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. We propose that empirical research that ignores disbanded assets, and firms’ reasons for disbanding those assets, can lead to biased measurements and overstated conclusions regarding 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 firms disband their patents: specifically, not to renew the patent and allow the intellectual property right to expire before the end of the patent term.
1. INTRODUCTION

Scholars studying strategy and organizations historically have 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 tradeoff 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, 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, a critical question facing the strategy and organization theory fields is do different firm strategies result in different distributions of abandoned assets within an industry?

In this paper, we 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.

We examine asset disbandment in the context of these exploratory strategies. 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, \textit{ceteris paribus}. Specifically, we 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 examine patents in the pharmaceutical industry. The tradeoff
between exploratory and exploitative search paths is particularly relevant to this industry. Patents serve as
critical instruments for appropriating value from research 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\textsuperscript{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\textsuperscript{2}. By
contrast, Merck only renewed 120 of 157 patents up for renewal in that year, effectively disbanding 24%

\textsuperscript{1} Sources: \textit{Merck Annual Report 2003} and \textit{Wyeth Annual Report 2003: Growth and Innovation}.

\textsuperscript{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.
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. Table 1 displays 2002 renewal rates for the largest 25 pharmaceutical firms. There is considerable heterogeneity in the rate in which pharmaceutical firms retain and disband their assets.

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. We find that more exploratory patents are more likely to be disbanded (i.e. not renewed). We find this effect to be significantly large: under different measures of the exploratory nature of a given patent, as the fraction of patent citations that are exploratory increases to 1, there is a 15% to 20% reduction in the odds of renewal. These results are robust to the introduction of firm-year fixed effects, removing any variation in the data attributable to firm unobserved characteristics, including firm performance, R&D level, therapeutic markets, quality of the legal team and other influences.

An implication of our results is that neglecting this asset disbandment may lead to an overstatement 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, few papers to date have sought to understand the nature of patent renewals. Given that the innovation literature has utilized patents and patent characteristics routinely in firm, industry, and public policy analysis, the results of this study demonstrate that further attention is needed for patent renewal data. We demonstrate that the likelihood of patent renewal 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.

2. A FRAMEWORK TO UNDERSTAND ASSET DISBANDMENT

2.1 Firm Strategy, Asset Accumulation and Disbandment

Strategy research has increasingly focused on the notion that firms establish competitive advantage through ‘strategic assets’. These assets provide a source of distinctive competitive advantage
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 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, empirical research has largely not examined the 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 specific assets that are disbanded. 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. Available data on products commercialized, product sales, etc., rarely includes data on which projects and products were no brought to market. As a result, the choice set of opportunities a firm is faced with is rarely observed after the fact.

Examining asset disbandment is of fundamental importance for two 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. This point is illustrated in Figure 1 below which provides a conceptual model of the observed data at the outcome level that might be examined by an investigator (representative of products, projects, revenues, or profits, etc.) under two different firm strategies, exploitation and exploration.

If in a particular industry, risky or exploratory research tends to lead to a few “home runs” but overall may have a lower average return than reliable, exploitative research ($\mu_{\text{exploit}} < \mu_{\text{explore}}$ in Figure 1), an investigator could mistakenly conclude that firms choosing the risky path perform better on average. The reason is that, if firms have a similar minimum expected return to pursue a given project or product idea commercially, marked by $\alpha$ in Figure 1, as researchers we might only observe all projects to the right of $\alpha$. Among the two distributions, the average return for exploratory projects above $\alpha$ exceeds the average return for exploitative projects above $\alpha$ since exploratory projects have a “fat tail” where successes are extremely profitable. The average of observed exploratory products is thus greater. Hence, by ignoring the product development failures, the researcher could overestimate the impact of risky innovation on performance.

For example, a number of recent publications have examined patent characteristics to assess 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 this line of research 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.

Another example arises from economics research on patent renewals and patent valuation. 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 the model of patent renewal presented by Shankerman and Pakes (1986). Shankerman and Pakes 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. As illustrated above, 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, but is actually endogenous to the strategic choices a firm makes ex ante.

2.2 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.

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.** We specifically 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).

While exploratory 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. 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.

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.

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:

\[ H2: \text{Developing strategic assets through exploration of knowledge outside firm boundaries will result in greater likelihood of asset disbandment, ceteris paribus.} \]
2.3 Exploration, Asset Investment and Disbandment in the Pharmaceutical Industry

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 largest 50 firms, as a particularly propitious environment to test our theory. 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. Moreover, 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 typically do not know what its potential value of that asset is. Firms learn more about the value of a particular patent asset with laboratory and clinical testing over time. For some patents, the low market value may not justify the cost of continuing to further pursue the development effort that led 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 of 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 infringes on a patent, the firm would nevertheless need to raise a costly lawsuit, simply to maintain their overall threat of legal recourse, even if the patent would be of little or no value.

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 as an effective method to capture value, especially if the firm does not have an active program to do so.

3. **DATA AND METHODOLOGY**

3.1 **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. 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”

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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.
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 2, there is a significant upward trend in both patents granted and renew rates by year.

3.2 Measures and Empirical Models

Our primary methodological challenge is to separate the impact of exploratory research strategy from other firm-specific factors that influence patent renewal. In particular, unobserved heterogeneity among firms influences renewal decisions for individual patents. For example, it is possible that firms pursuing an exploratory strategy also invest in better or more capable legal staff to write, evaluate, and manage their intellectual property. As a result, such firms might may have a higher renewal rate among their patent portfolio, but due to the quality of how their patents are written and applied for rather than the level of exploration associated to their patents. Another example of unobserved heterogeneity stems from research by Cockburn and Henderson (1998) on the performance of pharmaceutical firms that encourage scientific exploration and collaboration with university scientists. Cockburn and Henderson find that firms promoting more scientific exploratory research outperformed other firms because of their absorptive capacity for new knowledge. Building on this argument, successful exploratory firms may invest in higher quality scientists, resulting in research that is more likely to lead to commercial products and, hence, a higher likelihood of renewal, even if most of their patents are highly scientific. In sum, firms may disband or keep patent assets for a variety of unobserved factors and it is necessary to control for these firm specific characteristics that might influence the likelihood of patent renewal.

We approach the analysis with two sets of models. The first set of models tackles precisely the challenges posed above by specifying a binomial logistic estimation of the likelihood a given patent is renewed with firm fixed effects. The fixed effects regression allows us to isolate the effect of decisions related to the level of exploration that firms are pursing on the likelihood of patent renewal from other
unobserved firm effects that may also influence renewals. In addition, we include year fixed effects to control for potential trends in renewal across time that could bias our results. In two of our empirical models (Models 5 and 6), 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. This model specification separates variance on the renewal decision that is related to firm-specific effects from the marginal impact of an exploratory research path. If we define \( y_{ig} = 1 \) if patent \( i \) for firm \( g \) is renewed and \( = 0 \) otherwise, the probability that the invention \( i \) of a firm \( g \) is renewed is given by (we removed year subscripts for clarity):

\[
P(Y_{ig} = 1 | X_{ig}) = \frac{\exp(\alpha_g + X_{ig} \beta)}{1 + \exp(\alpha_g + X_{ig} \beta)}
\]

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

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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.
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 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.

Our second set of models aggregates data annually for firms to assess how overall patent renewal rate relates to their overall level of patent exploration. It is informative for any examination related to firm strategy to consider the impact of decisions on the overall corporation. We present this analysis to explore how our findings from the first set of models aggregate to consistent strategic choices at the firm level. However, we caution that results from this second set of models should be treated with reserve and viewed as a supplemental to the first set of analyses. As described at the beginning of this section, the strategic choices of a firm will be influenced by unobserved factors impacting renewal rates that are orthogonal to our variables of interest. In sum, while the empirical results are similar between these two sets of models, as discussed in the next section, the former set of analysis is more informative and presents stronger support on the specific theory and hypotheses proposed.

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.
Since the distribution of outcomes in this estimation is censored at 0 and 1, we estimate each firm’s annual renewal rate (% of patents up for renewal that were actually renewed) using a Tobit specification. Our unit of analysis in these models is a firm-year. While we cannot completely eliminate firm-specific effects in this regression, we can at least control for a number of firm-level factors that may impact the resources of firms to devote to commercialization and, as a result, impact renewal rate in a given year. The control variables considered are: number of patents issued, total revenue, profit margin, and R&D budget. We also control for time-specific effects with year dummies. Our independent variables of interest are annualized scores for the New_to_Firm and New_to_Science measures. To construct firm-level measures, we averaged the New_to_Firm and New_to_Science measures across all patents received by a firm in a given year\(^6\). These annualized measures can be interpreted as to indicate the overall level of exploration a firm engages in. A firm whose annual New_to_Science score approaches 1.0 indicates virtually all patents in the firm’s portfolio are based on new science and, as a result, are exploratory in nature. Hence, that firm engages in a purely exploratory strategy of research. Firms with scores approaching 0.0 engage entirely in exploitative research, capitalizing on existing knowledge within the company. Following our hypotheses, we expect that firms with more exploratory research on average will demonstrate a lower renewal rate in these regressions.

4. 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

\(^6\) In constructing the New_to_Firm and New_to_Science measures, we also tried a weighted approach by summing all the citations across all patents in constructing these measures to weight patents with many citations more in the measure construction. Our results from both constructions of were virtually identical.
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.

Models 12-16 analyze the impact of firm strategies for exploration and exploitation on asset disbandment. As noted before, firm level regressions help us understand the extent to which the differences in the overall level of exploration at a particular firm, either new to science or new to the firm, correlates with renewal rate. Table 6 presents results of the Tobit regressions. Each of the regressions includes year dummies to control for time-variant effects. Models 12 and 13 report each of the focal regressors (New_to_Firm and New_to_Science) separately, while Model 14 includes both together.
Model 15 includes the controls at the firm-year level. Finally, Model 16 includes pharmaceutical R&D as a percent of sales as an additional control. Model 16 is presented separately because many of the firms did not report R&D at a sufficient level to separate R&D related to pharmaceuticals vs. other areas within the company. As a result, were only able to estimate 140 observations for which we had complete R&D data.

Across all specifications, the coefficient on New_to_Firm is negative and statistically significant at 1%, while the coefficient on the New_to_Science measure is not significant. Thus, firms with an overall strategy to engage in research that requires substantial knowledge outside firm boundaries, but not necessarily new to science, are less likely to renew patents. Firms pursuing a strategy of exploration, pursuing knowledge across their boundaries, are also disbanding their assets at a higher rate. These results are roughly consistent with the analysis in models 1-11. Yet, it is important to remember that, as noted before, these relations are mostly indicative, since we cannot rule out the possibility that the results are determined by unobserved firm heterogeneity correlated with both renewal rate and level of exploration. In fact, it is interesting to note that, in Models 15 and 16, none of the specific firm controls we included in the estimation are significant. This finding suggests that neither size, profitability, nor commitment to R&D drive asset disbandment among pharmaceutical firms, suggesting that other omitted factors drive the variation in renewal rate.

5. DISCUSSION AND CONCLUSIONS

This paper argues a firm’s prior choices to develop strategic assets lead to different distributions of subsequent abandonment for these valuable assets. Using an econometric model that controls for alternative potential explanations as well as firm and year unobserved effects, we show that increases in the exploratory nature of the research underlying a firm’s patent portfolio reduces the likelihood of patent renewal. 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 study to directly show that a firm’s choice of research strategy affects the likelihood that a firm will disband the technological assets in which the firm has previously invested. 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
suggest that neglecting firm decisions (to disband assets) in strategy research may produce 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 was not able to account for the many failed
projects that tend to mostly result from exploratory search paths in the industry. Even when all outcomes
are observed, it is critical to account for the propensity of assets to be disbanded as a result of firm
strategic choices.

The results of this paper also show that both “new to science” and “new to the firm” exploratory
paths are associated with a greater likelihood of disbandment. This finding supports 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 confirm that
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 further explore sources of variation in the factors effecting renewal rate to make predictions regarding strategic behavior, industry structure, and market opportunities. Our exploration of firm level differences in their overall propensity to renew patents show that that firm results are consistent with the patent level regression for new to firm exploration, but not necessarily for new to science. We cannot say that consistent differences in levels of science exploration between firms are necessarily associated to diverse rates of patent renewal. This suggests that it may be possible for some firms to develop capabilities that counter the tendency for exploratory research avenues to be lead to higher rates of abandonment. Future research with richer firm level data could try to study if indeed such capabilities can indeed be developed and what is their nature. 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


Table 1. 2002 Renewal rate by firm, Top 25 firms by patent activity

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<tr>
<th>Firm</th>
<th>Patents up for 4-year renewal</th>
<th>Renewed Patents</th>
<th>Renewal Rate</th>
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<td>Wyeth</td>
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Figure 1. Conceptual model of exploratory and exploitative strategies

Figure 2. Patent and renewal rates by year of patent issue
### Table 2. Summary Statistics

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### Table 3. Correlation Matrix

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

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<td>Time_to_grant</td>
<td>1.044</td>
<td>1.040</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(1.21)</td>
<td>(1.06)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pseudo-R Squared</td>
<td>0.122</td>
<td>0.162</td>
<td>0.163</td>
<td>0.170</td>
<td>0.180</td>
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</tr>
<tr>
<td></td>
<td>0.188</td>
<td>0.188</td>
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<td></td>
</tr>
<tr>
<td>$\chi^2$ statistic</td>
<td>947.08***</td>
<td>1256.53***</td>
<td>1262.57***</td>
<td>1321.35***</td>
<td>1356.71***</td>
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</tr>
<tr>
<td></td>
<td>1411.28***</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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)

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

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%
### Table 6. Results for Tobit Regression of Firms’ Annual Renewal Rates

<table>
<thead>
<tr>
<th></th>
<th>Model 12 (Year Dummies)</th>
<th>Model 13 (Year Dummies)</th>
<th>Model 14 (Year Dummies)</th>
<th>Model 15 (Year Dummies)</th>
<th>Model 16 (Year Dummies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New_to_Science</td>
<td>0.132</td>
<td>0.158</td>
<td>0.165</td>
<td>0.167</td>
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<tr>
<td></td>
<td>(1.29)</td>
<td>(1.59)</td>
<td>(1.63)</td>
<td>(1.48)</td>
<td></td>
</tr>
<tr>
<td>New_to_Firm</td>
<td>-0.192</td>
<td>-0.204</td>
<td>-0.275</td>
<td>-0.293</td>
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</tr>
<tr>
<td></td>
<td>(2.53)***</td>
<td>(2.70)***</td>
<td>(3.13)***</td>
<td>(3.20)***</td>
<td></td>
</tr>
<tr>
<td>Patents</td>
<td>-0.001</td>
<td>-0.001</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(1.60)</td>
<td>(1.73)</td>
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<tr>
<td>Revenue (MM)</td>
<td>0.002</td>
<td>0.001</td>
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<tr>
<td></td>
<td>(0.47)</td>
<td>(0.31)</td>
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<td></td>
</tr>
<tr>
<td>Net Profit %</td>
<td>0.002</td>
<td>0.002</td>
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<tr>
<td></td>
<td>(1.29)</td>
<td>(1.04)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>R&amp;D Share</td>
<td></td>
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<td>-0.124</td>
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<tr>
<td></td>
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<tr>
<td>Constant</td>
<td>0.55</td>
<td>0.739</td>
<td>0.677</td>
<td>0.719</td>
<td>0.803</td>
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<tr>
<td></td>
<td>(9.76)***</td>
<td>(12.10)***</td>
<td>(9.36)***</td>
<td>(8.88)***</td>
<td>(7.33)***</td>
</tr>
<tr>
<td>$\chi^2$ statistic</td>
<td>34.92***</td>
<td>39.49***</td>
<td>41.99***</td>
<td>45.98***</td>
<td>33.19***</td>
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<tr>
<td>Observations</td>
<td>195</td>
<td>195</td>
<td>195</td>
<td>195</td>
<td>140</td>
</tr>
</tbody>
</table>

Year Dummies included in each regression were each significant at p>0.001. Absolute value of t-statistics in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%