Patently Wrong? Firm Strategy and the Decision to Disband Technological Assets

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Abstract

Considerable research in strategy and innovation has been devoted to examining when and how firms accumulate resources. Yet, little empirical work has focused on when firms disband resources and how this decision to disband resources is affected by firm strategy. This oversight is surprising since theoretical work has highlighted the importance of knowing which assets to grow and which assets to trim. This paper shows that firms' decisions to disband assets are significantly influenced by earlier strategic choices, and the effects are distributed non-uniformly across firms in the industry. These results suggest that empirical research that ignores disbanded assets, and firms' reasons for disbanding those assets, can lead to biased measurements and conclusions on the value of pursuing particular strategies. To test our hypotheses, we examine how the R&D strategy that a pharmaceutical firm chooses —exploratory versus exploitative—influences the likelihood that the firm disband their patents: specifically, not to renew the patent and allow the intellectual property right to expire before the end of the patent term.

INTRODUCTION

Scholars studying strategy and organizations historically focused on how firms acquire and exploit unique assets or resources for sustained competitive advantage (Teece, Pisano, and Shuen 1997). But, to the extent that firms consistently seek, acquire, and utilize assets in line with their corporate strategy, they also choose when *not* to further develop assets they previously invested in. As Porter (1996) notes, "Strategy is making trade-offs in competing. The essence of strategy is choosing *what not to do*" [emphasis added]. A number of recent scholars have emphasized the importance of understanding which assets and activities to stop investing in (see for example Siggelkow 2002 and Eisenhardt and Martin 2000). Despite this common observation in the theory literature, there has been virtually no empirical work on firms' decisions to retain some assets and disband others. Moreover, no empirical studies we are aware of incorporate this consideration in their analysis.

Ignoring this aspect is not an issue if there are no fundamental differences between the assets that survive and those that are disbanded; if for example the value realized on a given asset and the associated decision to retain or disband it results from a random stochastic process. But, on the contrary, we must be concerned that the likelihood of dropping or disbanding a particular asset might be correlated with strategic choices that a firm makes. Thus, the critical question to the strategy and organizations fields that this work addresses is *do different firm strategies result in different distributions of abandoned assets within an industry?*

To address this question, this paper investigates how a firm's research and development choices in asset creation influence the likelihood it will later forfeit its strategic assets. We introduce the term "asset disbandment" to capture a firm's decision to give up or forfeit ownership of property rights to an asset the firm previous developed. There is one subtle distinction in our definition of asset disbandment. Firms often come into ownership of assets for which the firm had no previous

investment in; such cases are not included in our definition. For example, an acquiring firm may gain ownership of assets peripheral to the firm's business after a corporate acquisition that was targeted at gaining ownership of only a subset of the target firm's assets. These peripheral assets may certainly be disbanded after such an acquisition, but not for reasons related to previous strategic choices, as are those assets we focus on in this paper.

Drawing on March and Levinthal's work, (March 1991; Levinthal and March 1993), the key hypothesis we test in this paper is that assets associated with exploratory search paths are more likely to be abandoned by firms working in research-intensive business environments, *ceteris paribus*. To test the importance of asset disbandment in the context of these exploratory strategies, we will consider two critical paths that are well established in the literature as clearly exploratory:

1. search into new, unexplored, scientific domains, and
2. search into knowledge domains that, albeit explored by others, are not part of a firm's existing knowledge base.

To be clear, we employ the Exploration-Exploitation paradigm merely as a convenient and well-established theoretic vehicle or analytic lens in order to establish empirically the phenomenon of asset disbandment as well as explore the impact of a different competitive strategies on the likelihood an asset owner disbands that asset.

For our empirical analysis, we look at patents in the pharmaceutical industry. The tradeoff between exploratory and exploitative search paths is particularly relevant to this industry setting. Moreover, patents are critical instruments for appropriating technological capabilities in the industry (Cohen, Nelson, and Walsh 2002), making it an appropriate setting to look at development and subsequent abandonment of assets. Pharmaceutical firms vary widely in the rate they disband their patent assets. For example, in 2002 Wyeth and Merck reported expenditures of $2,080,191,000

and $2,677,000,000 on research and development, respectively[1]. Total revenue exceeded $14 billion for Wyeth and $21 billion for Merck. In the same year, Wyeth renewed 88 of its 89 (99%) pharmaceutical patents granted in 1998 that were up for renewal[2]. By contrast, Merck only renewed 120 of 157 patents up for renewal in that year, effectively disbanding 24% of the patents it had originally been granted. In addition to Merck, other pharmaceutical giants such as Eli Lilly maintain low patent renewal rates relative to competitors, in contrast with other large firms like Wyeth, Pfizer and Bristol-Myers Squibb who often renew over 95% of their pharmaceutical patents. In fact, there is considerable heterogeneity in the rate in which pharmaceutical firms retain and disband their assets. Table 1 displays 2002 renewal rates for the largest 25 pharmaceutical firms. As it can be seen, there is considerable heterogeneity in the rate in which pharmaceutical firms retain and disband their assets.

TABLE 1 HERE

As hypothesized, the more exploratory a patent is, the more likely it is to be disbanded (i.e. not to be renewed). We find this effect to be significantly large: under different measures of the exploratory nature of a given patent, we find that a unit increase in the fraction of patent citations that are exploratory induces a 15% to 20% reduction in the odds of renewal. These results are robust to the introduction of firm-year fixed effects, such that we are only examining variation on patent characteristics for patents issued to the same firm in the same year and remove any variation in the data attributable to firm specific characteristics, such as a firm's performance, R&D level, therapeutic markets, and other influences.

[1] Sources: *Merck Annual Report 2003* and *Wyeth Annual Report 2003: Growth and Innovation.*

[2] Patentees are required to pay maintenance fees at several points in the life of a patent to maintain intellectual property rights conferred by the patent. We refer to this process as "patent renewal" throughout the paper and further discuss the details of patent renewal in Section 3.

A possible interpretation for the data we are studying is a real options story, whereby a firm makes an early investment in the patent and then, depending on subsequent information, makes a decision on whether or not to exercise (*i.e.* renew) the option. However, our approach in this paper is quite different. We are interested in understanding if certain early strategic decisions of the firm condition the future likelihood of patent disbandment, regardless of the particular signals on the value of the investment that the firm receives in the interim.

This paper advances the literatures on firm strategy and organizations on three fronts. First, our primary finding is that firms abandon assets as a result of previous strategy choices. Examining abandoned assets, to our knowledge, is unexplored territory in the strategy literature, yet appears critical to understanding trade-offs among competing strategic choices. In fact, an implication of our results is that neglecting this asset disbandment may lead to misinterpretations or bias in assessing the value of particular asset creation strategies. We believe this paper opens the area of asset disbandment for future empirical research by both connecting it to a received theory (e.g. resource based view of the firm and exploration-exploitation trade-offs) and providing a methodology that can be applied to other industries and market settings.

Second, the innovation literature has utilized patents and patent characteristics routinely in firm, industry, and public policy analysis. Despite widespread attention to patents and how firm patent portfolios may expand or change, much less work has sought to understand the nature of patent renewals. As mentioned above, we demonstrate that the probability that a patent is renewed can be explained systematically by technological characteristics and organizational choices. While research exists in the economics literature on using European patent renewals to estimate patent value (see for example Shankerman and Pakes 1986, Pakes and Simpson 1989, and Lanjouw, Pakes, and Putnam 1998), this paper shows that renewals represent a broader firm strategy perspective that demands greater examination.

Finally, we separate exploratory projects into “new to science” and “new to firm.” New to science captures projects whereby a firm’s R&D develops knowledge not previously known in the field. New to firm describes projects drawing on knowledge and capabilities outside a firm’s current boundaries, but for which the knowledge and capabilities may already exist in some level of development within the boundaries of other organizations. We find that “new to science” and “new to firm” are both important explanatory variables predicting the likelihood of renewal. We believe this theoretical distinction, combined with our results supporting the dual effects of these constructs on patent renewal, provides fertile ground for future research linking the notions of exploration and exploitation to what literature has characterized as a firm’s absorptive capacity (Cohen and Levinthal 1990)

In the next section, we discuss the relevant literature to motivate the study. We also summarize previous research on patent renewals to provide additional context for our paper. In section 3, we discuss the data and methodology. Section 4 summarizes results. Section 5 concludes with suggestions for future research in this area.

A FRAMEWORK TO UNDERSTAND ASSET DISBANDMENT

Firm Strategy, Asset Accumulation and Disbandment

Strategy research has increasingly focused on the notion that firms establish competitive advantage through ‘strategic assets’. These assets can be of a technological, financial or other nature and become the source of distinctive capabilities for the firm because they are valuable, rare, difficult to imitate and imperfectly tradable (Barney 1986, 1991; Dierickx and Cool 1989; Peteraf 1993; Wernerfelt 1984).

Two research approaches have been at the core of this literature, often called the resource based view of the firm. The first approach has sought to identify and characterize strategic assets, with a particular interest in studying how and why certain assets enable a firm to sustain

competitive advantage (see for example Henderson and Cockburn 1994; Huselid 1995; McGrath et al. 1995; Roth and Jackson 1995; Miller and Shamsie 1996; Dyer 1996; Huselid et al. 1997; Powell and Dent Micallef 1997). The second approach has sought to understand the process by which strategic assets are created and developed within an organization. Strategy research has considered issues in this area as diverse as the blending of resources and firm coordination (Sanchez 1995), resource recombination (Galunic and Rodan 1998), strategic product sequencing (Helfat and Raubitschek 2000), and a firm's embeddedness in a network (McEvily and Zaheer 1999).

In examining asset creation, scholars often draw on evolutionary frameworks based on the seminal work by Nelson and Winter (1982). The generalized consensus from this evolutionary approach is that firms follow particular search processes to identify and upgrade their existing strategic assets so that the firm can constantly improve its competitive position in an ever changing business environment. For example, Stuart and Podolny (1996) study patterns of localized technological search to understand the evolutionary process behind unique competitive positions. Chang (1996) characterizes entry into new industries as a critical search process, showing that properly directed entry has a positive impact on firm profitability. Sorenson and Fleming (2004) explore how science alters inventors' search processes by leading them along the critical path to useful combinations or eliminating fruitless paths of research, eventually resulting in more valuable technology. A number of other authors have looked at how search across technological and firm boundaries has a positive impact on the subsequent evolution of firm capabilities (see for example Rosenkopf and Nerkar 2001; Katila and Ahuja 2002; Ahuja and Katila 2004).

The importance of disbanding assets in evolutionary processes has been emphasized by a number of researchers. Porter's (1996) widely cited article on strategy stresses the importance of firms deciding what 'not to do'. In a literature review of the resource based view, Eisenhardt and Martin (2000) argue that the key to effective firm evolution in dynamic markets is a firm's ability to carefully decide which of the many experiences to incorporate into ongoing routines and, of

particular relevance to this paper, which to leave out. Siggelkow (2002) proposes four core processes to describe the creation and subsequent elaboration of core organizational capabilities when confronted with evolving market conditions: thickening, patching, coasting, as well as trimming. Silverman (1999) notes that “while the resource based view of the firm predicts growth and diversification, a resource-based theory of divestment is clearly lacking".

In spite of the recognized importance of asset disbandment, the empirical research on the creation of strategic assets has largely not considered the associated issue of disbandment. The few research studies addressing this issue do so in the context of financial divestiture of entire business units or product segments, often linking the decisions to theories on coherence vs. diversification in the firm (see for example Hoskisson *et al.* 1994; Chang 1996; Karim and Mitchell, 2000; Capron *et al.* 2001; Haynes et al., 2004). But none of these studies examine the more granular level of analysis: disbanding specific, strategic assets. The absence of empirical work on asset disbandment in the literature is not wholly unwarranted. In firm evolutionary processes we tend to observe only what survives, making it difficult to reconstruct and clearly identify what options or potential paths the firm decided not to pursue in academic research. Available data on products commercialized, product sales, etc., ignores failed product efforts within the firm. Hence, the choice set of opportunities a firm is faced with is rarely observed after the fact.

While it is clear that we lack an understanding on the why or when firms disband assets, one might still ask how relevant for understanding strategic asset creation and development is this shortcoming. We contend that looking at asset disbandment is of fundamental importance for at least two critical reasons. First, as Denrell (2003) notes, failing to appropriately sample from the paths the firm chooses not to pursue implicates possible bias in the value of particular strategies. As an illustrative example, consider a study linking innovation to firm performance. A researcher might be interested to compare the results of firms that pursue risky research with those that instead pursue a reliable research path. Using typical metrics such as product sales, profits, or market share

to measure performance ignores the many product development efforts that do not lead to final products introduced. Effectively, such analysis might be restricting the empirical investigation to a comparison of the right tails of the distribution of successful product performance among each firm in an industry. If in a particular industry, risky research tended to lead to a few "home runs" but overall may have a lower median return than reliable research, an investigator could mistakenly conclude that firms choosing the risky path perform better on average, when in fact the reality would be the opposite. Hence, by ignoring the product development failures, the researcher would overestimate the impact of risky innovation on performance.

Second, even if properly accounted for, the likelihood of disbanding a particular asset may be correlated with strategic choices that a firm does. As a result, we might need to understand and assess the difference in these odds if we are to make correct inferences on the success of particular development strategies for a firm. For example, a number of recent publications have been using patents and their characteristics to examine how the pursuit of "exploratory" paths on a firm's research direction relates to innovation success or impact (see, among others, Rosenkopf and Nerkar 2001, Ahuja and Katila, 2004, and Katila and Ahuja, 2002). These papers suggest that exploratory patents are indeed valuable for the firm (with value typically measured by forward citations and new product introduction). An unstated assumption of these papers is that there is no relevant unobserved difference between exploratory and non-exploratory patents in this industry; that is, these papers assume firms attempt to commercialize the same proportion of exploratory and non-exploratory patents. But let's consider that firms are more likely to abandon patents based on high-risk, "exploratory" research. Then, the results on the value of these search paths mask two conflicting dimensions that are overlooked in the findings. On one hand, the commercialization rate of products built on these exploratory patents will be substantially lower, diminishing the average value of the overall strategy. On the other hand, the "real impact" of successful exploratory research

must be very high and much larger than what the perceived average value when the estimation accounts for the assets that are subsequently disbanded.

Previous economics research on patent renewals illustrates a related example of potentially misinterpreted results that arise by not considering the strategic determinants of assent disbandment. As discussed in the introduction, patent renewal rates vary dramatically among the major pharmaceutical firms (see Table 1 in the data section for an account of the renewal rates of the top 25 patent holders in the pharma industry). A simple explanation for these differences is that some firms "get lucky" by randomly drawing a higher proportion of high value research projects, leading to increased valuations of the patents covering that research. This explanation reflects a model of patent renewal presented in previous research on patent renewals. For example, Shankerman and Pakes (1986) use European renewal data to estimate the value of patent rights, and assume there is an exogenous distribution of patents' initial values, common to and known to all firms, revealed to the firm once the patent is issued. However, if a firm's choice of R&D strategy has a significant impact on the likelihood a patent is renewed, the realized value of a patent is not random, as assumed by Shankerman and Pakes (1986), but is actually endogenous to the strategic choices a firm makes *ex ante*. The fact that firms exhibit a rather persistent average level of renewals over the years, maintaining the relative difference to other firms suggests precisely that such strategic endogenous decisions may be at play.

The examples above illustrate why ignoring asset disbandment might lead empirical strategy research to potentially misleading and even biased conclusions. They also point to the critical aspect of relevance for Strategy research – the correlation between asset disbandment and particular search paths. If asset disbandment is uncorrelated with particular development or search paths, then the potential bias discussed is simply not a relevant issue. Therefore, understanding the exact nature of the relationship between asset disbandment decisions and the firm's search path (such as risky vs. reliable research) that led to the creation and disbandment of a give asset is critical

to improving our understanding of how firm's create strategic assets and ultimately generate superior performance. Finding such a relation would indeed show the need for much more in depth analysis on the role of disbandment in the literature, especially the one related to strategic resources and capabilities.

Exploration Strategies and the Likelihood of Asset Disbandment

To examine how different strategies influence subsequent decisions to disband critical firm assets, we need a theoretical paradigm that characterizes two or more distinctive strategic choices. An important criteria in selecting such a theoretical paradigm is that such a theory should predict differences in performance based on the strategic choice a firm makes. To satisfy these criteria, we contrast the effects of exploration versus exploitation strategies described in the seminal work by March (1991), and established in a number of subsequent studies. Exploration entails more distant searches for new capabilities and technology trajectories relative to the firms' existing knowledge base (March, 1991; Levinthal and March, 1993). On the contrary, exploitation involves a search process that builds on a firm's existing processes and technological capabilities. Previous work proposed concepts or notions that were similar to March's assertions, including Argyris and Schon (1978)'s concept of single-loop vs. double-loop learning, Levinthal and March (1981)'s distinction between refinement search and innovative search, and Foil and Lyles's (1985) notions of first-order and second-order learning.

In their 1993 article, Levinthal and March remind us that one of the pervasive features of organizational life is that most exploratory ideas tend to fail. Therefore, returns to exploratory search paths tend to be more uncertain, distant, and more often negative relative to exploitative search paths. As firms accumulate experience with new knowledge, they pursue an exploitative search path that is typically associated with an increased likelihood of success (Levinthal and March, 1993). This contrast described by Levinthal and March provides the differential

performance predictions we seek between assets accumulated through exploratory search, and those accumulated through exploitative search.

The general argument we make in this paper builds from this literature cited in the previous section, but focuses on disbandment as a critical outcome in the process. As firms explore beyond their established practices, they realize a wider value distribution of research outcomes than under a carefully planned environment or, in terms of March and Levinthal (1993), an exploitative strategy. Firms will cease investing in assets associated with inferior opportunities; that is, firms will disband those assets that were realized to be of lesser value. Each firm will realize its own distribution of asset values as it evolves. However, the strategy a firm chooses, between exploitation and exploration, effects that distribution of asset values realized. Exploitative research projects will lead to more predictable outcomes, and a higher median value of assets (e.g., intellectual property) derived from this research but also fewer "big hits" or highly valuable innovations. Exploratory research promises to open entirely untapped markets and produce radical new technologies, resulting in more big hits. The average asset derived from this research will be of low value and will be more likely to be disbanded.

Therefore, the key hypotheses we test in this paper is that assets developed through exploratory paths are more likely to be abandoned by firms working in research-intensive business environments, *ceteris paribus*. The analysis of exploratory (vs. exploitative) search paths has been one of the critical areas addressed by work looking at the accumulation of capabilities and strategic assets. Yet, this research has never addressed the issue of asset disbandment as a key part of the asset accumulation process. To implement these ideas, we specifically will consider two critical paths that are well established in the literature as clearly exploratory: (1) search into new, unexplored scientific domains and (2) search into knowledge domains that, albeit explored by others, are not part of a firm's existing knowledge base. The latter category describes search for knowledge that is outside the existing boundaries of the firm.

The importance of scientific exploratory paths as a process to build new capabilities has deep roots in the study of technological innovation (Rosenberg 1982; 1990; 1994; Rosenberg and Birdzell 1986). The chemical industry in the earlier part of the last century is perhaps one of the first examples of how fundamental scientific understanding can play a critical role in advancing firm technology and capabilities (Arora *et al.* 1998; Hounshell and Smith 1988). Since then, the idea of exploring science as a mechanism for firms to enhance their capabilities has become widespread (Hounshell 1996).

Science can contribute to the buildup of unique firm capabilities along several dimensions. First, science establishes principles that guide the process of discovery in research and enable firms to better solve problems (Fleming and Sorenson 2004). For example, in the early history of the fiber industry, the fundamental understanding of polymer science, in particular the polymerization process, was critical in guiding the Dupont's research team towards the discovery of Nylon (Hounshell 1988). Second, to the extent that technological advances rely on recombination of knowledge elements within a firm (Kim and Kogut 1996; Galunic and Rodan 1998; Fleming 2001; Fleming and Sorenson 2004), scientific exploration enables the generation of novel elements to be used in the solutions to the technological challenges of the firm. A good illustration are recent scientific advances in alloying that have led the creation of high strength steels, which automotive companies are using to create car bodies that have the same physical properties as conventional steel bodies, but with 30-40% less weight. Third, scientific knowledge can enhance the ability of firms to absorb external technologies by creating awareness of external evolutions and a knowledge bridge to firm to access particular technologies deemed important (Cohen and Levinthal 1990; Rosenberg 1990).

Precisely because of its importance, the contribution of science to the generation of firm strategic assets or resources has been the focus of a number of papers in the last few years. Authors have found in general that scientific emphasis is associated with more valuable technology

(Sorenson and Fleming 2004), though it does not necessarily need to be the most cutting edge science (Gittelman and Kogut 2003). When looking at firms, research suggest that greater scientific propensity generates more technology (Henderson and Cockburn 1994; Gambardella 1995; Ahuja and Katila 2004) and even that science is associated to economic performance (Zucker et al. 1998), especially in high technology and science intensive sectors such as pharmaceuticals and biotechnology.

But while scientific search can lead to superior technology, it has also been recognized that outcomes are more likely to be uncertain, when compared to upgrading based on technological improvements (Rosenberg 1990). Some existing articles note the added uncertainty associated with unexplored technological spaces (Fleming 2001; Fleming 2002). Katila and Ahuja (2004) in particular suggest that uncertainty associated to scientific search limits leads to a decrease marginal benefit from investing in science after some point, posing an inverted U relation between scientific effort and subsequent innovation. Yet, none of these studies tests whether the choice of scientific exploration in a firm's search paths lead the firm to develop assets that the firm is subsequently more likely to disband. This scenario leads to our first hypothesis.

H1: Developing strategic assets through exploration of "new science" will result in a greater likelihood of asset disbandment, ceteris paribus.

Seeking new technologies through exploratory paths is not limited to creating knowledge that is in general "new to science". New science, or knowledge not previously established in the field, is merely a subset of exploratory search. Firms may also search for knowledge that is new to the firm, but may have previously been used by competitors, university researchers, or firms in related industries for different purposes (Benner and Tushman 2002; 2003). Existing results suggests that exploring knowledge existing outside the firm as a mechanism for gaining new

technological capabilities is indeed relevant. Rosenkopf and Nerkar (2001) find that search across firm boundaries benefits the subsequent evolution of firm's technological capabilities, while Katila and Ahuja (2002) show that search beyond a firm's own knowledge space matter for the ability of firms to introduce innovations.

Yet, once again, while the knowledge search paths associated to exploration beyond firm borders have the potential to generated valuable technologies, they are also beset with greater uncertainties than alternatives where internal local knowledge paths are pursued, what is usually termed an exploitative path (March, 1991; March and Levinthal, 1993). Precisely because they are different from a firm's existing knowledge space, they have the potential to create what Siggelkow (2002) calls misfits. Upon development, novel technologies or products away from the core knowledge base of the firm can create inconsistencies with existing organizational systems and strategies, which affect the overall performance of the firm. As a result, management may decide to drop further pursuit of a misfit development path not to risk the rest of the operation (Siggelkow, 2002). Research on corporate divestiture and downsizing has shown precisely that divisions that do not have a good fit with existing technological and business practices in a given firm are more likely to be disbanded when compared to other more closely aligned divisions (Duhaime and Grant, 1984; John and Ofek, 1995; Hamilton and Chow, 1993; Karim and Mitchell, 2000). In a paper looking at search paths for developing capability development, Katila and Ahuja (2002) defend that there may be a limit in the ability of firms to increase their scope of new knowledge outside firm boundaries, such that new knowledge that is very far from the firm knowledge boundary may become detrimental for the development effort. The problem, like before for the case of science exploration, is that none of the previous articles examines if knowledge exploration across firm boundaries is likely to generate inadequate results that the firm subsequently decides to drop. Therefore our second hypothesis is:

H2: Developing strategic assets through exploration of knowledge outside firm boundaries will result in greater likelihood of asset disbandment, ceteris paribus.

Exploration, Asset Investment and Disbandment in the Pharmaceutical Industry

We focus on the major pharmaceutical firms to test the hypotheses presented above. While we believe the analysis in this paper is pertinent across a range of R&D-intensive industries, we focus on the pharmaceutical industry, especially the larger firms, as a particularly propitious environment to establish our theory and results. First, advancements in the industry allows for substantial heterogeneity among firms' emphasis on and approach to research and drug development across the industry (Henderson, Orsenigo, and Pisano 1999). Following the rise of guided drug discovery enabled by advancements in biotechnology and genetics, some pharmaceutical firms continue to place considerable value on basic science and exploratory research in general, while other firms have shifted emphasis to complementary assets, such as their sales staff ("pharmaceutical detailing"), in a narrow set of therapeutic classes to create and sustain competitive advantage. The importance of understanding research paths and outcomes in this industry is clearly recognized by the incredible growth in the number of articles in social sciences research that address issues in the management of the research, product development and product launch in this industry. Second, patents are critical instruments for appropriating technological capabilities in the industry (Cohen, Nelson, and Walsh 2002). Firms consider the generation and maintenance of their intellectual property, especially patents, as critical for their current and future success. As a result, decisions in this area are carefully planned and monitored at all levels of the firm.

Product development in the pharmaceutical industry is a long and uncertain process. Therefore, when firms first apply for a patent, they often do not know what its potential market value is. But they learn more about the value of a particular patent over time. For some patents, the

low market value may not justify the cost of continuing to further pursue the development effort that let to the original application. As a result, the firm may decide to abandon the patent, or to be more specific, it may decide not to renew it. Since the early 1980's, all U.S. utility patents have been required to be renewed by the inventor after 3½ years from the date of patent issue in order to maintain intellectual property rights. A decision not to pay the required maintenance fee is, in effect, one of disbanding an important asset, because the patent assignee forfeits their legal rights of intellectual property conferred by the patent. Thus, patent renewal data affords us a rare opportunity to examine the set of choices a firm has in terms of which resources to pursue further and which to disband.

The importance if this decision to renew or disband a patent is reflected in the structured nature of the process. As one attorney described the process at his firm, "We meet quarterly to review patents that are up for renewal. The meetings include attorneys, scientists, and business development. It's a joint decision [to renew]." In fact, while the administrative fee the renewal of a patent is small - in 2002 the fee was $880 per patent, there are significant organizational costs of maintaining a low value patent, which justify a decision not to renew it. First, there are costs associated with monitoring and litigating a broad portfolio of patents to ensure that others do not infringe. Firms need to employ internal or external groups to examine related uses of that intellectual property. As the number of patents in a firm's portfolio grows, these costs can become substantial. Monitoring is particularly important because firms often seek to build a credible legal reputation to pursue infringers (Somaya 2003). Therefore, if a competitor is found to infringe on a patent, the firm would nevertheless need to raise a lawsuit, simply to maintain their overall threat of legal recourse, even if the patent would be of little or no value. These costs could easily become quite substantial.

Internal management costs also contribute to the decision not to renew a patent. Firms must manage human capital resources across a number of different projects. We know from work by

Cockburn and Henderson (1998) that many pharmaceutical firms attract top scientists by allowing them to pursue scientific research and publish it in academic journals. The problem is that, occasionally, scientists will try to continue research on projects that are scientifically interesting to them, although they have been found to be of no market value to the firm. Often the researcher will do it with the firm belief that subsequent scientific results could change the firm's perspective towards the technology, ignoring that disbandment decisions are not always made based only on poor scientific achievements. The act of non-renewal can function as a credible commitment or signal within the firm to abandon a particular line of research.

A final aspect that is important to note is there is an underlying assumption on the decision to disband a valuable patent that firms only use these valuable assets internally. However, a firm could capture the value of the patent through "out-licensing" the patent to another pharmaceutical firm that maintains the appropriate complementary assets to commercialize the technology. Our field research, including interviews with patent attorneys for pharmaceutical firms, offers some insight. The idea is that out-licensing can be seen as an expensive endeavor, both politically within the firm and for the firm as a whole. As one attorney commented:

> If I get an out-license, what do I really get? Most of the time, the licensing fees are marginal. The worst case is they develop a drug, and that drug becomes a blockbuster. Then, management here asks why we didn't pursue the drug… Out-licensing is also time-consuming and needs a dedicated business group focused only on out-licensing. Margins are low.

To fully address this issue is outside the scope of this paper, but it stands that such licensing is not seen in some cases as an effective method to capture value, especially if the firm does not have an active program to do so.

DATA AND METHODOLOGY

Sample Construction

Our unit of analysis is a pharmaceutical patent issued between 1994-1998 and up for renewal between 1998-2002. Following McGrath and Nerkar (2004), we define our sample of patents based on the USPTO's concordance between US patent classes and SIC code 2834 Pharmaceutical Preparations[3]. To construct our data set, we used the Micropatent patent database as well as the NBER database constructed by Hall, Jaffe, and Trajtenberg (2001).

We restrict our examination to patents among the 50 largest pharmaceutical firms in terms of innovative output. The 50 largest firms were selected based on the total count of pharmaceutical patents issued between 1994-1998, the patent grant years for patents up for renewal in our sample frame. We restrict our analysis to this sample group because the *balance* of exploitation and exploration projects by a firm is most relevant to large firms with substantial R&D resources. The comparison of "Big Pharma" with small development firms is an intriguing, complementary topic but outside the scope of this present paper. In addition, we are also concerned about spurious results that might arise from smaller firms and individual assignees with only 1-3 patents issued in the sample frame. The final data set includes 7754 patents issued during the 5 year period, of which (76%) were renewed. As shown in Figure 1, there is a significant upward trend in both patents granted and renew rates by year.

Measures and Empirical Model

Our dependent variable in each of our empirical models is a dichotomous variable indicating whether a given patent was renewed (*Renewed*=1) or not (*Renewed*=0). This variable was constructed based on in the USPTO's *Patent Official Gazette*. The weekly *Gazette* publishes lists of

[3] This concordance is a slightly larger sample frame than the criteria used by Penner-Hahn (1998), which focuses on US patent classes 424 and 514, although these two classes include the majority of pharmaceutical patents.

patents failing to be renewed during the relevant renewal period. The USPTO requires that a maintenance fee be paid to renew utility patents at three times during the life of a patent: at 3 ½, 7 ½ and 11 ½ years after the patent is granted. This system differs from the European Patent Office, which requires annual renewal. The owner of a US patent has an additional six month period to pay the fee, after which time the patent rights expire. Once a patent has expired, any party may utilize the invention covered by the patent without permission of the patent owner. If a patent expires, the owner may petition the USPTO for consideration to reinstate the patent, however our interviews indicated this was rare and only a small fraction of pharmaceutical patents are reinstated.

We only examine the first renewal period (four years) because the data have only been made available electronically since 1995. Including the second, eight-year renewal period would limit our analysis to a single year of pooled data. Doing so would not allow us to account for year-specific effects.

We wish to examine the effects of exploration strategies, considering in particular that the latter may include "new to science" and "new to the firm." Unfortunately, no variables exist naturally to directly measure the characteristics of exploitative and exploratory knowledge. However, several measures have been developed in previously published research to capture these concepts based on patent characteristics

The first measure we use is *New_to_Science*, a variable examined among a variety of measures by Trajtenberg, Henderson, and Jaffe (1997). In their analysis, Trajtenberg et al. find that *New_to_Science* captures well the notion of basic research or new science, particularly relative to other patent based measures. *New_to_Science* is the percentage of citations to prior art listed on a patent that are to journal articles and other scientific publications listed in the "Other References" section of a patent. In general, utility patents cite several different types of sources of prior art, including other patents, as well as the works listed in the "Other References" section such as journal articles, conference proceedings, and published patent abstracts. Trajtenberg et al. (1997) argue that

works such as journal articles and conference proceedings tend to be closer to basic or new science in general, so that patents citing a higher *proportion* of these types of prior art on average represent underlying research that was closer to new science. The proportion is necessary, rather than a count of journal article citations, to ensure that the measure is not skewed by patents that simply cite more prior art for reasons unrelated to our topic of interest. As suggested by Trajtenberg, Henderson, and Jaffe (1997) we also removed from the list of references to scientific literature any published patent abstracts.

Our second variable, *New_to_firm*, was adopted from previous work by Benner and Tushman (2002) and captures the extent to which a given (focal) patent draws on knowledge outside the focal patent owner's existing knowledge base[4]. To construct this score, we examine characteristics of the patent citations made by a focal patent, similar to Benner and Tushman (2002). We first define a patent citation to represent knowledge drawn from outside the firm if the citation is to a patent that is neither one of the firm's own patents (that is, not a "self-citation), nor a patent cited previously by the firm in another of the firm's patents. The idea is that original patent citations represent knowledge outside the firm boundaries, *i.e.*, exploratory knowledge or knowledge that is "new to the firm". *New_to_firm* is then the percentage of patent citations on a focal patent that are *not* self-cites (citations to patents assigned to the same firm as the focal patent) nor citations to patents that the focal patent's assignee has previously cited.

It is critical to note that we employ this measure in a quite different manner than Benner and Tushman (2002). They use the percent of exploratory citations to classify patents as either "exploratory" or "exploitative", using the counts of such patents as a dependent variable in their regressions. However, our primary analysis utilizes the percentage of exploratory citations as the main explanatory variable such that *New_to_firm* is a continuous variable. In addition, we conduct

[4] Rosenkof and Nerkar (2001) use a similar approach in establishing the distinction between exploration and exploitation, but do not address the issue of prior citations by the focal firm to patents that do not belong to the organization.

several robustness checks, detailed in the next subsection, with a modification of the *New_to_firm* variable. Mirroring Benner and Tushman (2002), we construct a dichotomous explanatory variable equal to 1 if the percentage of exploratory citations is greater than or equal to various thresholds (specifically, 100% and 80%).

We include a number of control variables to capture additional influences on patent renewal rates. Our control variables are of two types: patent-specific (*Claims*, *Time_to_Grant*) and assignee-specific (*Foreign* and *Annual_pats*). Patent-specific controls are used to account for technology factors outside of exploitation-exploration that may explain renewal rates. A myriad of patent-based measures have been used in the economics and management literatures to measure technological characteristics. A critical recognition in this paper is that forward or subsequent citation-based measures (e.g. Nerkar and MacMillan, 2004; Fleming and Sorenson, 2004) cannot be employed due to likely endogeneity between the measure and the renewal decision. Firms may decide whether to renew a patent long before the renewal date arrives, but the actual date a firm decided not to renew is unobservable to us. Once a firm has chosen not to renew a patent, the firm is likely to engage in behavior that affects the rate and type of forward citations. For example, the firm itself may be less likely to cite a patent that it knows will not be renewed. Industry insiders, such as major competitors, may also find out through the invisible college or by observing the focal firm's behavior that a certain patent is not likely to be renewed. These firms may in turn be less likely to cite the patent in effort to strengthen their own patents' merits. Hence, while we expect that patents that are not renewed will have fewer forward citations, those forward citations may be associated with bias on the sources of those citations. As a result, we restrict our analysis to patent characteristics not associated with forward citations.

Claims reflect the number of claims on a patent to control for the breadth of a patent under the hypothesis that patents issued on a broader set of claims may be more valuable and therefore more likely to be renewed. We would expect that the more claims a patent has should increase the

likelihood of renewal, *ceteris paribus*. Similar to *Claims*, *Time_to_Grant* controls for the potential complexity of the patent. *Time_to_Grant* is the time between application date and issue date. This variable ranges from 1-10 years, but the median patent requires 3 years to issue.

Foreign is a dummy variable equal to 1 if the assignee on a given patent is foreign-based, under the notion that a patent in the U.S. may be less important than a patent in their home country or region. This hypothesis suggests there should be a lower renewal rate among patents that whose assignee is not located in the U.S.[5]. In our sample, 48% of patents are assigned to foreign laboratories.

Annual_pats indicates the total number of patents granted to the patent assignee in the same year. We include *Annual_pats* to control for scale effects and analyze whether larger firms disproportionately increase the likelihood that any individual patent is renewed.

To test our hypothesis, we consider a binomial logistic estimation. If we define y_{ig}=1 if patent *i* for firm *g* in renewed and =0 otherwise, the probability that the invention i of a firm *g* is renewed is given by:

$$P(Y_{ig} = 1 \mid X_{ig}) = \frac{\exp(\alpha_g + X_{ig}\beta)}{1 + \exp(\alpha_g + X_{ig}\beta)}$$

We specify a firm fixed effects regression to allow us to isolate the likelihood of patent renewal from unobserved firm effects. In addition, we will also include year fixed effects to control from potential trends in renewal across time and within year that could bias our results. Finally, in one of our specifications, we interact firm and year effects. This is the strictest test we can apply to focus narrowly on the technological determinants of patent renewal even within a firm-year.

[5] Note that most of the large pharmaceutical companies have multiple laboratories around the world. Our foreign measure is associated to the locations of the particular laboratory to which the patent is assigned, not to the nationality of the firm.

RESULTS

Tables 2 and 3 report summary statistics and the correlation matrix for these variables, respectively. Our two primary variables of interest, *New_to_Science* and *New_to_firm*, have means approximating 0.5; that is, the citations of the average patent reference knowledge sources outside the assignee's boundaries roughly as often as they reference knowledge already existing within the assignee's boundaries. It is interesting to note that the correlation between our two critical variables *New_to_Science* and *New_to_firm* is 0.199, which confirms our approach in considering each dimension of exploration in the analysis.

Regression results are reported in Tables 4 and 5. Table 4 provides the main empirical analysis, while Table 5 includes additional robustness checks. These tables report odds ratios plus the z-scores from individual tests for significance. Recall that odds ratios are the antilogarithm of estimated coefficients from a logistic model and thus can be interpreted as the percentage increase (or decrease for odds ratio <1) *in the odds* that a focal patent is renewed attributable to a unit increase in a given explanatory variable.

Models 1-4 includes fixed effects for assignee firms and years. Models 5-6 interact year dummies and assignee firm dummies to restrict the analysis to variation within a firm-year (*e.g.*, Merck in 1999). This specification allows us to control for unobserved firm-year specific effects that could bias our estimation at the potential cost of reducing substantial variation in the model. For lucidity, we do not report estimates for the effect of year and firm fixed effects.

The results are striking and consistent across specifications, even in the more restrictive Models 5 and 6. In each model we find *New_to_Science* and *New_to_firm* to be negatively correlated with the likelihood that a given patent is renewed (odds ratio<1). These results indicate that the more new to science and new to the firm's knowledge base that the science underlying a given patent is, the less likely that patent is to be renewed. Odds ratios of approximately 0.8 and

0.85 for *New_to_Science* and *New_to_firm* respectively indicate that an additional percentage of citations that are exploratory decreases the odds of patent renewal by 20% and 15%, respectively.

The coefficients on our control variables largely make intuitive sense, as well, lending credibility to the models. We find strong evidence that patents with more claims, representing broader patents, are more likely to be renewed. Although significant, the effect of *Claims* is relatively small: an additional claim only boosts the renewal rate by 1%. We also find that foreign assignees, which make up almost half of the sample (48.3%), are significantly less likely to renew patents. Interestingly, *Time_to_grant* is positively related to the likelihood of renewal. These results suggest that more complex patents tend to be renewed.

Models 7-11 present results of a robustness test. The previous models employ continuous measures *New_to_Science* and *New_to_firm* each ranging from 0 to 1 to capture the distribution of exploratory characteristics among all patents in the sample. We are concerned that the above results could be driven by small differences at the mean of each individual variable, rather than an increasing relationship between the level of science or exploration and renewal rate. To verify this relationship, we wish to check whether the patents with extreme science and exploration scores continue to negatively correlate with the likelihood of renewal.

For models 7-11, we create discrete variables based on an arbitrary cut-off to categorize a patent as "Scientific" or "Exploratory". The cutoffs we employ are 100% of citations on a patent are to scientific journal articles (*New_to_Science_100*=1, and =0 otherwise) and 80% of citations on a patent are to scientific journal articles (*New_to_Science_80*=1, and =0 otherwise). We also create discrete variables for *New_to_firm* based on 100% and 80% of patent citations referring to exploratory knowledge (*Explore_100* and *Explore_80*, respectively). We find that indeed our results hold when examining the discrete categorizations of *New_to_Science* and *New_to_firm*: each of the discrete variables lower the odds ratio of patent renewal. The odds ratio is lower for the discrete variables based on 100% of citations vs. 80% of citations, indicating that the more "scientific" or

"exploratory" patents are, the less likely they are renewed. In addition, Model 11 includes both *New_to_Science_100* and *New_to_firm_100* and our results continue to hold.

DISCUSSION AND CONCLUSIONS

This paper argues that a firm's choice towards an exploratory search strategy is reflected in the firm's subsequent decisions to abandon valuable assets. Using an econometric model that controls for alternative potential explanations as well as firm and year unobserved effects, we show that an increase in the exploratory nature of research underlying a given pharmaceutical patent reduces the likelihood that the patent will be renewed. A number of scholars have discussed the importance of understanding firm decisions to disband assets in the context of the resource-based view of the firm. Yet, we believe this is first to directly show that a firm's choice of research strategy affects the likelihood that a firm will disband technological assets. It opens the area of asset disbandment for future empirical research by both connecting it to a well-established theory (e.g. resource based view of the firm or exploration-exploitation trade-offs) and providing a methodology that can be applied to other industries and market settings.

Examining abandoned assets is critical to understanding firm strategies and tradeoffs. Our results show that neglecting firm decisions (to disband assets) in strategy research may lead to misleading or biased assessments of the value of particular asset creation strategies. Bias arises from the researcher only observing realized product, sales, project outcomes, etc., combined with our finding that failed, unobserved outcomes are disproportionately the result of a particular strategic choice. For example, in context of our study bias would arise from an overvaluation of exploratory strategies as a path to build competitive advantage if a researcher only observed products commercialized, product sales, clinical trial success, and other realized outcomes in pharmaceuticals and did not account for the many failed projects that tend to result from exploratory search paths in the industry.

Even if outcomes are observed, it may be of critical importance to distinguish the propensity of the underlying assets to be disbanded as result of firm strategic choices In fact, a simple explanation for differences in levels of renewals would be that some firms "get lucky" by randomly drawing a higher proportion of high value research projects. This explanation reflects a model of patent renewal that assumes an exogenous distribution of patents' initial values, common to and known to all firms, revealed to the firm once the patent is issued. But, our results show that a firm's choice of R&D strategy has a significant impact on the likelihood a patent is renewed, so that the realized value of a patent is endogenous to the strategic choices a firm makes *ex ante*. In our case, different levels of exploration entail different value distributions from which patents are drawn, each with a different expected level of renewal.

The results also show that both "new to science" and "new to the firm" exploratory paths are associated with a greater likelihood of disbandment. Our results support the notion that knowledge that is not part of the firm's existing knowledge base poses significant challenges, consistent with the absorptive capacity literature. We believe that this distinction provides a framework for future research in exploitation-exploration strategies and is among the few empirical studies to simultaneously control for both types of knowledge. Similar to Rosenkopf and Nerkar (2001), our results show how exploratory search is both a technological and organizational phenomena. The striking finding in our results is that previously existing knowledge that is outside the firm's current knowledge base, even after controlling for knowledge that is new to science, has a significant negative impact on the outcome of a project. We believe these results provide traction for other empirical studies of absorptive capacity (Cohen and Levinthal 1990).

Finally, we believe our approach and findings provide a valuable framework for examining a number of other issues related to strategy and knowledge management. First, we anticipate future work could explore sources of variation in the factors effecting renewal rate to make predictions regarding strategic behavior, industry structure, and market opportunities.

For example, we observe considerable heterogeneity among pharmaceutical firms' propensity to renew patents in our sample. Future research could examine the volatility of renewal rates, related to how commonly firms shift the mix of exploratory projects over time. Such research would directly relate to March (1991) and Levinthal and March (1993) in which they discuss the importance of balancing the levels of exploration and exploitation within the firm. In addition, we know from Cohen, Nelson, and Walsh (2002) that the pharmaceutical industry in particular relies heavily on patents to protect the returns to innovation. However, many other industries rely more on secrecy and lead time in production to appropriate the value of their innovations. Future research could examine the likelihood of patent renewal among industries that vary in their reliance on patents to appropriate value from innovation.

Second, variance in the institutional environment affecting the value of patent protection provides further ground for research. The annual renewal cycle for the European Patent Office (EPO) provides an interesting comparison point, particularly since most large pharmaceutical firms patent in both the U.S. and Europe. EPO data offers a more refined comparison on the *timing* of renewal decisions, compared to the U.S. environment, where renewals are only made every 4 years. Industries that rely more heavily on patents to profit from innovation, such as pharmaceuticals and certain chemicals, may strategically patent products in multiple regions. A dynamic examination of both the decision to patent an innovation in multiple regions and the subsequent decisions to renew these patents will provide a much richer understanding of how firms utilize intellectual property strategically.

In summary, we believe the framework of asset disbandment proposed in this paper opens a number of new avenues of research on patent renewals as a result of R&D strategies. Our results demonstrate that carefully considering the decision of asset disbandment is a critical aspect of a firm's strategic decision making, and a topic in strategy research that deservers far more attention than it has garnered to date.

REFERENCES

Abernathy, W. J. 1978. *The Productivity Dilemma*. Baltimore, MD: Johns Hopkins Press.

Ahuja G., Katila R, 2004. Where do Resources Come From? The Role of Idiosyncratic Situations. Strategic Management Journal, 25: 887–907

Arora, A. Landau, R. and Rosenberg, N., 1998.*Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*. New York: John Wiley & Sons

Argyris, C., & Schon, D. A. 1978. *Organizational Learning: A Theory of Action Perspective*. Reading, MA: Addison-Wesley Publishing.

Barney, J. B. 1986. Strategic factor markets: Expectations, luck, and business strategy. *Management Science* (32): 1231–1241.

Barney, J. B., 1991. Firm Resources and Sustained Competitive Advantage. Journals of Management 17 (1):99-120.

Benner, M. & Tushman, M., 2002. Process management and technological innovation: A longitudinal study of the photography and paint industries. Administrative Science Quarterly, 47: 676-706.

Benner, M. & M. Tushman. 2003. "Exploitation, Exploration And Process Management: The Productivity Dilemma Revisited" *Academy of Management Review* (28): 238-256.

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

Chang, S.J., 1996. "An Evolutionary Perspective on Diversification and Corporate Restructuring: Entry, Exit, and Economic Performance during 1981-89" *Strategic Management Journal* (17): 587-611.

Cockburn, I. and Henderson R. 1998. "Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery." *Journal of Industrial Economics*, 46(2), 157-182.

Cohen, W. M., and D. A. Levinthal, 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* (35): 128-152.

Cohen, W.M, Nelson, R.R. and Walsh, J.P., 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D" *Management Science* (46): .

Danneels, E., 2002. "The Dynamics Of Product Innovation And Firm Competences" *Strategic Management Journal* (23): 1095-1121.

Denrell, J., 2003. Vicarious Learning, Undersampling of Failure, and the Myths of Management. *Organization Science*, 14 (3): 227–243

Dierickx, I. and Cool, K., 1989. “Asset Stock Accumulation and Sustainability of Competitive Advantage” *Management Science* (35): 1504-1511

Duhaime, I.M. and Grant, J.H., 1984. Factors Influencing Divestment Decision Making: Evidence from a Field Study. *Strategic Management Journal* 15(1): 301-318

Dyer JH, 1996. Specialized supplier networks as a source of competitive advantage: Evidence from the auto industry *Strategic Management Journal* 17 (4): 271-291

Eisenhardt, K. and Martin, J., 2000. “Dynamic Capabilities: What Are They?” *Strategic Management Journal* (21): 1105-1121.

Fleming, Lee, 2001. "Recombinant Uncertainty in Technological Search." Management Science 47 (1).

Fleming, L., 2002. Finding the organizational sources of technological breakthroughs: The story of Hewlett-Packard’s thermal ink-jet. Industrial and Corporate Change 11 (5): 1059-1084

Fleming, L., and Sorenson, O., 2004. "Science as a Map in Technological Search." Strategic Management Journal 25: 909-928.

Foil, C. M., & Lyles, M. A. 1985. “Organizational Learning” *Academy of Management Review* (10): 803-813.

Galunic DC, Rodan S, 1998. Resource recombinations in the firm: Knowledge structures and the potential for Schumpeterian innovation. *Strategic Management Journal* 19 (12): 1193-1201

Gambardella, Alfonso. 1995. *Science and Innovation: The U.S. Pharmaceutical Industry During the 1980s.* Cambridge: Cambridge University Press.

Ghemawat, P., & J. E. Ricart i Costa. 1993. “The Organizational Tension Between Static and Dynamic Efficiency” *Strategic Management Journal* (14): 59-73.

Gittelman, M. and B. Kogut (2003). “ Does Good Science Lead to Valuable Knowledge? Biotechnology Firms and the Evolutionary Logic of Citation Patterns,” Management Science, 49(4), pp. 366-382.

Hall, B. H., A. B. Jaffe, and M. Trajtenberg. 2001. "The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools," August 2001.

Hamilton, R.T. and Chow, Y.K., 1993. Why Managers Divest – Evidence from New Zealand’s Largest Companies. Strategic Management Journal 14(6): 479-484.

Haynes, M., Thompson, S. and Wright, M., 2003. The determinants of corporate divestment: evidence from a panel of UK firms. *Journal of Economic Behavior & Organization*, 52: 147–166

Helfat CE. 1994. “Evolutionary trajectories in petroleum firm R&D” *Management Science* (40): 1720–1747.

Henderson, R., and Cockburn, I. "Measuring Competence: Exploring Firm Effects in Pharmaceutical Research." Strategic Management Journal, 1994, 15, pp. 63-84.

Henderson, R., L. Orsenigo, and G. Pisano. 1999. “The pharmaceutical industry and the revolution in molecular biology.” D. Mowery, R. R. Nelson, eds. *Sources of Industrial Leadership*. Cambridge University Press. New York, 267-311.

Hoskisson RE, Johnson RA, Moesel DD. 1994. Corporate divestiture intensity in restructuring firms: effects of governance, strategy, and performance. *Academy of Management Journal* (37): 1207–1252.

Hounshell, D., 1995. "The Evolution of Industrial Research in the United States," in R. S. Rosenbloom and W. J. Spencer, eds., *U.S. Industrial Research at the End of an Era*. Cambridge: Harvard Business School Press, 1995.

Hounshell, D. and Smith, J., 1988. *Science and Corporate Strategy: Du Pont R&D, 1902-1980*. Cambridge: Cambridge University Press.

Huselid, M.A., 1995. The Impact of Human Resource Management Practices on Turnover, Productivity and Corporate Financial Performance. *ACADEMY OF MANAGEMENT JOURNAL* 38 (3): 635-672

Huselid MA, Jackson SE, Schuler RS., 1997. Technical and strategic human resource management effectiveness as determinants of firm performance. ACADEMY OF MANAGEMENT JOURNAL 40 (1): 171-188

John, K and Ofek, E., 1995. Asset Sales and Increase in Focus. *Journal of Financial Economics* 37: 105-126.

Karim, S. and Mitchell, W., 2000. “Path-Dependent And Path-Breaking Change: Reconfiguring Business Resources Following Acquisitions In The U.S. Medical Sector” 1978–1995. *Strategic Management Journal* (21): 1061-1081

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

Kim, Dong Jae and Bruce Kogut, 1996, "Technological Platforms and Diversification," *Organization Science*, 7: 283-301.

Lanjouw, J. O., A. Pakes, and J. Putnam. 1998. “How to Count Patents and Value Intellectual Property:The Uses of Patent Renewal and Application Data” *The Journal of Industrial Economics* (46): 405-432.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter. 1987. “Appropriating the Returns from Industrial Research and Development” *Brookings Papers on Economic Development: Special Issue on Microeconomics* (1987): 783-820.

Levinthal, D. A., & March, J. G. 1981. A Model of Adaptive Organizational Search. Journal of Economic Behavior and Organization (2): 307-333.

Levinthal, D., and J. G. March, 1993. "The myopia of learning." *Strategic Management Journal*, (14): 95-112.

March, J. G. 1991. "Exploration and Exploitation in Organizational Learning" *Organization Science* (2): 71-87.

McEvily W.and Zaheer A, 1999. Bridging ties: A source of firm heterogeneity in competitive capabilities STRATEGIC MANAGEMENT JOURNAL 20 (12): 1133-1156

McGrath R.G., MacMillan, I.C, and Venkataraman, S., 1995. Defending and Developing Competence – a Strategic Process Paradigm. *Strategic Management Journal* 16 (4): 251-275.

McGrath, R. G. and A. Nerkar. 2004. "Real Options Reasoning and a new look at the R&D Investment Strategies of Pharmaceutical Firms" *Strategic Management Journal* (25): 1-21.

Nelson, R. and Winter, S., 1982. *An Evolutionary Theory of Economic Change*. Belknap Press of Harvard University Press: Cambridge MA

Nerkar, A. and I. MacMillan. 2003. Giving up competitive advantage: The role of learning in the disbandment of real options. *Working Paper*.

Pakes, A. and M. Simpson. 1989. "Patent Renewal Data" *Brookings Papers: Microeconomics* (1989): 331-410.

Palich, L.E., Cardinal, L. and Miller, C.C., 2000. Curvilinearity in the Diversification- Performance Link: An Examination of Over Three Decades of Research. *Strategic Management Journal* 21: 155-174.

Penner-Hahn, J. 1998. "Firm and Environmental Influences on the Mode and Sequence of Foreign Research and Development Activities" *Strategic Management Journal* (19): 149-168.

Peteraf MA. 1993. The cornerstones of competitive advantage. *Strategic Management Journal* (14): 179–191.

Powell T.C., and Dent Micallef, A., 1997. Information technology as competitive advantage: The role of human, business, and technology resources. *STRATEGIC MANAGEMENT JOURNAL* 18 (5): 375-405.

Porter ME. 1996. What is strategy? *Harvard Business Review* (74): 61–78.

Rosenberg, N., 1982. *Inside the Black Box*. Cambridge: Cambridge University Press.

Rosenberg, N. 1994. *Exploring the Black Box: Technology, Economics and History*. Cambridge: Cambridge University Press.

Rosenberg, N., 1990. Why do Firms do Basic Research (with their own money)? Research Policy 19(2): 165-174

Rosenberg, N. and Birdzell, L.E., 1986. *How the West Grew Rich*. New York: Basic Books.

Rosenkopf and Nerkar 2001

Roth, A. V. and Jackson, W. E. (1995), "Strategic Determinants of Service Quality and Performance: Evidence from the Banking Industry," Management Science 41, 1720-1733.

Schankerman, M. and A. Pakes. 1986. “”Estimates of the Value of Patent Rights in European Countries during the post-1950 period” *Economic Journal* (96): 1166-1186.

Siggelkow, N. 2002, “Evolution toward fit.” *Administrative Science Quarterly* (47): 125-159.

Silverman, B.S. 1999. “Technological Resources and the Direction of Corporate Diversification: Toward an Integration of the Resource-Based View and Transaction Cost Economics” *Management Science* (45): 1109-1124.

Simon M, Houghton SM, 2003. “The relationship between overconfidence and the introduction of risky products: Evidence from a field study”. *Academy Of Management Journal* (46): 139-149.

Somaya, D. 2003. “Strategic Determinants of Decisions not to Settle Patent Litigation," *Strategic Management Journal* (24): 17-38

Sorenson, J.B. and Stuart, T.E., 2000. Aging, obsolescence and organizational innovation. *Administrative Sciences Quarterly* (45): 81-112.

Stuart TE, Podolny JM, 1996. Local search and the evolution of technological capabilities *Strategic Management Journal* 17: 21-38 Sp. Iss. SI SUM.

Teece, D.J. 1986. “Profiting from Technological Innovation” *Research Policy* (15): 285-305.

Teece, D.J., G. Pisano, and A. Shuen. 1997. “Dynamic Capabilities and Strategic Management” *Strategic Management Journal* (18): 509-533.

Trajtenberg, M., R.A. Henderson, and A.B. Jaffee. 1997. “University versus Corporate Patenets: A Window on the Basicness of Invention” *Economics of New Technology and Innovation* (80): 119-127.

Wernerfelt B. 1984. “A Resource-Based View of the Firm”. *Strategic Management Journal* 5(2): 171–180.

Zucker L, Darby M, Brewer M. 1998. Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review* 88: 290–306.

Table 1. Renewal rate by firm, 2002

Firm	Patents up for 4-year renewal	Renewed Patents	Renewal Rate
Schering Plough	37	37	100%
Genentech	35	35	100%
Wyeth	89	88	99%
Pfizer	80	77	96%
Monsanto	49	47	96%
Johnson & Johnson	47	45	96%
Bristol-Myers Squibb	56	53	95%
Glaxo Wellcome	35	33	94%
Abbott Laboratories	34	32	94%
Loreal	54	48	89%
Hoechst	102	89	87%
Pharmacia	47	41	87%
Proctor & Gamble	53	46	87%
Rhone Poulenc	41	35	85%
Hoffmann La Roche	38	32	84%
Zeneca	44	37	84%
Eli Lilly And Company	109	91	83%
Astra	36	30	83%
Takeda	39	32	82%
Novo Nordisk	43	35	81%
Novartis	54	42	78%
Merck	157	120	76%
Bayer	81	56	69%
Smithkline Beecham	67	46	69%
Sanofi	35	17	49%

Figure 1. Patent and renewal rates by year of patent issue

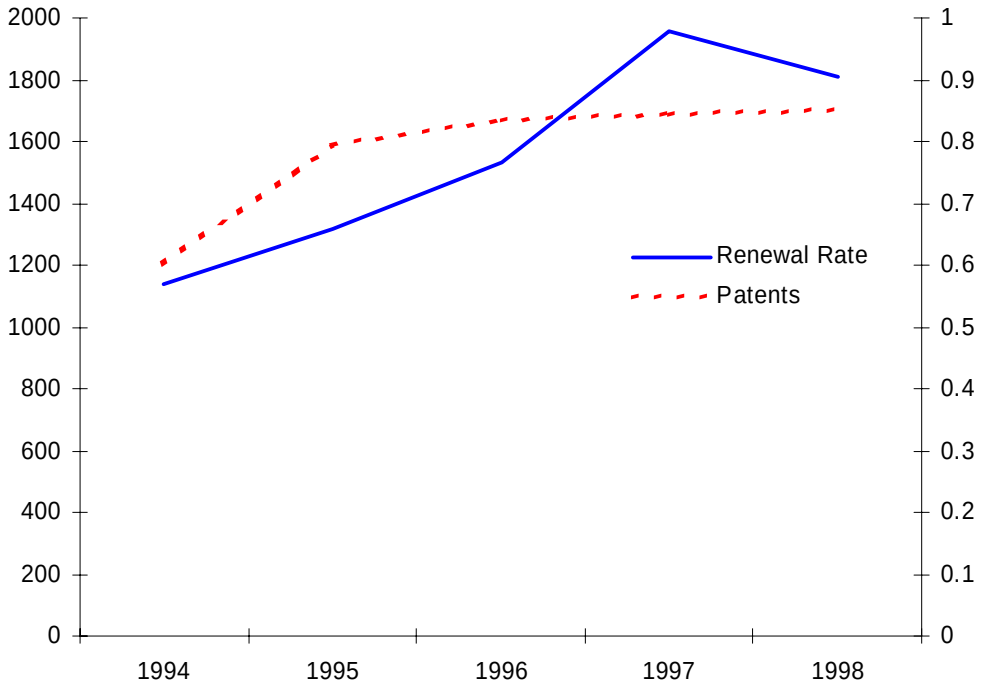

Table 2. Summary Statistics

Variable	Mean	Standard Deviation	Min	Max
New_to_Science	0.455	0.352	0	1
New_to_Firm	0.538	0.428	0	1
Claims	13.409	11.315	1	152
Annual_pats	57.935	40.843	1	157
Foreign	0.483	0.500	0	1
Time_to_grant	1.972	0.942	0	10

Table 3. Correlation Matrix

	New_to_Science	New_to_Firm	Claims	Annual_pats	Foreign	Time_to_grant
New_to_Science	1.000					
New_to_Firm	0.199	1.000				
Claims	-0.023	-0.004	1.000			
Annual_pats	0.069	-0.206	-0.024	1.000		
Foreign	-0.030	0.161	-0.080	-0.240	1.000	
Time_to_grant	0.055	0.087	0.083	-0.040	0.012	1.000

Table 4. Results for Binomial Regression of Renewal Decision (Odds Ratios Reported)

	Model 1 (Fixed Effects)	Model 2 (Fixed Effects)	Model 3 (Fixed Effects)	Model 4 (Fixed Effects)	Model 5 (Year-Firm interations)	Model 6 (Year-Firm interations)
New_to_Science	0.844		0.797	0.800	0.749	0.752
	(1.96)**		(2.45)**	(2.4)**	(2.99)***	(2.94)***
New_to_Firm		0.797	0.841	0.853	0.850	0.862
		(2.97)***	(2.18)**	(1.98)*	(1.95)*	(1.77)*
Claims				1.011		1.011
				(3.22)***		(3.05)***
Annual_pats				1.004		1.013
				(1.70)*		(1.33)
Foreign				0.575		0.560
				(6.25)***		(6.29)***
Time_to_grant				1.044		1.040
				(1.21)		(1.06)
Pseudo-R Squared	0.122	0.162	0.163	0.170	0.180	0.188
χ^2 statistic	947.08***	1256.53***	1262.57***	1321.35***	1356.71***	1411.28***

Fixed Effects for firm and year are included in Models 1-4; Models 5 and 6 include year-firm interactions
Absolute value of z-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5. Results for Binomial Regression of Renewal Decision (Odds Ratios Reported)

	Model 7	Model 8	Model 9	Model 10	Model 11
	(Fixed Effects)	(Fixed Effects)	(Fixed Effects)	(Fixed Effects)	(Fixed Effects)
New_to_Science_100	0.681				0.766
	(4.23)***				(2.60)***
New_to_Science_80		0.792			
		(3.15)***			
New_to_Firm_100			0.766		0.835
			(4.09)***		(2.46)**
New_to_Firm_80				0.810	
				(3.25)***	
Claims	1.010	1.010	1.011	1.011	1.011
	(3.09)***	(3.12)***	(3.25)***	(3.30)***	(3.14)***
Annual_pats	1.004	1.004	1.004	1.004	1.004
	(1.76)*	(1.77)*	(1.76)*	(1.72)*	(1.76)*
Foreign	0.580	0.569	0.581	0.577	0.585
	(6.12)***	(6.36)***	(6.12)***	(6.21)***	(6.03)***
Time_to_grant	1.033	1.038	1.041	1.043	1.037
	(0.90)	(1.04)	(1.14)	(1.17)	(1.03)
Pseudo-R Squared	0.171	0.170	0.171	0.170	0.171
χ^2 statistic	1325.30***	1317.74***	1324.63***	1318.48***	1331.30***

Fixed Effects for firm and year are included in Models 7-11
Absolute value of z-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%