>0.046***</td>
</tr>
<tr>
<td>_cons</td>
<td>0.518***</td>
<td>0.256***</td>
<td>0.124</td>
</tr>
<tr>
<td>N</td>
<td>517</td>
<td>517</td>
<td>517</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>coef</th>
<th>se</th>
<th>coef</th>
<th>se</th>
<th>coef</th>
<th>se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm Competition Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.009</td>
<td>0.006</td>
<td>0.020</td>
<td>0.006</td>
<td>0.046</td>
<td>0.007</td>
</tr>
<tr>
<td>_cons</td>
<td>0.518</td>
<td>0.090</td>
<td>0.256</td>
<td>0.085</td>
<td>0.124</td>
<td>0.114</td>
</tr>
</tbody>
</table>

Several of my hypotheses predict broadcast search involvement. My data testing these predictions violated ordinary least squares (OLS) assumptions in two ways. One, broadcast search involvement was measured in the form of a dichotomous dependent variable. Two, the number of firms actually engaged in broadcast search is low so that the outcome variable is positively skewed (Cohen, Cohen, West, & Aiken, 2003). For the hypotheses that predict a binary outcome in regards to a focal organization’s involvement in broadcast search, I thus had to revert to statistical analyses generally framed under the category of generalized least squares models (Cohen et al., 2003). In my analyses I used probit regression analyses. Although differences of results between probit and logit regressions are small, I have chosen to use a probit approach since this approach is based on a normal distribution rather than a log transformation.

5.5.1.7 Hypothesis 3a

“Mounting resource depletion (relative increase in number of expiring patents) and mounting use of internal R&D leads to adoption of broadcast search approach.”
Table 36 outlines the results of the probit regression of R&D expenditures and patent expiration pressure on the likelihood to employ broadcast search. The regression is conducted based on data from the year 2002 and the outcome in regards to broadcast search engagement as observed up to the year 2012. From the results in Table 36 there does not seem to be a statistically significant relationship between the independent variables and the dependent variable.

Table 36: Probit regression of research activity and resource depletion on non-routine search

<table>
<thead>
<tr>
<th></th>
<th>Model_1</th>
<th>Model_2</th>
<th>Model_3</th>
<th>Unrestricted sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D expenditures (xrd)</td>
<td>0.001*** 0.000</td>
<td>0.0001 0.000</td>
<td>0.0001 0.000</td>
<td>0.0001 0.000</td>
</tr>
<tr>
<td>Number of patents expiring in the next 5 years</td>
<td>-0.005 0.004</td>
<td>-0.005 0.004</td>
<td>-0.004 0.004</td>
<td>-0.004 0.004</td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>0.001 0.001</td>
<td>0.0004 0.001</td>
<td>0.001 0.001</td>
<td>0.000 0.001</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.042*** 0.010</td>
<td>0.047** 0.021</td>
<td>0.047** 0.021</td>
<td>0.047** 0.021</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.215*** 0.452</td>
<td>-2.315*** 0.499</td>
<td>-2.469*** 0.591</td>
<td>-2.184*** 0.363</td>
</tr>
<tr>
<td>N</td>
<td>64</td>
<td>62</td>
<td>62</td>
<td>90</td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.8 Hypothesis 3b

"Mounting resource depletion (relative increase in number of expiring patents) and mounting use of alliances leads to adoption of broadcast search approach."

Table 37 outlines the results of the probit regression of current alliances and patent expiration pressure on the likelihood to employ broadcast search. The regression is conducted based on data from the year 2002 and the outcome in regards to broadcast search engagement as observed up to the year 2012. From the results in Table 37 there does not seem to be a statistically significant relationship between the independent variables and the dependent
variable. Running the same analyses on a sample with alliances restricted to only include R&D alliances does not alter the results.

Table 37: Probit regression of current distant search (alliances) and resource depletion on non-routine search

<table>
<thead>
<tr>
<th></th>
<th>Broadcast search employment</th>
<th></th>
<th></th>
<th></th>
<th>Unrestricted search</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Number of current alliances</td>
<td>0.031</td>
<td>-0.037</td>
<td>-0.019</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>(4 years)</td>
<td>0.034</td>
<td>0.048</td>
<td>0.046</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of patents expiring in</td>
<td>-0.005</td>
<td>-0.007</td>
<td>-0.005</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>the next 5 years</td>
<td>0.004</td>
<td>0.006</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>0.001*</td>
<td>0.001</td>
<td>0.000</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Number of employees</td>
<td></td>
<td>0.001</td>
<td>0.000</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>-1.793***</td>
<td>-2.399***</td>
<td>-2.490***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.314</td>
<td>0.539</td>
<td>0.624</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.042***</td>
<td>0.056***</td>
<td>0.053***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.011</td>
<td>0.016</td>
<td>0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>-2.214***</td>
<td>-2.14***</td>
<td>-2.053***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.357</td>
<td>0.364</td>
<td>0.371</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.9 Hypothesis 3c

“Mounting resource depletion (relative increase in number of expiring patents) and mounting use of M&As leads to adoption of broadcast search approach.”

Table 38 outlines the results of the probit regression of recent M&A activity and patent expiration pressure on the likelihood to employ broadcast search. The regression is conducted based on data from the year 2002 and the outcome in regards to broadcast search engagement as observed up to the year 2012. From the results in Table 38 there does not seem to be a statistically significant relationship between the independent variables and the dependent variable. Sensitivity analyses conducted on the value of recent M&As as opposed to the number also failed to show significant results.
Table 38: Probit regression of recent distant search (M&As) and resource depletion on non-routine search

<table>
<thead>
<tr>
<th>Source of Resource Depletion</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Restricted sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of recent M&amp;As</td>
<td>0.084*</td>
<td>-0.142</td>
<td>-0.142</td>
<td>0.097</td>
</tr>
<tr>
<td>(4 years)</td>
<td>0.045</td>
<td>0.097</td>
<td>0.097</td>
<td></td>
</tr>
<tr>
<td>Number of patents expiring in the next 5 years</td>
<td>-0.006</td>
<td>-0.008</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>Number of active patents held</td>
<td>0.001**</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Number of employees</td>
<td>-1.878***</td>
<td>0.332</td>
<td>-2.666***</td>
<td>-2.666***</td>
</tr>
<tr>
<td>_cons</td>
<td>0.042***</td>
<td>0.010</td>
<td>0.081***</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>0.081***</td>
<td>0.499</td>
<td>0.756</td>
<td>0.756</td>
</tr>
<tr>
<td>_cons</td>
<td>0.332</td>
<td>-2.315***</td>
<td>0.756</td>
<td>0.756</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.666***</td>
<td>0.499</td>
<td>-2.666***</td>
<td>0.756</td>
</tr>
<tr>
<td>N</td>
<td>66</td>
<td>62</td>
<td>62</td>
<td>62</td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.10 Hypothesis 4a

“Mounting rivalry (increase in new patents in core research area) and mounting use of internal R&D leads to adoption of broadcast search approach.”

Table 39 outlines the results of the probit regression analysis of R&D expenditures and the 5-year average number of competing patents in the primary technology area of an organization on the likelihood to employ broadcast search. The analyses showed no statistically significant effect after controlling for firm size. As shown in Table 39, the alternative measure for competition—Firm Competition Index—did not show a meaningful effect either.
Table 39: Probit regression of research activity and direct competition on non-routine search

$$
\begin{array}{ccccccccc}
\text{R&D expenditures (xrd)} & 0.001^{***} & 0.000 & -0.00001 & 0.000 & 0.0005^{**} & 0.000 & 0.00001 & 0.000 \\
\text{Average number of competing patents in primary patent class} & 0.000 & 0.000 & 0.000 & 0.001 \\
\text{Firm Competition Index} & 43.006 & 27.849 & 10.041 & 30.696 \\
\text{Number of employees} & 0.042^{***} & 0.010 & 0.041^{**} & 0.019 & 0.042^{***} & 0.010 & 0.037^{*} & 0.022 \\
_{\text{cons}} & -2.296^{*} & 1.274 & -2.315^{***} & 0.499 & -3.147 & 2.091 & -2.138^{***} & 0.452 & -2.315^{***} & 0.499 & -2.259^{***} & 0.523 \\
N & 62 & 62 & 60 & 55 & 62 & 53 \\
\end{array}
$$

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.11 Hypothesis 4b

“Mounting rivalry (increase in new patents in core research area) and mounting use of alliances leads to adoption of broadcast search approach.”

Table 40 outlines the results of the probit regression analysis of current alliances and the 5-year average number of competing patents in the primary technology area of an organization on the likelihood to employ broadcast search. The analysis does not show a statistically significant effect after controlling for firm size. Results for similar analyses based on alternative measures using the Firm Competition index or a restricted set of only R&D alliances were also statistically non-significant.
Table 40: Probit regression of current distant search (alliances) and direct competition on non-routine search

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th></th>
<th>Model 2</th>
<th></th>
<th></th>
<th>Model 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
</tr>
<tr>
<td>Number of current alliances (4 years)</td>
<td>0.077***</td>
<td>0.026</td>
<td>-0.012</td>
<td>0.036</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average number of competing patents in primary patent class</td>
<td>0.00003</td>
<td>0.000</td>
<td>0.0003</td>
<td>0.001</td>
<td>0.042***</td>
<td>0.010</td>
<td>0.043***</td>
<td>0.011</td>
</tr>
<tr>
<td>Number of employees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>-1.676*</td>
<td>0.862</td>
<td>-2.315***</td>
<td>0.499</td>
<td>-3.243</td>
<td>2.158</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>64</td>
<td>62</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.12 Hypothesis 4c

“Mounting rivalry (increase in new patents in core research area) and mounting use of M&As leads to adoption of broadcast search approach.”

Table 41 outlines the results of the probit regression analysis of recent M&As and the 5-year average number of competing patents in the primary technology area of an organization on the likelihood to employ broadcast search. The analysis did not show a statistically significant effect after controlling for firm size. Again, alternative measures did not improve the predictability of the model.
Table 41: Probit regression of recent distant search (M&As) and direct competition on non-routine search

<table>
<thead>
<tr>
<th>Broadcast search employment</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of recent M&amp;As (4 years)</td>
<td>0.135***</td>
<td>0.042</td>
<td>-0.031</td>
</tr>
<tr>
<td>Average number of competing patents in primary patent class</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.042***</td>
<td>0.010</td>
<td>0.045***</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.342**</td>
<td>1.084</td>
<td>-2.315***</td>
</tr>
</tbody>
</table>

N | 64 | 62 | 60 |

note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.13 Hypothesis 5

“Companies that use higher proportion of alliances AND M&A over R&D expenditures are more likely to engage in broadcast search.”

Table 42 presents the results for the probit regression analysis of various forms of local and distant search on the likelihood of broadcast search employment. In the sample, neither the direct effects nor the interaction effect of two distant search mechanisms, alliances and M&As, seem to have an effect on the likelihood to employ broadcast search when controlling for size. Alternative measures again did not affect the results.

Table 42: Probit regression of routine local and distant search on non-routine search

<table>
<thead>
<tr>
<th>Broadcast search employment</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of current alliances (4 years)</td>
<td>-0.152</td>
<td>0.125</td>
<td>-0.130</td>
<td>0.172</td>
</tr>
<tr>
<td>Total number of alliances (experience)</td>
<td>0.018</td>
<td>0.018</td>
<td>0.002</td>
<td>0.023</td>
</tr>
<tr>
<td>Number of recent M&amp;As (4 years)</td>
<td>-0.004</td>
<td>0.131</td>
<td>-0.216</td>
<td>0.199</td>
</tr>
<tr>
<td>Total number of M&amp;As conducted (experience)</td>
<td>0.053*</td>
<td>0.029</td>
<td>0.090</td>
<td>0.062</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.042***</td>
<td>0.010</td>
<td>0.051***</td>
<td>0.020</td>
</tr>
<tr>
<td>Current alliances X Recent M&amp;As</td>
<td>-0.018</td>
<td>0.013</td>
<td>-0.126</td>
<td>0.019</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.046***</td>
<td>0.375</td>
<td>-2.315***</td>
<td>0.499</td>
</tr>
</tbody>
</table>

N | 66 | 62 | 62 | 62 |

note: *** p<0.01, ** p<0.05, * p<0.1
5.5.1.4 Hypothesis 6a

“Companies that use higher proportion of alliances over R&D expenditures are more likely to engage in broadcast search.”

Table 43 presents the results for the probit regression analysis of current alliances relative to total alliances and R&D expenditures on the likelihood of broadcast search employment. These factors show some marginal support (p < .10) for the existence of the proposed relationship. However, while the direction of the relationship remains stable, including only the R&D alliances as a predictor led to the loss of statistical significant as shown in Table 43.

Table 43: Probit regression of local and current distant search (alliances) on non-routine distant search

<table>
<thead>
<tr>
<th>Broadcast search employment</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
</tr>
<tr>
<td>Number of current alliances (4 years)</td>
<td>-0.089</td>
<td>0.083</td>
<td>-0.223*</td>
<td>0.132</td>
</tr>
<tr>
<td>Number of current R&amp;D alliances (4 years)</td>
<td>-0.019</td>
<td>0.215</td>
<td>-0.034</td>
<td>0.240</td>
</tr>
<tr>
<td>Total number of alliances (experience)</td>
<td>0.016</td>
<td>0.014</td>
<td>0.051*</td>
<td>0.031</td>
</tr>
<tr>
<td>Number of employees</td>
<td>0.044***</td>
<td>0.013</td>
<td>0.086**</td>
<td>0.035</td>
</tr>
<tr>
<td>R&amp;D expenditures (xrd)</td>
<td>0.003</td>
<td>0.021</td>
<td>0.040***</td>
<td>0.011</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.439***</td>
<td>0.588</td>
<td>-2.682***</td>
<td>0.711</td>
</tr>
<tr>
<td>N</td>
<td>62</td>
<td>62</td>
<td>62</td>
<td>62</td>
</tr>
</tbody>
</table>

note: *** p<0.01, ** p<0.05, * p<0.1

5.5.1.5 Hypothesis 6b

“Companies that use higher proportion of M&A over R&D expenditures are more likely to engage in broadcast search.”

Table 44 presents the results for the probit regression analysis of recent M&As relative to total M&As and R&D expenditures on the likelihood of broadcast search employment. The results show a statistically significant (p < .10), yet negative relationship between recent M&As
and broadcast search engagement when controlling for size. When replacing the count variable by a monetary value (either acq from Compustat or based on data from SDC), the statistical significance resolves as shown in Table 44.

Table 44: Probit regression of local and recent distant search (M&As) on non-routine search

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef</td>
<td>se</td>
<td>coef</td>
<td>se</td>
</tr>
<tr>
<td>Number of recent M&amp;As (4 years)</td>
<td>-0.209</td>
<td>0.129</td>
<td>-0.225*</td>
<td>0.136</td>
</tr>
<tr>
<td>Value (USD) of recent M&amp;As (4 years)</td>
<td>0.049</td>
<td>0.031</td>
<td>0.054</td>
<td>0.034</td>
</tr>
<tr>
<td>Total number of alliances (experience)</td>
<td>0.045***</td>
<td>0.015</td>
<td>0.053**</td>
<td>0.023</td>
</tr>
<tr>
<td>Number of employees</td>
<td>-2.771***</td>
<td>0.766</td>
<td>-2.768***</td>
<td>0.755</td>
</tr>
<tr>
<td>R&amp;D expenditures (xrd)</td>
<td>-0.000</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *** p<0.01, ** p<0.05, * p<0.1

5.5.2 Study 2—Corporate Communications: Interpretations / Implications:

The results from the panel regression indicated that there was support for the existence of innovation pressure in the pharmaceutical industry. The effects of looming patent expirations increased the investment in overall R&D as reflected in the firms’ increasing R&D expenditures for firms which had relatively higher numbers of patents within their portfolio expiring within the next five years of a focal year. Similar results, although less strong, were found for the number of alliances and M&As undertaken. Using an alternative measure for the M&A activity, the idea was supported for the shorter term time lags of 1 and 5 years. This indicated that innovation pressure existed and had statistically meaningful effects on corporate decision making in terms of search behavior, particularly in the short run of alleviating the problem. Overall, the results from testing Hypothesis 1 indicated that firms use both local and distant search to address innovation pressures which they experience.
Similarly, results from testing my second set of hypotheses supported the notion that pressure from rivalry existed and, as per hypothesis 2a this pressure had a statistically significant effect on firms’ overall R&D involvement as measured by their R&D expenditures. Contrary to predictions, higher pressure stemming from an increase in competitor patents in a focal firm’s core research area had a statistically significant, but negative, effect on the number of alliances a firm engaged in. Potentially, this could mean that firms engaged less in cooperation if competition forces were increasing. The analyses of Hypothesis 2c suggested that there was no connection between the competitive intensity within a firm’s core research area and its engagement in M&As. Both the number of M&As conducted as well as the value of acquisitions made by a firm suggested no relationship between competition in a core field and M&A activity.

5.6 Post-hoc Analysis

The scientific research process has been outlined as “the continuous expansion of knowledge involving the generation, refutation and application of theories” (Montgomery, Wernerfelt, & Balakrishnan, 1989, p. 189). The three steps are seen as equally important and there is no pre-determined starting position in the research process (Montgomery et al., 1989). The chosen starting position for this dissertation was the development of relevant theory in response to a phenomenon observed in practice. Therefore, the current dissertation had been developed with propositions in mind which had been put forth by Montgomery and colleagues (1989). In summary, these propositions state that theory generation should be based on past observation and prior theoretical work, that observations should be interpreted through theory, that the theory be testable, and that ultimately science should lead to application (Montgomery et al., 1989). Notably, these propositions have been criticized for their normative form in which they were presented (Seth & Zinkhan, 1991). In a positive rather than normative way, which is
the position taken in adopting the propositions for the current dissertation, there is general agreement on the validity of the basic notions of these propositions (Seth & Zinkhan, 1991). Furthermore, Seth and Zinkhan (1991) stress the validity and value of a phenomenon centered research approach which draws on a variety of methodologies. Within the research process, individual tests may offer support or an indication in terms of the applicability of a theoretical explanation. The goal of scientific research is to disentangle meaningful relationships between constructs and to determine boundary conditions (Bacharach, 1989). The current work employed the described scientific process (Montgomery et al., 1989; Seth & Zinkhan, 1991) to build and test an explanatory frame for the observed use of broadcast search in the pharmaceutical industry.

The non-significance of findings for the econometric analyses in study 2 regarding the probit regressions for Hypotheses 3 through 6 could stem from various factors. A very likely issue is the small sample size. Notably, the restrictions employed to ensure compliance of the data with the assumptions of the theory, missing data points, and the need to constrain the analysis to one base year instead of being able to employ the full panel, left a toll on the number of observations which could be used in the probit regression analyses. I was looking at 66 observations which meant that the test would have low power. Issues concerning the “sparseness of data” have been outlined in the context of logistic regression analyses (Cohen et al., 2003, p. 506 + 515) which would also be problematic for the same logic in probit regressions since there are similarities in these statistical approaches. Therefore, one important limitation which could be a cause for the lack of significant findings stems from the small number of observations, especially in regards to the group of organizations conducting broadcast search.

Another potential issue could be related to the measures used for constructs of importance. For example, using an indicator variable to assess the engagement in broadcast
search is a rather coarse measure. Such an approach did not allow to differentiate between organizations which were substantially involved in creating new organizational structures and processes to fully integrate broadcast search into their core search strategy for R&D processes and those organizations which merely tinker with the approach for a small development project in a strategically unimportant, non-core area. Assuming that both types of firm strategies could legitimately be part of the sample, the concern becomes how this would affect the analyses. It is feasible that by weighing both organizations equally, the data is unable to reflect the inherent differences and behavioral consequences between these approaches.

It is also possible that the construct relationships are not adequately captured by the measures employed in my studies. Similar to the concerns with using a binary variable to capture broadcast search behavior, the chosen measures could be rather coarse in capturing the construct of interest and thus fail to pick up differences between observations. Furthermore, the measures might be capturing broader concepts or be convoluted by adjacent constructs. For example, firm involvement in M&As is not purely a reflection of intentional organizational search behavior for R&D purposes but could also reflect expansion based on random financial opportunities, such as the acquisition of a failing organization with complementary assets even if the purchasing firm was not actively pursuing a search for acquisition targets.

There are possible alternative explanations and drivers of firm behavior which are outside the boundary conditions of my theory but which nonetheless could lead to similar outcomes. My theory suggests that organizations under innovation pressure search for innovation alternatives of which broadcast search is one. There is also the possibility that other factors could drive the decision to engage in broadcast search. For example, taking an institutional theory perspective (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977), an organization might have chosen to
experiment with a broadcast search approach because other organizations are doing it as well. As such, the driver of their behavior is not related to the drivers discussed in the theory of this dissertation. While I attempted to predict who would engage in broadcast search, the predictions are considered to be constraint by certain boundary conditions. As such, this dissertation was aimed at mapping out and understanding boundary conditions which would have the potential to lead to a substantial change in organizational behavior.

In order to test whether the sample size limitations are a legitimate concern or whether there are likely more substantial theoretical issues in the development of the theory, I decided to conduct a brief non-parametrical test of the data employed. While such a non-parametric investigation would be no substitution for further empirical investigations using more extensive and precise data, it should offer a foundation for future research. I conducted a post-hoc follow-up investigation of the dataset generated for study 2. Reverting back to my findings from study 1, I hypothesized that the bilateral grouping based on the breadth of the knowledge base reflected in the dispersion index DISP, adopted with a slight modification from Bierly and Chakrabarti (1996a) would constitute a relevant indicator of a boundary condition in which my theory should be supported. In study 1 I argued that group membership to the highly dispersed knowledgebase group should be a necessary but not sufficient condition for broadcast search engagement based on an organization’s strategic decision to change its search behavior in response to pressure. A first step was to test if group membership had a significant impact on the engagement in broadcast search over what would be expected by chance. I therefore conducted a Chi-square test to investigate whether or not the two categorical variables were related (http://statistics.ats.ucla.edu/stat/stata/whatstat/whatstat.htm). The results from this analysis are shown in Table 45. Specifically, there was support reflected in a Pearson’s chi-square
coefficient and Fisher’s exact test being statistically significant (p < .001) for the notion that
group membership with regards to a broad knowledge base was a necessary condition to engage
in broadcast search. A chi-square test compares the number of observations in each group
created by a matrix of two categorical variables with the expected frequency for this group and
returns a test statistic regarding the likelihood that the observed distribution is a chance
occurrence (Cohen, 2008). The reliability of the chi-square test is however restricted by the
assumption that there are at least 5 observations in each group (Cohen, 2008). To overcome this
assumption, I conducted a Fisher’s exact test which was not constraint by this assumption
(Cohen, 2008). The finding that the four groups were significantly different from their expected
values was supported by a statistically significant (p <.001) Fisher’s exact test.

**Table 45: Chi-square test of the relationship between group membership and broadcast search engagement**

<table>
<thead>
<tr>
<th></th>
<th>Group 1: Broad knowledge base (1)</th>
<th>Group 2: Narrow knowledge base (0)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaged in broadcast search (1)</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Refrained from broadcast search (0)</td>
<td>4</td>
<td>50</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>50</td>
<td>62</td>
</tr>
</tbody>
</table>

Pearson chi2(1) = 38.2716  p < 0.001
Fisher's exact: p < 0.001

I conducted a χ2 test to evaluate whether there was a relationship between the two groups.
I conducted a Fisher's exact test to confirm the results of the χ2 test since some of group values were n < 5
5.7 Results Summary

Addressing the key research questions outlined in chapter 1, the current dissertation examined the use of alternative knowledge sourcing approaches in the pharmaceutical industry and inquired about the type of organization which would likely alter its search behavior by engaging in broadcast search activities. Pre-study A was a semi-structured search conducted as an indication for the general occurrence of broadcast search in the pharmaceutical industry. Pre-study B investigated a set of broadcast search calls, so-called challenges, and found support for the notion that pharma-related challenges were unique in terms of their specificity but that the broadcast search approach in general was an option for this type of research. This investigation thus served as a test addressing my exploratory research question. Pre-study C was a survey of managers from pharmaceutical firms interested in the topic of open innovation in regards to R&D. This examination further probed the exploratory question and also offered some indication regarding the question of who is likely to engage in broadcast search. The survey revealed that the understanding of managers regarding the open innovation concept is generally in line with the academic literature and supported the finding from pre-study B that it was a viable option for the industry. It also offered an insightful description of the current use and indicated that broadcast search was for the most part only marginally employed in these firms. This was in line with the theoretical notion that broadcast search is used after other attempts have failed—as a search mechanism at the margin. The combined findings from the pre-studies offered support that the research concern with this topic was legitimate, as opposed to it being a “toy problem” (Sprague & Sprague, 1976, p. 57). Study 1 offered support for the general notion of the existence of similarities based on knowledge strategies within the pharmaceutical industry (Bierly & Chakrabarti, 1996a). More importantly, study 1 was able to single out the breadth of a
firm’s knowledge base as the defining factor in the formation of groups within my samples. This finding was a response to the question of who engaged in broadcast search. The empirically derived observation was in line with theoretical arguments on the importance of a firm’s ability to combine knowledge (Henderson & Cockburn, 1994; Kogut & Zander, 1992) and may function as a unique starting point for future research on that topic. In study 2 the focus shifted further to testing the hypotheses outlined in the development of the theoretical model using an econometric approach. A restrictive dataset was used to resemble the type of organization described in the theory. Panel regression analyses conducted in study 2 offered some support for the idea of innovation pressures affecting organizational search behavior. Innovation pressure in the form of resource depletion measured as expiring patents to some extent affected both the intensity of local and of distant routine search, especially as a short-term solution. Rivalry with regards to other firms’ patents in core research areas had similar effects on local search, but opposite effects on the expansion to routine distant modes of search in regards to alliances. Probit regression analyses were unable to support innovation pressure as an actual predecessor of the use of broadcast. However, in a post-hoc analysis combining findings from study 1 with the data employed in study 2, a non-parametric chi-square test found strong statistical support (p < .001) for the notion that broadcast search engagement is preceded by a strong knowledge base, indicating that certain firm characteristics have an effect on organizational change in regards to search behavior. Asking who engages in broadcast search led to the focus on firm characteristics. Certain pre-requisites seem to be essential which in the current sample are reflected in or associated with a broad knowledge base. Better understanding these firm characteristics is the task of future research. Overall, the results of this dissertation indicate that broadcast search can be used to conduct R&D related search for new products and technologies in the pharmaceutical
firms. The combined findings also offer interesting points of departure for future research to further understand organizational search behavior, both in theory and practice.
6.0 DISCUSSION AND CONCLUSIONS

This dissertation was conducted to develop and test a theory of organizational search starting from the assumptions and boundary conditions presented by Cyert and March’s (1963) behavioral theory of the firm. By incorporating foundational aspects of evolutionary theory (Nelson & Winter, 1982) and other theories of innovation and technological change (Schumpeter, 1934) the expanding search process advocated in the behavioral theory of the firm was reformulated to better suit the underlying assumption of problemistic search (Cyert & March, 1963). A particular focus was placed on the development of the idea of search in organizationally vulnerable areas (Cyert & March, 1963) within open innovation (Chesbrough et al., 2006; Chesbrough, 2003a). Tests were developed to reflect and evaluate this aspect of the expanding search process. The studies conducted offered insights into various aspects of organizational search behavior by providing a multitude of perspectives (Scandura & Williams, 2000) on the subject. The different approaches aided the understanding of the current landscape and offered a rich exposition for future research. The combined results of the analyses indicated that such research is necessary to further our understanding of the theoretical constructs and that such further investigations should be fruitful for clarifying the theoretical constructs underlying expansive search (Cyert & March, 1963). The findings from my investigations suggested that our understanding of organizational search processes is still limited especially with regards to the escalation of search and how organizations respond to search failures. My research also indicated that this aspect of the organizational search process is difficult to capture, which might help explain the relative absence of research on this specific phase. The statistical findings from my analyses were not strong enough to suggest conclusive answers to the questions raised but they provide starting points for further interrogations into the aspects of search expansion and the
use of broadcast search as a tool for pharmaceutical R&D. The results also indicated that firms within the industry were serious about the employment of broadcast search as an alternative to current practices.

The state and history of an industry and of individual firms with the industry in regards to their behavior is a complex issue which cannot be condensed easily into a single number or function. The pharmaceutical industry is no exception in this regard. As such, rather than offering a prescription in form of a ‘how to’ list, the current dissertation aimed to offer a basis for future research on the use of broadcast search—with a particular focus on technological R&D. Its aim was to test the feasibility of the establishment of broadcast search in practice where the use of such an approach might be of value. Importantly, the dissertation was structured in a way that took a scientific approach which was not guided by ex ante selection on the dependent variable, but instead considered the full set of organizations which would be considered a sample of the population—not just a successful subsample.

6.1 Limitations

Looking at the corporate level, it is possible that various strategies are being employed simultaneously. Firms could go outside for some projects, but be more internal for others. The current work does not distinguish the level of engagement and as such a minor engagement by a company has the same weight as a full commitment. As such, it would be interesting to not only see who is most likely to engage in broadcast search, but also the level of engagement.

6.2 Contributions to Research

The current research hype about open innovation (Huizingh, 2011) has not yet substantiated itself in the development of a theory of open innovation nor has it produced clearly distinguished, commonly agreed constructs. However, the open innovation domain is young and
the continued interest, which is also reflected by the interest shown in the many presentations on this topic at conferences such as the Academy of Management and the Strategic Management Society meetings held in 2011 and 2012, suggests that there is value in conceptually framing research under the open innovation umbrella. The apparent move toward publications in more theory-oriented journals that can be witnessed in recent years is a promising start to building a more theory-solid foundation. Dodgson, Gann, and Salter (2006, p. 334) specifically pointed to theories which are founded in “traditions [that] analyze the firm as bundles of resources, routines and capabilities, and consider their construction, internal configuration and reconstitution as the primary determinant of business competitiveness” as foundations for developing our understanding of open innovation. They offer resource-based theories (citing: Penrose, 1959; Barney, 1986; Grant, 1996), behavioral theories of the firm (citing: March & Simon, 1958; Cyert & March, 1963), ‘learning’ theories (citing: Argyris & Schön, 1978; Senge, 1990; Nonaka & Takeuchi, 1995; Brown & Duguid, 2000), evolutionary theory (Nelson & Winter, 1982), dynamic capabilities theory (Teece & Pisano, 1994), and the concept of absorptive capacities (Cohen & Levinthal, 1990) as examples of theories underlying open innovation (Dodgson et al., 2006). The focus on the resource-based view is mirrored by Sofka and Grimpe’s (2010, p. 311) statement that “[r]ecent research points to the emergence of a so-called ‘open innovation’ paradigm (Chesbrough, 2003a). The crucial role of external knowledge sources can be traced back to the literature focusing on the resources and capabilities of firms (Wernerfelt, 1984; Barney, 1991; Conner, 1991; Peteraf, 1993), culminating in a knowledge-based perspective (Grant, 1996).” The current work places emphasis on the importance of a solid theory foundation. In so doing, it advances our understanding of the open innovation concept by examining the impacts of a specific example—broadcast search—as an
organizational search option placed in behavioral (Cyert & March, 1963) and evolutionary (Nelson & Winter, 1982) theories.

As outlined earlier, in some instances during the early development of the open innovation concept, case descriptions have been the basis for premature (i.e., not scientifically based) recommendations (Chesbrough, 2003a). Therefore, I move carefully beyond the case study method without erroneously jumping to an approach that was disconnected from practice. Simultaneously, the current research is intended to serve as a starting point for a stream of future research embedded in the theoretical foundations outlined in this dissertation not limited to the phenomena discussed here. As a side-contribution the current work points to unresolved level issues in the literature on (organizational) routines. Contrary to the plea of Dosi et al. (2000), this paper comes to the conclusion that the term routines should not be used without a level-specifier clearly articulating whether a discussion is concerned with routines at the individual or collective level. For open innovation in particular, this consideration is important since open innovation has implications for various levels. It can be looked at from a firm level, team level, or individual level. Incorporating or changing to an open approach to innovation has implications for all levels and research needs to consider each one. The current work does not, however, suggest that it needs to be considered as a multi-level construct at this point; it merely is not confined to one level in terms of its effects and informative potential to research.

6.3 Managerial Implications

The current dissertation revealed that up to this point, the pharmaceutical industry has not been able to find a definite way in which it can leverage broadcast search in a way that it replaces other search alternatives. The dissertation outlined broadcast search as a potential search alternative to current routines in the industry. The direct interaction with industry
practitioners through the third pre-study supports this view. Pre-study C also reveals that the industry is still in an experimentation stage when it comes to the use of broadcast search. At the same time, secrecy concerns became apparent, suggesting that considerations around the use of broadcast search are seen as potentially critical to firms’ core R&D activities.

One of the most striking findings from this dissertation in regards to practical applicability is that as of today, despite anecdotal evidence (Agres, 2012; Fleming Europe, 2012; pre-study C of this dissertation), there does not seem to be a direct link established between a firm’s position in regards to innovation pressure and the decision to engage in broadcast search. The theory developed in this dissertation has been constructed based on soundly established concepts of strategy theory coupled with a close eye on the perception of broadcast search in practice. However, the inability to establish a definitive link between the ex ante situation of an organization and its switch in search behavior suggests that such far reaching strategic decisions have been made on the grounds of unsupported assumptions. This does not mean that such decisions were necessarily wrong for individual organizations, but it raises concerns regarding the stability and legitimacy of decision making procedures in large organizations. As such, this dissertation has far reaching implications beyond the aspect of broadcast search.

6.4 Directions for Future Research

Settings in which broadcast search by large multinational corporations can be observed often have a social aspect to it. They include for example green technologies as in the case of General Electric (Immelt, Govindarajan, & Trimble, 2009) and poverty alleviation as in the case of DuPont (Kunzig, 2011) or orphan drug research in the pharmaceutical industry (Kar, 2010). For this reason potential related research fields would be Bottom of the Pyramid research (Hart, 2005; Prahalad & Hammond, 2002; Prahalad, 2004) or a setting that looks at developing
countries in general. There are first attempts in the literature to connect those areas (Christensen, Hang, Chai, & Subramanian, 2010). Future research may thus transpose ideas from the current work to research in the field of emerging markets.

Along the social aspect of broadcast search approaches, an alternative explanation to the pressure / innovation driven explanation of using broadcast search outlined in the current work is the idea that engagement in broadcast search could be based on the publicity factor of such systems. Corporate social responsibility (CSR) could be a driver in the decision to engage in broadcast search. For example, companies could use broadcast search to solicit ideas, feedback and actual involvement by customers and partners in areas which are related to the firm’s development efforts in areas with high social responsibility factors. Examples would again include the projects mentioned above (Immelt et al., 2009; Kar, 2010; Kunzig, 2011). Such an approach would draw heavily on the non-pecuniary aspect of broadcast search (Dahlander & Gann, 2010; Lakhani et al., 2007; www.innocentive.com accessed 10/11/2012) discussed in Chapter 4.

While I have stressed the importance of the question in broadcast search and potential effects on the outcome of the search, in my analysis of the pharmaceutical company this aspect is held constant. The variation of the question raised by pharmaceutical companies is relatively small as it generally asks for the development of certain compounds. There might however be differences in the amount of information provided to solvers. Future research could look at the effects of the information provided in challenges, and as such the level of openness. It would also be most interesting to investigate effects stemming from varying levels of specificity of the question. Research at the level of the question could offer interesting insights and could potentially be investigated in a broad, industry-spanning setting.
Within the pharmaceutical industry, practitioners have pointed to various new paths in which pharmaceutical firms try to alleviate the pressure to innovate (Agres, 2012). These include re-focusing on in-house R&D, open innovation approaches such as the one addressed in this dissertation, and a focus on niche-markets reflected in orphan drug research (Agres, 2012). The current dissertation dealt with the underlying idea of responsive search and examined one alternative to previous paths. Future research could take a broader perspective, examine various new development paths simultaneously, and potentially pit these approaches against each other or evaluate their complementarity. Specifically, the area of orphan drug research in combination with open innovation and broadcast search approaches (Kar, 2010) could be investigated further with a focus on the potential of generating breakthrough innovations. A core goal in pharmaceutical R&D which could be satisfied through such combinative approaches is the development of new technological trajectories (Dosi, 1982) which would be the basis for future developments with broader application and sustained revenue streams. The high and increasing R&D costs for developing new drugs (DiMasi et al., 2003; Pisano, 2006) necessitate a cost conscious approach to R&D. Being able to control costs by building platforms (Christensen, 2000) becomes essential. Radical innovations (Ettlie, Bridges, & O’Keefe, 1984) can serve as the pillars of such platform technologies. Creating these pillars cost effectively becomes the focal challenge of pharmaceutical organizations. I have noted the importance of radical innovations and future empirical work could investigate this aspect further by including a measure for radical innovations to estimate the effects of organizational search practices on an organization’s ability to generate breakthrough innovations. Furthermore, research on the business models (Wizemann, Robinson, & Giffin, 2009) and research at the level of the
technological search process (Campbell, 1960; Souriau, 1881 as cited by Campbell, 1960; Stevens & Burley, 1997) can offer valuable insights in this regard.


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Appendix B: License agreement for Christensen (2000)

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Sent: Wednesday, December 12, 2012 3:39 PM
To: hanko@vt.edu
Subject: reproduction of a figure in a dissertation (#8095-332302465-7303)
Attachments: Exhibit 2 Hank Z.docx

Dear Hanko Zeitzmann,

Thank you for your email. As long as the HBS Case exhibit is only being used to fulfill the dissertation in the pursuit of your degree, permission is granted at no charge as long as the material is fully cited (see following).


If the dissertation is later published or distributed as training material, however, then there would be a royalty charge for use of the HBP material that would be based on how much material is used and the print run. At that time, you must come back to us with a new permission request.

I've attached a clean copy of the exhibit. Please let me know if this works.

Regards,
Nancy
Appendix C: Examples of challenges being coded pharma-related (left) versus non-pharma (right)
Synthesis of YM Depsipeptide

The Seeker desires a proven route for synthesizing YM depsipeptide, or a biologically functional equivalent, on a scale of at least 1 mg and ideally ≥10 mg. There will not be any awards made for theoretical submissions to this Challenge, however the Seeker may allow additional time beyond the posted Challenge deadline for Solvers to complete their synthetic efforts.

This is a Reduction-to-Practice Challenge that requires a written proposal, experimental proof-of-concept data, and sample delivery. For this Challenge, however, the Seeker only requires a non-exclusive license to the solution in exchange for the $100,000 USD award. The Seeker is quite certain that other researchers, both industrial and academic, would like to purchase this compound and will in no way interfere with Solvers’ efforts in this regard.

Challenge Overview

The Seeker desires a proven route for synthesizing YM depsipeptide, or a biologically functional equivalent, on a scale of at least 1 mg and ideally ≥10 mg.

This is a Reduction-to-Practice Challenge that requires a written proposal, experimental proof-of-concept data, and sample delivery. For this Challenge, however, the Seeker only requires a non-exclusive license to the solution in exchange for the $100,000 USD award. The Seeker is quite certain that other researchers, both industrial and academic, would like to purchase this compound and will in no way interfere with Solvers’ efforts in this regard.

The submission to the Challenge should include the following:
1. The detailed description of the proposed Solution addressing specific Solution Requirements presented in the Detailed Description of the Challenge. This description should be accompanied by a well-illustrated rationale supported by literature precedent.
2. Experimental proof-of-concept data obtained as outlined in the Detailed Description of the Challenge.

The award is contingent upon theoretical evaluation and experimental validation of the submitted Solutions by the Seeker.

To receive an award, the Seeker will not have to transfer their exclusive IP rights to the Seeker. Instead, they will grant to the Seeker non-exclusive license to practice their solution.

Algorithm for Matching Latent Fingerprints

This Challenge seeks to identify innovative methods to perform fully automated matching of digital latent fingerprints against a gallery of known and unknown reference fingerprints, to support law enforcement agencies’ ability to identify suspects from the scene of a crime. Current Automated Fingerprint Identification Systems (AFIS)’s attempt to match a latent fingerprint an enrolled print in a gallery and provide a list of candidate matches for a trained Latent Print Examiner.

This Challenge includes a real-time online scoring utility for Solvers to easily score their own code for accuracy on a blinded data set and compare performance versus other Solvers.

Awards for this Challenge depend on three performance thresholds:
1. If no submissions exceed 35% accurate identification, a maximum total award of $25,000 will be made to the top two Solutions (i.e., $12,500 per submission) that meet all Challenge requirements.
2. If one or more submissions are between 35% and 50% accuracy, a maximum total award of $40,000 will be made to the top two Solutions that meet all Challenge requirements.
3. If one or more submissions exceed 55% accuracy, then the full $100,000 award will be made to the best submission that meets all Challenge requirements.

The Seeker is not entitled to make multiple awards when multiple submissions meet the requirements. However, where two or more awards meet the requirements for the full award, the quality of the proposal combined with the Seeker’s validation of the submitted algorithm will determine if a single or split award will be made of the full amount.

As a Reduction-to-Practice Challenge, Solvers must provide a full and complete written description of the proposed algorithm and source code and any supporting information that validates the performance of the proposed solution. During the evaluation phase, the Seeker may validate submitted algorithms using additional offline datasets. This award is contingent upon theoretical evaluation and experimental validation of submissions by the Seeker. To receive an award, Solvers must transfer to the Seeker their exclusive Intellectual Property (IP) rights to the solution.
Appendix D: Types of Premium Challenges used by InnoCentive, Inc.

Ideation
A global collaboration for producing a breakthrough idea. This could include ideas for a new product line, creative solutions to technical problems, a new commercial application for a current product, or even a viral marketing idea for recruiting new customers. Ideation Challenges guarantee that at least one Solver will win an award. Additionally, the posting period is typically shorter than with other Challenge types, resulting in quicker time-to-solution. Ideation Challenges involve intellectual property licensing; a Solver grants the seeking organization a non-exclusive license to use any IP upon submission.

Theoretical
A feasible design that may not yet be reduced to practice. A solution to a Theoretical Challenge will solidify the Solver’s concept with detailed descriptions, specifications, supporting precedents, and requirements necessary to bringing a good idea closer to becoming an actual product, technical solution, or service. A Solver can expect a substantial financial reward if their submission is chosen as the winning solution by the seeking organization, but an award need only be made if all the Challenge criteria are met. Depending on the Challenge requirements, Solvers will be required to either transfer or license the IP in their solutions to the seeking organization.

Reduction-to-Practice (RTP)
A prototype that shows an idea in actual practice (though on a non-commercial scale). In an RTP Challenge, in addition to a detailed description, Solvers are asked to present physical evidence that proves their solution will work within the seeking organization’s specific needs, decision criteria, or manufacturing parameters. Solvers are given more time to generate data needed to support their proposals and prepare a response, and the financial awards are typically larger to reward the greater commitment required to work on these Challenges. Like the Theoretical Challenge, an award need only be made if all the Challenge criteria are met. Depending on the Challenge requirements, Solvers will be required to either transfer or license the IP in their solutions to the seeking organization.

Computational
A computational Challenge with an online scoring and feedback component. Also called Prodigy "Big Data" Challenges by InnoCentive, these are add-ons to Theoretical or RTP Challenges which enable Solvers to obtain objective feedback on the accuracy of their solutions relative to the Challenge requirements and to other Solvers. The accuracy of each solution is compared, scored, and published in a leaderboard format on the InnoCentive website. Solvers are then able to rework and resubmit their solutions based on feedback to see their status on the leaderboard change. Many types of computational Challenges can be formulated to use the Prodigy online scoring system, including statistical analysis, predictions, and optimization of computer programs. Large financial awards for the winners of these Challenges are typical.

Novel Molecule Challenge (NMC)
A request for various non-commercial chemical compounds, proteins, extracts, polymers, and DNA sequences linked by a common sub-structure, property, origin, or biological activity. Seeking organizations use these Challenges to investigate structure-activity relationships, obtain novel intermediates, expand library diversity, and so on. Solvers submit structures they have or are willing to make, and seeking organizations choose those of interest. Solvers receive a modest award in exchange for delivery of the compound and non-exclusive rights for the seeking organization to use the compound internally. Solvers may receive a much larger award in the future if the seeking organization decides that they desire exclusive IP rights to the compound.

Electronic Request for Proposal (eRFP)
A request for a partner or supplier to provide materials or expertise to help solve a business Challenge. Seeking organizations use the InnoCentive marketplace to find businesses or consultants that have already developed the technology they need or have the experience to help them develop it. Unlike other Challenges where a cash award is granted for the winning solution, eRFP winners typically negotiate the terms of the contract directly with the seeking organization.
Appendix E: Conference call by Fleming Europe

Solving the „Productivity Crisis“
Open Innovation in Pharmaceutical R&D
26th & 27th April 2012, Amsterdam

EVENT INTRODUCTION
In previous decades, traditional R&D methods have yielded blockbuster drugs, allowing companies to recoup the costs of development. Nowadays, with patent expiries, more complex disease targets, pricing pressures and increased regulatory requirements, the industry must find a different model to adapt to these changes. As we are experiencing a lag between R&D spending and the extraction of value from that investment, open innovation presents an opportunity to break the mould of current drug research, innovate exponentially without expanding R&D investment and speed the development of tomorrow’s life-saving medicines for diseases.

TOPICS TO DISCUSS
- The challenges of sustained productivity: Are we on the "patent cliff" as the patents for blockbuster drugs expire?
- Could Open Innovation provide answers to these challenges?
- Is sharing of intellectual property a barrier to Open Innovation?
- Engaging in Public-Private Partnerships to enhance drug development
- Successful examples of sharing patents, compounds, data and expertise: Collaboration between Academia and the corporate sector, Crowd sourcing initiatives, Neglected diseases drug discovery, etc.

WHO WILL YOU MEET?
- CXOs, SVPs, VPs, Heads, Directors of major Pharmaceutical/ Biotech companies responsible for: Biomedical Research, Drug Discovery, External R&D, Medicinal Chemistry, Alliance Management, Intellectual Property, Non-Clinical Safety, External Networks and Partnerships, Strategic Alliances, Collaborative Research, etc.
- Professors, scientists and researchers from Universities and Research Centres with an expertise in: Biomedical Research, Biology, Medicinal Chemistry, Drug Discovery, Intellectual Property, etc.
- Representatives from Governmental bodies and Non-profit drug R&D organisations

YOUR PRESTIGIOUS SPEAKER PANEL

Dr. Timothy Grees
Eli Lilly & Co., USA
Chief Scientific Officer, Lead Generation and External Innovation

Dr. Duncan Richards
GlaxoSmithKline, UK
Vice President and Clinical Head of Academic Discovery Performance Unit

Dr. Marie-Pierre de Bethune
Tibotec, a Johnson and Johnson company, Belgium
Vice President, External Innovation

Prof. Michel Goldman
Innovative Medicines Initiative, Belgium
Executive Director

Dr. Martino Picardo
Stevenage Bioscience Catalyst, UK
CEO

Dr. Wen-Hwa Lee
Structural Genomics Consortium, UK
Scientific Coordinator – University of Oxford

Dr. Paul Fehlner
Novartis Pharma, Switzerland
Global Head, Pharma Intellectual Property

Dr. Labeeb Abboud
International AIDS Vaccine Initiative, USA
Senior Vice President and General Counsel

Prof. Graham Dutfield
University of Leeds, School of Law, UK
Professor of International Governance

Dr. Jacques Delort (TBC)
Sanofi, France
Vice President, Prospective and Strategic Initiatives in R&D

Dr. Anthony Coyne
Pfizer, USA
Vice President & Chief Scientific Officer, Centers for Therapeutic Innovation

Thomas Krohn, RPh
Eli Lilly & Co., USA
Director, Clinical Open Innovation

Dr. Robert Sebbag
Sanofi, France
Vice President, Access to Medicines

Dr. Mike Strange
GlaxoSmithKline, UK
Head of Operations, Tres Cantos Medicines Development Campus

Dr. Menghia Bairu (TBC)
Elan, USA
Executive Vice President, General Manager (and Board Member at the Institute for OneWorld Health)

Dr. Jeroen Tonnaer
Merck Sharp & Dohme, the Netherlands
Senior Director, Head European Team, External Scientific Affairs

Prof. Daria Meshuly-Rosen
Stanford University, School of Medicine, USA
Professor of Chemical and Systems Biology

Prof. Stan van Boeckel
Leiden University, the Netherlands
Professor of Industrial Medicinal Chemistry and Drug Discovery, Former Head of Medicinal Chemistry, MSD

Dr. Beatrice De Vogel
Promethera Biosciences, Belgium
Chief Medical Officer

Dr. Kathryn Chapman
NC3Rs, UK
Head of Innovation and Translation
Day 1 | 26th April, 2012

8:30 Registration and Coffee

9:00 Opening remarks from the chair

Is Open Innovation an Answer to the Challenges of Sustained Productivity?

9:05 Dynamics of Big Pharma, SME and academic research in Pharmaceutical R&D
- Are there many differences yet not better nor worse?
- Are there entities phases of a natural growth curve or are they equal partners?
- How realistic is open innovation in the current legal, regulatory, and commercial environment?

Beatrice De Vos, Promethera Biosciences
Chief Medical Officer

9:40 Driving Innovation in Drug Discovery through Network Collaborations
- New partnerships with academia and industry
- Novel approaches to drug discovery
- Strengthening the scientific core of pharma

Anthony Coyle, Pfizer, Centers for Therapeutic Innovation, Vice President & Chief Scientific Officer

10:05 Accelerating Clinical Development through Open Innovation
- The case for open innovation in clinical development
- Leveraging public data and open networks in clinical development
- Establishing a clinical research commons: initial experience

Thomas Krohn, Eli Lilly & Co., Director, Clinical Open Innovation

10:40 Morning coffee & networking

Overcoming Barriers to Open Innovation

11:10 PANEL DISCUSSION: Alternative Patent Management Strategies for Drug Discovery (Perspectives of Academia, Non-for-profit and Industry)
Each of the panelists will deliver a 15-minute presentation. The presentations will be followed by a discussion focusing on these issues:
- Open innovation (allowing the knowledge of a company to spill over to others) vs. IP protection (enabling a company to exclude others from using that knowledge) - Are these concepts really irreconcilable?
- Is the IP framework a reason for the decline of open innovation? Or is open innovation undermining the concept of IP?
- Difference between open source and open innovation in terms of IP
- How can “heavy patients” in the Pharmaceutical industry use their IP system while engaging the new open innovation model?
- Need for proactive IP management – sharing royalties and commercialization rights, but protecting the IP rights to enhance drug development
- Important negotiating points in collaboration agreements

Paul Fechner, Novartis Pharma
Global Head, Pharma Intellectual Property

Graham Dutfield, University of Leeds, School of Law
Professor of International Governance

Labeeb Aboud, International AIDS Vaccine Initiative, Senior Vice President and General Counsel

12:30 Investing in a Culture of Collaboration and Innovation Within a Company
- The “discovered in house” syndrome
- Building the open innovation culture
- Complementary or supplementary external research?
- Get the buy-in from all involved
- Don’t forget about the internal resources needed to implement the model

Dr. Marie-Pierre de Bethune, Tibotec, a Johnson and Johnson company, Vice President, External Innovation

13:05 Luncheon

External Partnerships to Increase Innovation

14:50 CASE STUDY: Innovative Medicines Initiative: the European response to the innovation challenge in the pharmaceutical sector
- Non-competitive research and open innovation: the way forward for big pharma
- Concrete achievements of ongoing projects
- Best practices in managing IP
- Rewards and incentives for collaborative innovation
- The patient at the core of IMI projects

Michel Goldman, Innovative Medicines Initiative
Executive Director

15:25 CASE STUDY: Structural Genomics Consortium: one of the world’s leading pre-competitive consortia
- Benefitting from pre-competitive research – getting access to expertise and facilities, leveraging funds and mitigating risks
- Promoting the development of new medicines and placing all information and know-how into the public domain without restriction
- Engaging Academia with large Pharmaceutical companies in pre-competitive research of 3D structure of proteins to facilitate the discovery of new medicines
- Generation of open-access chemical and biological probes to enable target validation

Wen-Hwa Lee, Structural Genomics Consortium
Scientific Coordinator – University of Oxford

16:00 CASE STUDY: Stevenage Bioscience Catalyst: UK’s first open innovation campus
- What examples of Open Innovation are there in the sector?
- What is the landscape like in the UK?
- What is the Stevenage Bioscience Catalyst doing in the Open Innovation space?

Martino Picardo, Stevenage Bioscience Catalyst, CEO

16:35 Interactive Discussion featuring speakers from the afternoon session

16:50 Closing remarks from the Chair

17:00 Close of Day 1

Speakers and delegates are cordially invited to attend a Networking Cocktail Reception
**Day 2 | 27th April, 2012**

**9:00** Opening remarks from the chair

**9:10** Case Studies: Collaboration between Academia and the Corporate Sector toward Therapeutic Innovation

Each of these speakers will deliver a 20-minute presentation:
- **Jeroen Tonnser, Merck Sharp & Dohme**, Senior Director, Head European Team, External Scientific Affairs
- **Jacques Delper, Sanofi (B&C)**: Vice President, Prospective and Strategic Initiatives in R&D
- **Jean van Boeckel, Leiden University & Eindhoven University of Technology**, Professor of Industrial Medicinal Chemistry and Drug Discovery

**Academia perspective**
- *How can Pharma profit more from the technological and scientific capabilities at Academia?*
- *How can Academia become more attractive for Pharma?*

**SPARK Program**
- **SPARK mission** – to facilitate transfer of academic research discoveries for society’s benefit and health
- **Our approach and remaining challenges**
- **Report on the program, now in its sixth year**

**10:55** Morning coffee & networking

**11:25** Case Studies: Crowdsourcing as an Open Innovation Model for Drug Discovery and Development

Each of these speakers will deliver a 20-minute presentation:
- **Timothy Crese, Eli Lilly & Co.**
  - Chief Scientific Officer, Lead Generation and External Innovation
  - The Lilly Open Innovation Drug Discovery Program
    - Why “open innovation” in Drug Discovery
    - How Lilly is developing a unique framework to support open innovation
    - Early results from Lilly’s program and plans for expansion and future development
- **Duncan Richards, GlaxoSmithKline**
  - Vice President and Clinical Head of Academic Discovery Performance Unit
  - Experience with the GSK open innovation platform: Pharma in Partnership
    - Open innovation as a means to connect to the academic community
    - Open innovation as a means to repurpose molecules from larger Pharma

**13:00** Luncheon

**14:30** Patent and Data Sharing in Neglected Disease Drug Discovery

Each of these speakers will deliver a 20-minute presentation:
- **Mike Strange, GlaxoSmithKline**
  - Head of Operations, Tres Cantos Medicines Development Campus
- **Robert Sebag, Sanofi**
  - Vice President, Access to Medicines
- **Menghis Bairu, the Institute for OneWorld Health (TBC)**
  - Board Member

**15:55** Closing remarks from the Chair

**16:00** End of Day 2 followed by Farewell coffee & networking
Appendix F: IRB approval for Survey of Open Innovation in Pharmaceutical R&D

MEMORANDUM

DATE: April 4, 2012

TO: Donald E. Hatfield, Hanko Zeitzmann

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Survey of Open Innovation in Pharmaceutical R&D

IRB NUMBER: 12-340

Effective April 2, 2012, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the new protocol for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: Expedited, under 45 CFR 46.110 category(ies) 7
Protocol Approval Date: 4/2/2012
Protocol Expiration Date: 4/1/2013
Continuing Review Due Date*: 3/18/2013

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERAFLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.
Appendix G: Survey screenshots

Dear survey participant,

Thank you for participating in the following survey of open innovation in pharmaceutical R&D. The survey is sent out by Fleming Europe to all companies invited to attend the “Open Innovation in Pharmaceutical R&D” conference to be held in Amsterdam, April 26th and 27th, 2012. Participation in the survey is completely voluntary and you may stop offering responses at any time. You may also choose not to answer individual questions. There will be no compensation for participating in this study. By answering this survey you give implied consent for the use of your responses in the analyses.

You are asked to provide some company information and answer about 45 questions on broadcast search. Answering the survey will take about 20-30 minutes. Estimates are acceptable so please answer all questions to the best of your ability. We understand that some information is of strategic importance for organizations so we will ensure that identification of the survey participants and their companies will remain confidential.

The research is conducted by a team of researchers at Virginia Tech. PhD candidate Hanko K. Zeitzmann is conducting this survey as part of his dissertation research under the supervision of Dr. Donald E. Hatfield. For any questions regarding this research and the survey please contact Hanko Zeitzmann directly at hz@vt.edu.

Thank you very much for offering your valuable insights to this research.
Please provide the following information

Your company name (will remain confidential):

Your name (will remain confidential):

Will you or someone from your company attend the "Open Innovation in Pharmaceutical R&D" conference to be held in Amsterdam, April 26th and 27th, 2012?

- yes, I myself
- yes, someone else from my organization
- no
- maybe/undecided

What is your title/function:

My organization is...

- privately held
- publicly traded

Please classify your institution according to the following:

Private enterprise
- a) National (no controlled affiliates abroad).
- b) Multinational, of which there might be three types:

if Multinational:
- foreign-controlled affiliates (CAs) (where the affiliate does not control any other affiliates abroad).
- foreign-controlled affiliates with CAs (parent companies under foreign control).
- Parent companies with CAs abroad (parent company not under foreign control).

Public enterprise "resident non-financial corporations and quasi-corporations that are subject to control by government units, control over a corporation being defined as the ability to determine general corporate policy by choosing appropriate directors, if necessary."

- Not-for-profit organization

What is your company’s main industry:

- biotechnology
- pharmaceutical
- other

What is your company size (number of employees):

- 1-9
- 10-49
- 50-249
- 250-499
- 500-4999
- 5000-24999
- 25000 and above

You will have an opportunity to provide additional information at the end of the survey.
Within the open innovation framework, a structured inbound open innovation approach labeled “broadcast search” has been characterized as a “problem-solving process [which operates] by disclosing the details of the problem at hand and inviting the participation of anyone who deems themselves qualified to solve the problem.” (Jeppesen & Lakhani, 2010). In practice, the reach of the broadcast search is sometimes restricted to pre-selected groups such as scientists at universities. Also, it is often just labeled ‘open innovation’.

With this understanding in mind, please answer the following questions.

My organization uses broadcast search in the research and development (R&D) process. (check all that apply)

☐ yes, we currently use broadcast search
☐ no, we currently do not use broadcast search
☐ we intend to use broadcast search in the future
☐ we use other inbound open innovation approaches; please explain:

Please rate the following on a scale from (1) 'I strongly disagree' to (5) 'I strongly agree':

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tbody>
<tr>
<td>A systematic process has been established for carrying out the broadcast search activities.</td>
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<td>There is a formalized corporate strategy for broadcast search.</td>
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<td>All persons involved in the broadcast search process know exactly their particular tasks.</td>
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<td>The interfaces between different persons and units involved in the broadcast search process are well defined.</td>
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<td>The reward for solutions is generally pre-determined and clearly stated (i.e., as a monetary amount) in the call.</td>
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<td>Compensation for solutions are generally negotiated individually with the solvers after the solution has been submitted and evaluated.</td>
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<td>Responses to our broadcast search activities are generally of high quality.</td>
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<td>The variety of solutions offered in response to our broadcast search activities generally exceeds that of our internal research on the same or comparable projects.</td>
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<td>In relation to our direct competitors, we are successful in the broadcast search activities.</td>
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<td>We use broadcast search more successfully for strategic objectives than our direct competitors.</td>
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<td>We use broadcast search to replace other forms of knowledge acquisition (such as M&amp;As, Alliances, internal R&amp;D, etc.).</td>
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Please describe the strategic objective of your company's use of broadcast search.
How many innovations has your company made based on responses to broadcast search activities?
- 0
- 1-5
- 6-10
- 11-25
- 26-100
- more than 100

How many products have been introduced to the market based on solutions received from broadcast search activities?
- 0
- 1-5
- 6-10
- 11-25
- 26-100
- more than 100

Please rate the following on a scale from (1) 'I strongly disagree' to (7) 'I strongly agree':

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tr>
<td>The return on our investments in broadcast search activities is high.</td>
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<td>Broadcast search is important for our core business.</td>
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<td>Broadcast search is only used for peripheral R&amp;D activities.</td>
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<td>We employ broadcast search only after we are unable to solve the problem internally.</td>
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<td>We employ broadcast search as a core strategic tool.</td>
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<td>We often use broadcast search for our research projects.</td>
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<td>We spend considerable resources to communicate our intention to seek solutions to our posted broadcast search calls.</td>
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<td>I often hear of broadcast search activities of our direct competitors.</td>
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<td>In comparison with our competitors, our patent portfolio is technologically superior.</td>
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<tr>
<td>In comparison with our competitors, we hold more patents on breakthrough inventions.</td>
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<td>In comparison with our competitors, our patent position is weaker overall.</td>
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</tbody>
</table>

In the last financial year, what percent of total R&D spending went to broadcast search activities?
Please rate the following on a scale from (1) ‘I strongly disagree’ to (7) ‘I strongly agree’:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host competitors in our industry are active in broadcast search activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our spending on broadcast search activities increased considerably during the last 5 years.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We use a formalized strategy for broadcast search.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our broadcast search activities are closely coordinated with our product strategies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our use of broadcast search is restricted to non-core technologies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What is the (approximate) number of persons in your firm who are occupied full-time with broadcast search activities? (absolute value)

Please rate the following on a scale from (1) ‘I strongly disagree’ to (7) ‘I strongly agree’:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organizational level at which the final decision to use broadcast search is taken is clearly defined (corporate or business unit).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In relation to our direct competitors, we are successful in the broadcast search activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We use broadcast search more successfully for strategic objectives than our direct competitors.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The return from our investments in broadcast search activities is high.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My company is involved in orphan drug research.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We use broadcast search mainly or exclusively for orphan drug research.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What is your company’s total budget for broadcast search?

How many R&D co-operations or joint ventures with other organizations does your company have? (approximate value)

Since we started using broadcast search approaches, the number of co-operations with established companies within the industry...

increased. | decreased. | remained the same. |
|-----------|------------|--------------------|

Since we started using broadcast search approaches, the number of mergers and acquisitions (M&As) we have been involved in...

increased. | decreased. | remained the same. |
|-----------|------------|--------------------|

Since we started using broadcast search approaches, the number of internal research and development projects has...

increased. | decreased. | remained the same. |
|-----------|------------|--------------------|

Please provide any additional information that might be of interest for this research:
Appendix H: Email to pharmaceutical companies

Dr. Donald E. Hatfield  
Associate Professor of Strategic Management and Entrepreneurship  
Department of Management  
2090 Pamplin (0233)  
Blacksburg, Virginia 24061  
540/231-4887 Fax: 540/231-3076  
www.management.pamplin.vt.edu

Dear Madam or Sir,

A research group at Virginia Tech under the leadership of Professor Donald E. Hatfield is currently preparing a study on open innovation in pharmaceutical companies. We kindly ask for your support by providing some very brief responses to four questions. The research is conducted in compliance with and under the supervision of the Institutional Review Board (IRB) at Virginia Tech and all information provided will be kept strictly confidential and not be used for any purposes outside of this research.

Specifically, our research is concerned with an inbound open innovation process called ‘broadcast search’ which has been characterized as a “problem-solving process [which operates] by disclosing the details of the problem at hand and inviting the participation of anyone who deems themselves qualified to solve the problem.” (Jeppesen & Lakhani, 2010). In practice, it is often just labeled ‘open innovation’.

For our research we kindly ask for the following:

1. Please provide the name and contact information of the person in charge of such open innovation projects.
2. Please provide the date (year) such open innovation was first instituted in your company.
3. If available, please provide press releases or brief descriptions about your open innovation activities.
4. If available, please provide links to your open innovation projects.

Please also inform us if your company does NOT engage in open innovation activities. Responses should be sent to hz@vt.edu.

Thanks and best regards,

Hanko Zeitzmann  
Research Assistant  
Department of Management  
2059 Pamplin (0233)  
Blacksburg, Virginia 24061  
540/231-4024 Fax: 540/231-3076  
www.management.pamplin.vt.edu
Appendix I: IRB approval for Email Inquiry about Broadcast Search Involvement

MEMORANDUM

DATE: August 27, 2012
TO: Donald E Hatfield, Hanko Kalle Zeitzmann
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Email inquiry about Pharmaceutical Companies’ involvement in Broadcast Search

IRB NUMBER: 12-731

Effective August 25, 2012, the Virginia Tech Institutional Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:
Approved As: Exempt, under 45 CFR 46.110 category(ies) 2
Protocol Approval Date: August 25, 2012
Protocol Expiration Date: N/A
Continuing Review Due Date*: N/A

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Initial IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.
### Appendix J: Select responses to email inquiry at pharmaceutical organizations

<table>
<thead>
<tr>
<th>Response</th>
<th>Final Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thank you for your inquiry to XXX. This is an automated note to provide you with the case number: XXX, and to let you know that our Customer Service goal is to reply within two business days (based on U.S. Central time). We appreciate your interest in XXX.</td>
<td>Never received a follow-up</td>
</tr>
<tr>
<td>Dear Mr. Hanko Zeitzmann,</td>
<td>Went with the coding already conducted</td>
</tr>
<tr>
<td>Thank you for contacting XXX.</td>
<td></td>
</tr>
<tr>
<td>The information you requested is available online at <a href="http://www.xxx.xx">www.xxx.xx</a> If you are unable to locate the specific information requested, please call the XXX Customer Information Center at XXX.</td>
<td></td>
</tr>
<tr>
<td>Sincerely,</td>
<td></td>
</tr>
<tr>
<td>XXX</td>
<td></td>
</tr>
<tr>
<td>Customer Information Center</td>
<td></td>
</tr>
<tr>
<td>Dear Mr. Hanko Zeitzmann:</td>
<td></td>
</tr>
<tr>
<td>Thank you for contacting XXX .</td>
<td></td>
</tr>
<tr>
<td>At this time, we do not have any information to offer with regard to your specific request. If you have further questions concerning XXX or our products, please contact our Response Center at XXX during our normal business hours, Monday through Friday 8:00 A.M. to 6:00 P.M. (Eastern Time). This is a send only email address. Please do not reply to this email.</td>
<td></td>
</tr>
<tr>
<td>Sincerely,</td>
<td></td>
</tr>
<tr>
<td>XXX</td>
<td></td>
</tr>
<tr>
<td>Response Center Representative</td>
<td>coded 0</td>
</tr>
<tr>
<td>XXX Customer Care has received your request. We will reply to your message as soon as possible. Please do not reply to this email. If you have an urgent question please call XXX. Thank you for contacting us. Sincerely, XXX Customer Care</td>
<td>Never received a follow-up</td>
</tr>
<tr>
<td>Your inquiry has been received. We are currently investigating your request and we will get back to you as soon as possible. THREAD ID: XXX</td>
<td>Never received a follow-up</td>
</tr>
</tbody>
</table>
Dear Hanko:
Thank you for contacting XXX. It is always important to hear from our customers and we appreciate the time you have taken to contact us.
As you can imagine, we receive many more inquires from students regarding school projects than we are able to handle. As indicated on our Web site, due to the volume of these requests, we are unable to answer individual questions or participate in surveys or interviews.
There is a wealth of information on our Web site, and we suggest you start by looking under Resources for Students: http:xxx.htm, where you will find links to our history and financial information. You may find our new history blog at www.xxx.com particularly interesting.
Unfortunately, we do not provide proprietary information on manufacturing, advertising, market share, competition, pricing, strategic planning or sales information by operating unit, geographic area or product category. We also cannot provide the names of our employees.
We hope you'll search all the parts of xxx.com. We especially encourage you to take a look at our current Annual Report and those from past years, which you may find on our Web site in the Investor Relations section.
Again, thank you for your interest in XXX.
XXX.
Customer Care Center

Your email below was forwarded to me from our VP Investor Relations. At this time we do not use open innovation as you described. We utilize contract resources and our internal and external resources to network for solutions to particular issues or research.
I hope this is beneficial to your research.
Thanks
XXX

XXX declines to participate.
Thank you,
XXX

XXX doesn't have an open innovation project per se. We would be able to participate in this survey. Please remove from mailing list. Thank you.

Dear Hanko Zeitzmann,
Thank you for contacting XXX. Our database does not contain any information specific to your inquiry.
If we can further assist you or your health care professional, please call the Information Center at XXX at XXX, Monday through Friday, from 8 a.m. to 6 p.m. ET, excluding holidays.
Sincerely,
Information Center at XXX
Thank you for contacting us.
This message is to confirm we have received your message and will be contacting you shortly.

Thank you for contacting XXX through the Business Development mailbox. We are engaged exclusively in out-licensing at this time, and are not considering any in-licensing opportunities. If your e-mail was related to a licensing opportunity that you have, this is the last e-mail you will receive. If your e-mail is related to a product or service that you offer, we will forward it to the appropriate department within XXX and they will contact you if there is interest. If you contacted us because of interest in one of the programs we have available for partnering, we will be in touch shortly to arrange appropriate follow up. Thank you again for your interest in XXX.
XXX Business Development
Please do not reply to this e-mail.

Mr. Zeitzmann: Please accept our apologies for the delay responding to your inquiry. Our Senior Director of Investor/Public Relations and Corporate Communications has reviewed your request and feels that the request is not applicable to XXX. Thank you for your interest in XXX. Best wishes with your study.

Thank you for the information, but this is not an appropriate study for XXX.
Many thanks,
XXX

Hello Hanko:
We do not currently participate in any open innovation activities, so we are not good candidates for your study.
Best regards,
XXX

Your email has been sent.
Thank you.
PLEASE DO NOT REPLY TO THIS AUTOMATED MESSAGE AS IT WILL NOT BE RECEIVED.

Dear Dr. Zeitzmann,
Thank you for your inquiry. XXX does not engage in open innovation activities.
Best regards,
XXX

Other responses were similar to those that ignored follow ups or were otherwise generic.
Appendix K: Survey responses

Results from the survey administered to organizations invited for participation in Fleming Europe's "Open Innovation in Pharmaceutical R&D" conference held in Amsterdam on April 26th + 27th, 2012

<table>
<thead>
<tr>
<th>Company name provided by</th>
<th>12 respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal name provided by</td>
<td>11 respondents</td>
</tr>
<tr>
<td>Title / function provided by</td>
<td>14 respondents</td>
</tr>
</tbody>
</table>

Will you or someone from your company attend the “Open Innovation in Pharmaceutical R&D” conference to be held in Amsterdam, April 26th and 27th, 2012?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>yes, I myself</td>
<td>5</td>
</tr>
<tr>
<td>yes, someone else from my organization</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>maybe/undecided</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
</tr>
</tbody>
</table>

My organization is…

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>privately held</td>
<td>5</td>
</tr>
<tr>
<td>publicly traded</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
</tr>
</tbody>
</table>

Please classify your institution according to the following:

- a) National (no controlled affiliates abroad).
  - 3 21.4%
- b) Multinational, of which there might be three types:
  - 8 57.1%
  - Foreign-controlled affiliates (CAs) (where the affiliate does not control any other affiliates abroad).
  - 4 28.6%
  - Foreign-controlled affiliates with CAs (parent companies under foreign control).
  - 3 21.4%
  - Parent companies with CAs abroad (parent company not under foreign control).
  - 1 7.1%
- Public enterprise “resident non-financial corporations and quasi-corporations that are subject to control by government units, control over a corporation being defined as the ability to determine general corporate policy by choosing appropriate directors, if necessary”.
  - 3 21.4%
- Not-for-profit organization
  - 3 21.4%

What is your company’s main industry:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>biotechnology</td>
<td>0</td>
</tr>
<tr>
<td>pharmaceutical</td>
<td>10</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
</tr>
</tbody>
</table>

What is your company size (number of employees):

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-9</td>
<td>0</td>
</tr>
<tr>
<td>10-49</td>
<td>2</td>
</tr>
<tr>
<td>50-249</td>
<td>1</td>
</tr>
<tr>
<td>250-499</td>
<td>0</td>
</tr>
<tr>
<td>500-4999</td>
<td>1</td>
</tr>
<tr>
<td>5000-24999</td>
<td>5 35.7%</td>
</tr>
<tr>
<td>25000 and above</td>
<td>5 35.7%</td>
</tr>
</tbody>
</table>
The above definition of broadcast search is congruent to my understanding of open innovation.
Yes, I see the two as interchangeable 3 25.0%
No, open innovation for me is more broad 9 75.0%
No, open innovation for me is more narrow 0 0.0%
Total 12 100.0%

My organization uses broadcast search in the research and development (R&D) process. (check all that apply)
yes, we currently use broadcast search 3 30.0%
no, we currently do not use broadcast search 6 60.0%
we intend to use broadcast search in the future 1 10.0%
we use other inbound open innovation approaches; please explain: 1 10.0%
-- no explanations were given --
Total Responses 10

How many innovations has your company made based on responses to broadcast search activities?
0 3 50.0%
1-5 3 50.0%
6-10 0 0.0%
11-25 0 0.0%
26-100 0 0.0%
more than 100 0 0.0%
Total 6 100.0%

How many products have been introduced to the market based on solutions received from broadcast search activities?
0 4 66.7%
1-5 2 33.3%
6-10 0 0.0%
11-25 0 0.0%
26-100 0 0.0%
more than 100 0 0.0%
Total 6 100.0%

In the last financial year, what percent of total R&D spending went to broadcast search activities?
< 1 %
0%
Total Responses 3

What is the [approximate] number of persons in your firm who are occupied full-time with broadcast search activities? (absolute value)
10
0
Total Responses 3
What is your company’s total budget for broadcast search?

<table>
<thead>
<tr>
<th>Budget Range</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&lt;1 million SEK</td>
<td>0</td>
</tr>
</tbody>
</table>

Total Responses 3

How many R&D co-operations or joint ventures with other organizations does your company have? (approximate value)

<table>
<thead>
<tr>
<th>Number of Co-operations</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

Total Responses 3

Since we started using broadcast search approaches, the number of co-operations with established companies within the industry...

<table>
<thead>
<tr>
<th>Change</th>
<th>0</th>
<th>0.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>increased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>decreased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>remained the same</td>
<td>5</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Total 5 100.0%

Since we started using broadcast search approaches, the number of mergers and acquisitions (M&As) we have been involved in...

<table>
<thead>
<tr>
<th>Change</th>
<th>0</th>
<th>0.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>increased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>decreased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>remained the same</td>
<td>4</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Total 4 100.0%

Since we started using broadcast search approaches, the number of internal research and development projects has...

<table>
<thead>
<tr>
<th>Change</th>
<th>0</th>
<th>0.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>increased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>decreased</td>
<td></td>
<td></td>
</tr>
<tr>
<td>remained the same</td>
<td>5</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Total 5 100.0%

How old is your company? (years)

<table>
<thead>
<tr>
<th>Age</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>100+</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>8 years</td>
<td></td>
</tr>
<tr>
<td>115 years</td>
<td></td>
</tr>
</tbody>
</table>

Total Responses 5

What is the geographic location of the corporate headquarters?

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td></td>
</tr>
<tr>
<td>Amsterdam</td>
<td></td>
</tr>
<tr>
<td>Helsingborg, Sweden</td>
<td></td>
</tr>
<tr>
<td>Basel, Switzerland</td>
<td></td>
</tr>
</tbody>
</table>

Total Responses 5
<table>
<thead>
<tr>
<th>What was your revenue for the last financial year?</th>
</tr>
</thead>
<tbody>
<tr>
<td>not disclosed</td>
</tr>
<tr>
<td>10 Billion EUR</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>2.7 Billion CHF</td>
</tr>
<tr>
<td>Total Responses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How much did your company spend on R&amp;D in the last financial year?</th>
</tr>
</thead>
<tbody>
<tr>
<td>not disclosed</td>
</tr>
<tr>
<td>1.5 Billion EUR</td>
</tr>
<tr>
<td>SEK 40 million</td>
</tr>
<tr>
<td>for the Chemical R&amp;D ca. 50 Mill. CHF</td>
</tr>
<tr>
<td>Total Responses</td>
</tr>
</tbody>
</table>
### Appendix L: Survey responses for 7-point Likert scale questions (ratings)

**Please rate the following on a scale from (1) ‘I strongly disagree’ to (7) ‘I strongly agree’:**

<table>
<thead>
<tr>
<th>Block I:</th>
<th>Min Value</th>
<th>Max Value</th>
<th>Mean</th>
<th>Variance</th>
<th>Standard Deviation</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>A systematic process has been established for carrying out the broadcast search activities.</td>
<td>1</td>
<td>6</td>
<td>4.00</td>
<td>3.11</td>
<td>1.76</td>
<td>10</td>
</tr>
<tr>
<td>There is a formalized corporate strategy for broadcast search.</td>
<td>1</td>
<td>6</td>
<td>3.90</td>
<td>2.99</td>
<td>1.73</td>
<td>10</td>
</tr>
<tr>
<td>All persons involved in the broadcast search process know exactly their particular tasks.</td>
<td>1</td>
<td>7</td>
<td>4.10</td>
<td>3.66</td>
<td>1.91</td>
<td>10</td>
</tr>
<tr>
<td>The interfaces between different persons and units involved in the broadcast search process are well defined.</td>
<td>1</td>
<td>6</td>
<td>3.80</td>
<td>3.51</td>
<td>1.87</td>
<td>10</td>
</tr>
<tr>
<td>The reward for solutions is generally pre-determined and clearly stated (i.e., as a monetary amount) in the call. Compensations for solutions are generally negotiated individually with the solvers after the solution has been submitted and evaluated. Responses to our broadcast search activities are generally of high quality. The variety of solutions offered in response to our broadcast search activities generally exceeds that of our internal research on the same or comparable projects. In relation to our direct competitors, we are successful in the broadcast search activities. We use broadcast search more successfully for strategic objectives than our direct competitors. We use broadcast search to replace other forms of knowledge acquisition (such as M&amp;As, Alliances, internal R&amp;D, etc.).</td>
<td>1</td>
<td>6</td>
<td>3.70</td>
<td>2.90</td>
<td>1.70</td>
<td>10</td>
</tr>
</tbody>
</table>
Please rate the following on a scale from (1) ‘I strongly disagree’ to (7) ‘I strongly agree’:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Min Value</th>
<th>Max Value</th>
<th>Mean</th>
<th>Variance</th>
<th>Standard Deviation</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>The return on our investments in broadcast search activities is high.</td>
<td>1</td>
<td>4</td>
<td>3.50</td>
<td>1.50</td>
<td>1.22</td>
<td>6</td>
</tr>
<tr>
<td>Broadcast search is important for our core business.</td>
<td>1</td>
<td>5</td>
<td>3.50</td>
<td>1.90</td>
<td>1.38</td>
<td>6</td>
</tr>
<tr>
<td>Broadcast search is only used for peripheral R&amp;D activities.</td>
<td>1</td>
<td>4</td>
<td>2.60</td>
<td>1.80</td>
<td>1.34</td>
<td>5</td>
</tr>
<tr>
<td>We employ broadcast search only after we are unable to solve the problem internally.</td>
<td>1</td>
<td>5</td>
<td>3.67</td>
<td>1.87</td>
<td>1.37</td>
<td>6</td>
</tr>
<tr>
<td>We employ broadcast search as a core strategic tool.</td>
<td>1</td>
<td>4</td>
<td>3.00</td>
<td>1.60</td>
<td>1.26</td>
<td>6</td>
</tr>
<tr>
<td>We often use broadcast search for our research projects.</td>
<td>1</td>
<td>4</td>
<td>3.50</td>
<td>1.50</td>
<td>1.22</td>
<td>6</td>
</tr>
<tr>
<td>We spend considerable resources to communicate our intention to seek solutions to our posted broadcast search calls.</td>
<td>1</td>
<td>5</td>
<td>3.33</td>
<td>2.27</td>
<td>1.51</td>
<td>6</td>
</tr>
<tr>
<td>I often hear of broadcast search activities of our direct competitors.</td>
<td>1</td>
<td>7</td>
<td>3.33</td>
<td>5.07</td>
<td>2.25</td>
<td>6</td>
</tr>
<tr>
<td>In comparison with our competitors, our patent portfolio is technologically superior.</td>
<td>4</td>
<td>6</td>
<td>4.50</td>
<td>0.70</td>
<td>0.84</td>
<td>6</td>
</tr>
<tr>
<td>In comparison with our competitors, we hold more patents on breakthrough inventions.</td>
<td>3</td>
<td>5</td>
<td>4.00</td>
<td>0.40</td>
<td>0.63</td>
<td>6</td>
</tr>
<tr>
<td>In comparison with our competitors, our patent position is weaker overall.</td>
<td>2</td>
<td>4</td>
<td>3.50</td>
<td>0.70</td>
<td>0.84</td>
<td>6</td>
</tr>
</tbody>
</table>
Please rate the following on a scale from (1) ‘I strongly disagree’ to (7) ‘I strongly agree’:

**Block III:**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Min Value</th>
<th>Max Value</th>
<th>Mean</th>
<th>Variance</th>
<th>Standard Deviation</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most competitors in our industry are active in broadcast search activities.</td>
<td>2</td>
<td>6</td>
<td>4.00</td>
<td>1.60</td>
<td>1.26</td>
<td>6</td>
</tr>
<tr>
<td>Our spending on broadcast search activities increased considerably during the last 5 years.</td>
<td>1</td>
<td>5</td>
<td>3.83</td>
<td>2.17</td>
<td>1.47</td>
<td>6</td>
</tr>
<tr>
<td>We use a formalized strategy for broadcast search.</td>
<td>1</td>
<td>5</td>
<td>3.33</td>
<td>2.27</td>
<td>1.51</td>
<td>6</td>
</tr>
<tr>
<td>Our broadcast search activities are closely coordinated with our product strategies.</td>
<td>1</td>
<td>7</td>
<td>4.00</td>
<td>3.60</td>
<td>1.90</td>
<td>6</td>
</tr>
<tr>
<td>Our use of broadcast search is restricted to non-core technologies.</td>
<td>1</td>
<td>4</td>
<td>2.67</td>
<td>2.27</td>
<td>1.51</td>
<td>6</td>
</tr>
</tbody>
</table>

**Block IV:**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Min Value</th>
<th>Max Value</th>
<th>Mean</th>
<th>Variance</th>
<th>Standard Deviation</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organizational level at which the final decision to use broadcast search is taken is clearly defined (corporate or business unit).</td>
<td>1</td>
<td>6</td>
<td>3.50</td>
<td>3.10</td>
<td>1.76</td>
<td>6</td>
</tr>
<tr>
<td>In relation to our direct competitors, we are successful in the broadcast search activities.</td>
<td>1</td>
<td>4</td>
<td>3.17</td>
<td>1.77</td>
<td>1.33</td>
<td>6</td>
</tr>
<tr>
<td>We use broadcast search more successfully for strategic objectives than our direct competitors.</td>
<td>1</td>
<td>4</td>
<td>3.00</td>
<td>1.60</td>
<td>1.26</td>
<td>6</td>
</tr>
<tr>
<td>The return from our investments in broadcast search activities is high.</td>
<td>1</td>
<td>4</td>
<td>3.17</td>
<td>1.77</td>
<td>1.33</td>
<td>6</td>
</tr>
<tr>
<td>My company is involved in orphan drug research.</td>
<td>1</td>
<td>7</td>
<td>4.33</td>
<td>4.27</td>
<td>2.07</td>
<td>6</td>
</tr>
<tr>
<td>We use broadcast search mainly or exclusively for orphan drug research.</td>
<td>1</td>
<td>4</td>
<td>3.00</td>
<td>1.60</td>
<td>1.26</td>
<td>6</td>
</tr>
</tbody>
</table>