External funding and emergent technology inputs

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ARTICLE INFO

Article history:

Received 12 August 2020

Received in rev. form 01 Sept. 2020

Accepted 07 Sept. 2020

Keywords:

Knowledge-Based View, Patents and R&D Strategies, Innovation Process and Management

JEL Classification:

031, 032, 034, 016

ABSTRACT

The research and development (R&D) process is critical to a firm's competitive advantage and often requires external funding. Yet, we know little about how different types of investors respond to the cash needs of established R&D intensive firms nor about how external financial analysts influence those decisions. We address these gaps by examining how a firm's patenting activity affects its ability to raise cash. We distinguish the motivations of two investor groups: open-market and alliance partners. We focus on how patents based on emergent technologies impact two types of investors and their willingness to fund the R&D process. We develop theory and test our hypotheses using data from publicly traded biopharmaceutical firms by drawing upon knowledge-based view, alliance, and investment theories. We find evidence that patents built upon emergent technologies are viewed differently by the two types of investors. We find open market investors were less likely to invest in emergent technologies and invested less when they did. Conversely, alliance partner investors would be more appreciative of the opportunities new technology inputs present, thus, more likely to invest in firms using emergent technologies and invest more.

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Introduction

Research and development (R&D) is critical to developing and maintaining a firm's sustainable competitive advantage (Grant, 1996; Kogut & Zander, 1992). Yet, the process is an especially precarious undertaking for the firm. R&D requires a firm to venture into unknown domains, often in areas where others have not travelled. Furthermore, innovative firms have little opportunity to consult previous successes and failures of others for guidance. The output of innovation is new knowledge. Yet, history provides only imperfect models as newly created knowledge by definition will bear only nominal similarity to previously successful knowledge (Holmstrom, 1989). Novelty also leads to unforeseen obstacles and contingencies, reducing a firm's chances of successfully generating new and useful knowledge.

Such circumstances create difficulties for firms seeking external funding to support knowledge development. Although knowledge is critical to firm success and thus investor returns (Teece, Pisano & Shuen, 1997), it may paradoxically reduce investors' willingness to fund firm operations (Litov, Moreton, & Zenger, 2012). Further, efficient markets where buyers and sellers can accurately value knowledge generally do not exist (Arrow, 1962), creating uncertainty on the part of investors and raising costs of procuring external finance (Hall, 2000; Myers & Majluf, 1984). This is especially true since most of what the inventive firm creates is in the form of tacit knowledge which, by definition, is not easily articulated (Kogut & Zander, 1992). Tacitness, in turn, makes investors' comprehension of firm activities even more remote.

One solution to this problem is for the knowledge producing firm to provide investors tangible indicators of knowledge creation endeavors. Indicators such as patents act as evidence to investors of the firm's knowledge creation abilities while minimizing competitors' expropriation of such disclosures. For example, some studies describe how a firm's patents provide evidence to stakeholders of the tacit ability to create knowledge while simultaneously allowing the firm to exclude others, at least temporarily, from using this technology (Griliches, Pakes, & Hall, 1987). Patents may increase investors' willingness to fund a knowledge-

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<https://doi.org/10.20525/ijrbs.v9i5.833>

producing firm's operations by demonstrating knowledge-creation capacity, simultaneously limiting knowledge expropriation (Levitas & McFadyen, 2009).

Up until now, researchers have primarily examined patenting in young firms, finding evidence of a positive relationship between venture capital financing and patenting. However, conflicting evidence exists as to whether patenting affects more established, publicly traded firms' access to equity capital (Hottenrott, Hall, & Czarnitzki, 2016). Moreover, previous research has not distinguished among the different desires of various types of investors, but rather treated investors homogenously by assuming all equity investors share the same interests. As a consequence, we know relatively little about how different types of investors respond to cash needs of established firms whose operations are highly knowledge intensive.

We address these gaps by examining how a firm's patenting activity affects its abilities to raise cash from two types of external investors. First, we examine how the age of technology inputs provides unique insights into the firm's knowledge creating capabilities, reducing knowledge asymmetries and thus some uncertainties for external investors. We also distinguish the motivations and actions of two types of equity investor groups: open-market investors that includes individual and institutional investors who generally buy shares on organized exchanges, and alliance partners which purchase a firm's equity in non-exchange transactions upon formation of an alliance. We chose these groups since they represent the vast majority of investors of US biopharmaceutical industry firms.¹ We use the US biopharmaceutical industry for our study, not only because of the type of investors it attracts, but also due its focus on ground-breaking but risky knowledge development. US biopharmaceutical firms often rely on external equity investments to fund growth (Czarnitzki & Hottenrott, 2011). And, given the majority of firm assets assume the form of intangible knowledge, debtholders willingness to lend to these companies is even further reduced (Williamson, 1988). Thus, equity investments provide the primary source of externally derived funds in this industry (Brown, Fazzari, & Petersen, 2009).

We define emergent technologies following Ahuja & Lampert (2001) as technologies on which a patent is based that are so new they reside at the leading edge of an industry's technological frontier. Patents built upon emergent technologies are often considered risky and can create considerable uncertainties in the eyes of open-market investors. As research suggests, open-market investors recoil from such novelties (He & Tian, 2013). We argue the level of patents based on emergent technologies reduces the *likelihood* the firm will raise money from open-market investors, and lower the *amount* of money raised from these investors. In contrast, we argue production of patents based on emergent technologies will have the opposite effects on the *likelihood* of raising and *amount* of equity from alliance partners. Use of emergent technologies offers a rather new and unexplored set of possibilities to be uncovered and generated. Basing a firm's patents on emergent technologies can provide the basis for technological superiority vis-à-vis competitors due to their potential novelty and value. These characteristics are often the reasons why collaborators seek to establish partnerships with knowledge producing firms (Shan, Walker, & Kogut, 1994; Rothaermel & Deeds, 2004).

Our study is important to understanding how patents affect raising equity (Brown et al., 2009), especially when internal cash generation is not sufficient to maintain operations. First, we attempt to understand in what contexts do more established firms benefit from patenting when attempting to raise external capital. We examine how different types of investors respond to the same patent characteristics when making funding decisions. Given the importance of new technologies to firm survival in technologically intense industries, we focus on patents based on emerging technologies. These are patents whose foundations are especially new and groundbreaking (Ahuja & Lampert, 2001). Our focus is on the creation of new knowledge, and unlike other commonly used patent measures, we examine use of emergent technology inputs to capture the novelty of the patent. Our sample consists of 286 firms and 1,363 firm-year observations of publicly traded U.S. biopharmaceutical firms engaged in novel drug discovery for the years 2000–2006. We estimate our empirical models in two ways. First, we use a logit estimation technique to model the probability of receiving funding, utilizing a dichotomous dependent variable. Second, we utilize an ordinary least squares estimator with fixed firm effects to examine the amount of total funding. We draw upon knowledge, alliance, and investment theories. What follows is a literature review, proceeded by an overview of our research and methodology. We conclude with implications and conclusions.

Literature Review

Theoretical Background and Conceptual Framework

Financing of Knowledge Creation

Invention entails the recombining of knowledge and resources in novel and potentially valuable manners (Schumpeter, 1934). As this ability to create new knowledge provides the basis for R&D success and, potentially elevating organizational performance (Helfat, 1994), one might expect investors to cheer investment in knowledge production. Nonetheless, research suggests investors often demonstrate reluctance when financing such activities, especially when the funds-seeking firm targets cutting-edge knowledge (Hall & Lerner, 2010; Heeley & Jacobson, 2008). There are several reasons for this. Arrow (1962:609) notes the difficulty in appropriating the returns to knowledge production since the produced knowledge will fall short of its true value to investors unless

¹ Please note, we applied dummy variables to Bushee's various categories of investors (transient, quasi-indexer and dedicated as open market investors) and received similar results (Bushee, 2004).

the producer fully discloses that knowledge. Knowledge producers, however, will eschew full disclosure since complete revelation provides the knowledge to the financier at zero cost, mitigating financiers' need to purchase it.

Further, the speculative nature of predicting the success of knowledge production in relation to the evaluation and financing of more physical products that are actively traded on well-established markets, further dissuades investment (Arrow, 1962:618). The likelihood of successful knowledge development and subsequent use can be very difficult to predict in terms of assessing completion points, success, and returns to the development of usable knowledge. For these reasons, Arrow (1962) believes investors will undervalue knowledge production. Similarly, Holmstrom (1989) notes that the risks inherent in venturing into the "unknown" can dissuade investment in knowledge creation. Since knowledge creation entails novelty, investors cannot identify similar projects on which to base valuations of the project under consideration. Furthermore, Myers & Majluf (1984) and Stulz (1990) argue knowledge production can reduce a firm's ability to obtain external equity as knowledge creation widens the information asymmetry between the firm and investors, reducing investors' willingness to invest in the firm. Asymmetry expands when one considers that much of what a firm "knows" is tacit, and thus not easily accessed by financiers.

Because of these difficulties, knowledge oriented firms often choose to fund their operations through internally held cash when available (Himmelberg & Petersen, 1994). These funds, however, are easily depleted due to the resource intense, uncertain and tortuous knowledge development processes (Levitas & McFadyen, 2009). In industries like biopharmaceuticals, many early-stage firms have little or zero product revenues to offset the costs of operations. Borrowing entails considerable costs since firms lack the collateral necessary to secure debt financing (Berger & Udell, 1990; Williamson, 1988), and do not have predictable cash inflows needed to make associated interest payments. Thus, empirical studies indicate growing knowledge-based firms often require equity capital to fund operations (Brown et al., 2009).

An effective solution to the problems of firm-investor knowledge asymmetries is for the firm to provide tangible indicators of successes in the knowledge creation process (Hottenrott et al., 2015). Such indications may also reduce investor fears associated with the unpredictability of the seemingly amorphous nature of knowledge creation. Tangible indicators, such as patents, signal to investors the firm possesses knowledge with economic value (Levitas & McFadyen, 2009).

We focus on attributes of patents that reflect tangible and newly-developed knowledge (Arrow, 1962). While patents can provide especially useful insights to knowledge-deficient environments, patents do not indicate the development of a marketable product or process. Rather, they demonstrate a firm's ability to successfully recombine knowledge in a potentially useful manner (Griliches, 1990). Patents are also costly to replicate as they are neither easily granted nor inexpensive to pursue. Patenting tends to provide clear distinctions between firms that can successfully advance through the knowledge creation process and those that cannot. Hence, patents can, under certain conditions, increase investors' willingness to fund a knowledge-producing firm's operations by demonstrating knowledge-creation capacity while simultaneously limiting knowledge expropriation (e.g., Levitas & McFadyen, 2009).

Emerging Technology Inputs

We believe the ability of a firm to raise equity capital will depend on investors' perceptions, among other things, of the understandability of technology produced. We also believe investor perceptions will vary depending on their unique investment goals, characteristics and situations. Investors will use certain experience-based decision rules to evaluate a firm's knowledge creating abilities (Paredes, 2003, Hirshliefer, 2001). We distinguish between open-market investors (i.e., retail or individual investors and institutional investors such as banks or mutual funds) who buy company shares on public exchanges, and equity investing alliance partners who typically buy shares directly from the company. Previous research has often treated investors relatively uniformly (e.g., Potter, 1992; Binay, 2005; Park & Steensma, 2012). We believe open-market investors and equity investing alliance partners will have highly contrary investing styles, horizons, and goals. We focus on these two groups as both have important roles in raising equity for biotech companies; yet, differ in their motivation to do so.

In terms of knowledge creation, we focus on the technological *inputs* utilized to produce new patents, and financial analysts' reactions to such inputs. With regard to patents, technologies on which patents are grounded are represented by cited patents, or those patents referenced by a focal patent. Similar to journal articles which list references on which the knowledge provided in the article is based, granted patents cite preceding patents which form the technological foundation on which the current patent is based. Research suggests the discovery of new technology rests on the foundation laid by previous technology (Arrow, 1962; Scotchmer, 1987) as new ideas generally do not emerge out of "thin air" but rather develop as major or minor modifications of previous ideas (Schmookler, 1966). These cited patents shape the technological problems addressed and opportunities created by the focal patent (Dosi, 1982). Cited patents, therefore, form the historical base on which the focal patent is grounded.

We extend patent research, not by studying patent citations (citations which a patent receives), but by focusing on the age of the technology inputs of the firm's patents (cited patents upon which the new patent is built). Ahuja & Lampert (2001:527) dichotomize input technologies into "mature" technologies which are relatively older and well-established in the industry, and "emergent," or those technologies which are "new in chronological terms... [and] represent the leading edge of technology." Emergent technologies are those which have been developed relatively recently and thus embody the most current technological advances in the industry.

Empirical Studies and Hypothesis Development

Open-Market Investors versus Alliance Partner Investors

Generally, research suggests open-market investors although not privy to a firm's tacit knowledge, respond favorably to a firm's tangible revelation of this knowledge. And, patenting provides some tangible indication of the possession and ability to create intangible knowledge. For example, a long line of research in economics and strategy has mostly found various measures of a firm's patenting positively affect Tobin's q and other stock market-based measures of investor sentiment (e.g., DeCarolis & Deeds, 1999; Hall, Jaffe, & Trajtenberg, 2005). Yet, evidence also exists more established firms tend not to benefit in equity markets from patenting (Hottenrott et al., 2015).

Importantly, knowledge creation entails many difficulties for broader market investors. First, such projects have considerably high probabilities of failure to accompany their large potential returns (Arrow, 1962). And, since knowledge creation necessitates the search for novelty, investors cannot easily identify similar projects to on which to base valuations and assessments of failure probabilities (Arora & Gambardella, 2010; Holmstrom, 1989). Equally important, open-market investors often cannot attend to and evaluate all relevant information and may revert to some learning and rationalization strategy that compensates for limited cognitive resources. Considerable research suggests open market investors (i.e., equity owners and/or their advisors) face limitations in the amount and type of information they can fruitfully or willingly process (Hirshliefer, 2001; Paredes, 2003). Individuals must confront environments that contain voluminous and constantly changing data. Yet, open market investors are capable of absorbing only a small subset of this.

Instead of simultaneously acquiring, considering, and evaluating all relevant information, open-market investors may utilize certain resource-saving shortcuts, rules of thumb or heuristics that economize on limited cognitive resources. In contexts of simple limited information, such actions may lead to near-optimal decision-making. However, when complexity or novelty inherent in the information to be transferred increases or leads to heuristic changes, such intuitive thinking often leads to deterioration in decision quality. For example, Odean, (1999) argues individual investors cannot realistically consider all of the thousands of stock issues available to purchase through public capital markets but rather individuals focus on those that "catch their attention". Similarly, Barber & Odean, (2008) find prominent news stories which attract investor attention to be positively correlated with individual investors purchases, suggesting individual investors consciously or subconsciously limit their set of possible purchases to those highlighted in the media. It also appears investors categorize equity issues (e.g., growth vs. income) to simplify their rationalization of companies. If the firms' strategies do not reflect these categories, investors may avoid investment (Aghion & Stein, 2008). Simply put, investors are confronted with voluminous amounts of data that they must assimilate in manageable amounts (e.g., only focusing on income growth or future potential) to make investment decisions (e.g., Hong, Stein, & Yu, 2007).

Research has identified these tendencies with open-market investors and their advisors (Elliott, 2006; Hirst & Hopkins, 1998). For example, security analysts tend to discount the importance of radically new technologies introduced by a firm when evaluating that firm's prospects since such technologies challenge existing mental models of industry value (Benner, 2010). Other evidence exists that complexity in a firm's diversification structure increases the difficulty analysts have in valuing the firm, and in some cases, cause analysts to drop coverage of that firm (Zuckerman, 2000). Litov et al. (2012) find analysts tend to discount strategies based on managers' proprietary insights, and more highly value strategies using widely held industry knowledge. While such strategies are often seen as keys to long-term competitive advantages (Barney, 1991), the additional mental processing required to rationalize the strategies limits analysts' realization of such value.

These findings suggest that open-market investors will perceive less uncertainty with firms developing no or relatively few patents based on emergent technologies. Since use and dissemination of emergent technologies are limited given their recent discovery, investors may simply not have had as much time to explore and understand the nuances of these nascent technologies as they may have with more established technologies (Heeley & Jacobson, 2008). Often, the benefits or weaknesses of technologies are not known early in their lifespans, but are revealed only over time through continual use and experimentation. Relatively new technologies will have only a limited vetting process. Such uncertainties created by the limited lifetimes of emergent technologies, thus may create considerable reservations on the part of investors. Excessive uncertainty surrounding the investment may simply lead to investor reluctance to provide the firm with capital at low costs.

In contrast, when the majority of the firm's new patents are based on more mature technologies as opposed to emergent technologies, investors have more certain information with which to develop more precise estimates of a firm's technology value. This is consistent with finance and accounting literatures which indicate that information risk surrounding a firm's assets (Francis, Lafond, Olsson, & Schipper, 2007) is positively correlated with a firm's cost of capital. Management scholars also suggest that investors' find technological novelty difficult to rationalize. Hill & Rothaermel, (2003: 261-262) argue investors in general regularly prove to be "inflexible" when firms in which they have invested are confronted with radically new technologies, often inhibiting firms from adopting and utilizing these technologies.

We thus argue open-market investors will react to emergent technologies somewhat unfavorably as they represent relatively unvetted technologies with little or no historical precedent. We suggest production of low levels of patents using emergent technologies produces little knowledge asymmetries. Therefore, we expect open-market investors will react positively to the development of new

technology that is not based on emergent technology. In contrast, open-market investors will react negatively to high levels of patents based on emerging technologies due to considerable information asymmetry and uncertainties.

In short, open-market investors will prefer to evaluate companies on widely established and easily understood technologies rather than technologies whose value is less comprehensible. None or limited development of patents based on emerging technologies should present few new knowledge challenges and thus little new risk from the perception of open-market investors. Hence, we expect firms which develop few or no patents based on emerging technologies to experience higher rates of equity raised through open-market purchases.

Hypothesis 1a: The number of patents based on emerging technologies is negatively related to the probability a firm will raise equity through open-market purchases.

Hypothesis 1b: The number of patents based on emerging technologies is negatively related to the amount of equity raised through open-market purchases.

As stated, our goal is to examine not only open market investors but also alliance partner investors and to determine how the two differ in their motivation and desire to invest in knowledge creating firms. The biopharmaceutical industry relies on alliances to a great degree as technological advances in the industry make it difficult for one firm to possess all the knowledge needed for the creation process. While alliance partners in the same or similar industries should be in a better position to judge the merits of a new technology as well as that technology on which the new technology was based (Shan et al., 1994; Rothaermel & Deeds, 2004), we note that alliance partners will also face knowledge asymmetries. Interestingly, equity positions by alliance partners in knowledge-intensive industries are viewed as holding call options (Folta & Miller, 2002). Call options provide the alliance partner the opportunity to invest in the firm and provide a “first look” at new technologies with the option to purchase more.

Older established technology inputs are likely viewed by those outside the industry as less risky with fewer knowledge asymmetries and uncertainty. However, participants within the industry are more likely to recognize and appreciate the importance and possible value of emergent technologies. Basing a large number of the firm’s patents on emergent technology provides evidence to potential pharmaceutical research-experienced collaborators the firm’s focus on exploring ground-breaking research. When a firm uses inputs that are especially emergent in the production of its own new technology, that firm and its collaborators are highly likely to produce knowledge that resides at or beyond the cusp of an industry’s technological frontier (Ahuja & Lampert, 2001; Heeley & Jacobson, 2008). This results from the fact that, by definition, emergent technologies have been developed only recently and thus their prior exploration is limited. Emergent technologies simply have not existed long enough to allow for the uncovering of their many nuances and intricacies. Exploration of such technologies, therefore, will provide a wealth of discovery opportunities. Use of emergent technologies thus offers relatively new and unexplored sets of possibilities to be uncovered and generated. Basing a firm’s patents on emergent technologies can provide the basis for technological superiority vis-à-vis competitors due to the novelty and value they potentially provide.

Use of emergent technologies also indicates the firm possesses exceptional learning abilities. Cohen & Levinthal (1990) argue the ability to utilize technological inputs rests on prior experience in absorbing and utilizing similar technology. Experience allows firms to develop schema or cognitive structures that can facilitate the clarification and evaluation of new experiences. When faced with new knowledge, a firm attempts to identify similarities between its existing schema and novel knowledge to anchor the novelty in what it already knows. Learning, therefore, promotes the development of new, or alteration of old, schema. As a firm develops an appreciation for and dexterity in absorbing new knowledge, the speed with which it learns increases, allowing it to appreciate and utilize newly produced technologies before those firms with reduced learning speeds (Heeley & Jacobson, 2008; Narin, Albert, & Smith, 1992; Narin, Carpenter, & Woolf, 1984). The ability to utilize emergent technologies, in turn, can prove competitively advantageous since being one of the first to utilize technology may allow the firm and the alliance partner to gain an early foothold in a market, especially when competitors with less effective learning systems are unable to respond (Heeley & Jacobson, 2008).

Hence, we believe firms which produce relatively large amounts of patents based on emergent technologies will realize high levels of cash inflows from alliance partners. Potential collaborators may view partnering with an emergent technology-using firm as the key to its future survival. Often partners who themselves may lack learning skills will search for firms who have the ability to use emergent technologies to create technological breakthroughs (Powell, Koput, & Smith-Doerr, 1996; Rothaermel & Boeker, 2008). The ability to acquire and use emergent technologies can attract partners, leading to more cash inflows to the firm in the form of milestone, licensing, and royalty payments. Producing a large number of patents based on emergent technologies should increase the probability of raising funds as well as the amount of equity from alliance partners.

Hypothesis 2a: The number of patents based on emerging technologies is positively related to the probability a firm will raise equity through alliance partner purchases.

Hypothesis 2b: The number of patents based on emerging technologies is positively related to the amount of equity raised through alliance partner purchases.

Research and Methodology

Our sample consists of publicly traded U.S. biopharmaceutical firms engaged in novel drug discovery for the years 2000–2006. Our predictors and outcomes are measured contemporaneously. Collecting data from a single industry allows us to avoid potential industry confounds as well as difficulties in interpreting meanings of patents across various technological and appropriability regimes (Ahuja, 2000; Sorensen & Stuart, 2000). Using Compustat data files, we identified a set of firms listed as their primary Standard Industrial Classification (SIC) codes 2833-2836, 2890, 3672, 3841, 3842, 5122, 8071, 8731, and 8734. These codes are commonly associated with biopharmaceutical or traditional pharmaceutical firms. We then examined publicly available US Securities and Exchange Commission (SEC) firm filings, trade publications such as *Bioscan*, articles contained in *Nature Biotechnology*, the *ABI/INFORM* database of business-related periodicals, and company websites for further information about these firms' focus. We retained only companies whose primary business descriptions explicitly referred to the development of biotechnology-based human therapies. Phrases describing retained companies included "science and biotechnology therapies," "the leading biopharmaceutical company," "RNA-targeted drug discovery," and "genomics-based drug discovery". These procedures as well as patent/financial data availability limited our sample to 286 firms and 1,363 firm-year observations. We obtained all patent information from the National Bureau of Economic Research (NBER) Patent Citations database (Hall, Jaffe, & Trajtenberg, 2001; Hall et al., 2005) and the USPTO's Cassis database. All other data were obtained from Compustat, IMS Health's R&D Focus, and Deloitte's Recap database. Data collection was primarily limited as the NBER Patent Citations data was available only through 2006.

Dependent variables

Amount of Funding-Open Market Purchases (H1b). We identified the amount of cash raised through the sale of common and preferred stock for each firm year, then subtracted from it the amount of cash surrendered through dividends and the purchase of common and preferred stock. We collected these data from Compustat. This provides us the net proceeds that firm obtained from its equity finance activities. Note this number will also include equity purchased by "non-open market investors" such as alliance partners. To isolate equity raised via open-market purchases, we subtracted from this number the amount of equity purchased by alliance partners, obtained from Deloitte's rDNA database. We used its natural log to normalize the variable.

Amount of Equity Raised Through Open-Market Purchases (H1a). We coded a variable one if the amount of equity raised through open-market purchases was greater than zero, and zero otherwise.

Amount of Funding Alliance Partners' Purchases (H2b). We obtained the amount of equity purchased by alliance partners from Deloitte's rDNA database. To normalize this variable, we used its natural log to normalize the variable.

Amount of Equity Raised Through Alliance Partner Purchases (H2a). We coded a variable one if the amount of equity raised through alliance partner purchases was greater than zero, and zero otherwise.

Independent Variable

Patents Based on Emergent Technologies. To measure the degree to which a firm utilizes emergent technologies, we subtract from the filing year of each patent the year in which every citation on that patent was filed. We averaged these citation ages to identify patents whose citations' average age is less than three years (Ahuja & Lampert, 2001). A yearly sum of patents whose average citation age is less than three years old is then calculated. We then add the current year's total of emerging technology-based patents to the previous four years' totals².

Controls

We control for a number of factors that may explain the probability of receipt and levels of equity funding including: Drug Project Diversity, Liquidity, Drug on Market Dummy, Dedicated Institutions, Number of Financial Analysts. Diversity of potential products pursued by a firm may reduce perceived risks of investing in a firm as the firm may have multiple opportunities for product revenues; yet, may also reduce investors' understandings of firm activities. Using the IMS R&D Focus database, we identify therapeutic areas in which a firm's projects are classified in a focal year. The European Pharmaceutical Market Research Association (EPMRA) classifies pharmaceutical projects into therapeutic areas (Nicholson, Danzon, & McCullough, 2005). To estimate *Drug Project Diversity*, we calculate a Herfindahl Index of project classes in which the focal firm is involved in the current year. We calculate this as $1 - \frac{\sum_k M_{ijt-k}^2}{\sum_k (M_{ijt-k})^2}$ where M_{ijt-k} is the proportion of EPMRA class k projects of firm i in market segment j in year t . The amount of cash a firm holds on its balance sheet may also affect the degree to which a firm needs to solicit investors for external funds. We control for *Liquidity* by dividing the firm's total cash and equivalents by its total assets in the focal year. We use a *Drug on Market Dummy* if the firm had a US Food & Drug Administration approved drug for marketing in the focal year as product revenues may affect the firm's financial needs. We identify dedicated institutional investors, those which have relatively long-term investment

² As an example, assume that Patent A is granted in 2005. It cites patents that are granted in 2003 and 2002. The average age of these cited patents is then 2.5 (i.e. $\frac{(2005-2003)+(2005-2002)}{2}$). Since the average age of Patent A's citations is less than three, we consider this patent to be based on emerging technologies. In contrast, assume Patent B is granted in 2005. It cites patents granted in 1991 and 1990. The average age of these cited patents is 14.5 (i.e. $\frac{(2005-1991)+(2005-1990)}{2}$) and therefore Patent B would not be classified as based on emerging technologies.

horizons (Bushee, 1998). *Dedicated Institutions* is measured by total shares held by the dedicated investors divided by a firm's total outstanding shares. Using the IBES International databases, we counted the number of analysts that researched and reported on a firm at any point during the focal year to measure the *Number of Financial Analysts* following a firm in a given year.

R&D expenditures may also impact the transparency of firm operations as viewed by various investors (Hall & Lerner, 2010). We control for these possibilities through *R&D Intensity*, measured by dividing a firm's R&D expenses by its total assets in a focal year. We control for the possibility that the circumstances of raising cash through initial public offerings differ from subsequent equity events. We insert an *IPO Dummy*, coded 1 if funds were raised in the focal year through the firm's initial public offering, and zero otherwise. We measure *Firm Size* by the natural log of the firm's total assets. Strategic alliances may act as a signaling mechanism through which investors can ascertain the "quality" of a firm's expertise (Nicholson et al., 2005). We control for *Total Alliances* by counting all alliances in which the firm has engaged in the current year and the previous two years. In addition to equity investments made by partners in a focal firm (the funding on which we partly focus), partners may provide research and development funds to help catalyze exploration, and upfront funds or other funds provided at the commencement of a partnership to fund other operations. We control for the possible effects of these varying types of funding in our alliance funding regressions through a count of *Total R&D Funds* and *Upfront Funds*, both obtained from Deloitte's RDNA database. We control for the effects of debt on receiving equity financing by measuring *Leverage* as the ratio of total debt to invested capital. We insert yearly fixed effects to control for the varying influences of time.

We estimated our empirical models in two ways. First, in models where we examined the probability of receiving funding, we used a logit estimation technique to model probability utilizing a dichotomous dependent variable. We modeled random firm effects in our logit regressions since we could not achieve model convergence when utilizing fixed firm effects. Second, in models where we examined the amount of total funding, we utilized an ordinary least squares estimator with fixed firm effects. All empirical models were estimated with robust standard errors adjusted for within-firm (i.e., clustered by firm) correlation.

Table 1 provides the means, standard deviations, and pairwise correlations of the variables used in our models. Tables 2 & 3 present the results of our empirical estimations. The *p* values for all Chi-squared tests (Table 2) and F tests (Table 3) are less than 0.001.

Table 1: Correlations and Simple Statistics^a

Variables	Mean	S.D.	1	2	3	4	5	6	7	8
1. Amount of Funding-Alliance Partners ^b	0.04	0.19								
2. Equity Funds Raised from Alliance Partners	0.62	3.08	0.96							
3. Amount of Funding Open-Market Investors ^b	0.80	0.4	0.10	0.10						
4. Equity Funds Raised from Open-Mkt. Inv	12.44	6.67	0.12	0.12	0.94					
5. Patents Based on Emergent Technologies	0.42	1.69	0.03	0.04	0.05	0.07				
6. Number of Financial Analysts	2.13	3.44	0.001	0.001	0.16	0.20	0.21			
7. R&D Intensity	0.45	0.68	0.01	0.001	-0.10	-0.12	-0.06	-0.14		
8. Drug Project Diversity	0.72	0.34	-0.01	-0.01	-0.02	0.001	0.08	0.08	0.03	
9. IPO Dummy	0.14	0.35	0.01	0.01	0.11	0.16	-0.05	-0.09	-0.06	-0.07
10. Size	17.58	2.58	0.07	0.08	0.60	0.61	0.17	0.37	-0.22	-0.05
11. Total Alliances	2.59	3.50	0.08	0.09	0.13	0.17	0.18	0.36	-0.08	0.02
12. Drug on Market Dummy	0.16	0.37	0.01	0.02	0.09	0.11	0.18	0.32	-0.07	0.28
13. Total R & D Funds ^c	0.77	4.99	0.11	0.11	0.03	0.05	0.07	0.03	-0.02	0.01
14. Total Upfront Funds ^c	2.80	11.90	0.13	0.14	0.08	0.10	0.01	0.10	-0.05	0.04
15. Liquidity	0.66	0.26	0.03	0.03	0.06	0.11	0.001	-0.04	-0.03	0.11
16. Leverage	0.27	2.55	-0.01	-0.01	-0.04	-0.03	0.01	0.02	-0.04	-0.03
17. Dedicated Institutions	0.002	0.01	-0.01	-0.01	0.001	0.001	0.02	0.05	-0.03	0.001
18. Proportion of Equity	0.002	0.01	0.63	0.66	0.07	0.08	0.01	-0.02	0.01	-0.01

Variables	9	10	11	12	13	14	15	16	17
10. Size	0.11								
11. Total Alliances	0.001	0.26							
12. Drug on Market Dummy	-0.03	0.20	0.15						
13. Total R & D Funds*	0.02	0.05	0.09	0.01					
14. Total Upfront Funds*	-0.04	0.13	0.10	0.13	0.10				
15. Liquidity	0.03	-0.08	-0.07	-0.11	0.01	-0.03			
16. Leverage	-0.02	0.06	-0.01	0.01	0.01	0.01	-0.06		
17. Dedicated Institutions	0.03	-0.03	0.04	0.001	-0.01	-0.02	0.01	0.001	
18. Proportion of Equity	0.01	0.05	0.06	0.001	0.06	0.13	0.05	0.001	0.01

^aN=1,363. Correlations greater than 0.05 are significant at the *p* < 0.05 or lower levels..

^bexpressed as natural log

^cexpressed in millions of dollars.

Table 2: Random Firm-effects Logit Estimations of the Effects of Patents Based on Emergent Inputs on *Equity Raised Through Alliance Partner Purchases* and *Equity Raised Through Open-Market Purchases*

	Model 1	Model 2
Variables	DV: Equity Raised Through Alliance Partner Purchases	DV: Equity Raised Through Open Market Purchases
Patents Based on Emergent Technologies	0.083*	-0.182+
	(0.037)	(0.097)
Number of Financial Analysts	-0.093*	-0.107*
	(0.039)	(0.043)
R&D Intensity	0.118	0.174
	(0.138)	(0.322)
Drug Project Diversity	0.193	0.539
	(0.423)	(0.604)
IPO Dummy	0.299	0.666
	(0.584)	(0.528)
Firm Size	0.088	1.027**
	(0.064)	(0.127)
Total Alliances	0.078**	-0.106*
	(0.023)	(0.054)
Drug on Market Dummy	-0.275	-0.436
	(0.377)	(0.650)
Total R&D Funds	0.000*	
	(0.000)	
Total Upfront Funds	0.000**	
	(0.000)	
Liquidity	0.517	2.770**
	(0.527)	(0.616)
Leverage	0.045	-0.160
	(0.029)	(0.160)
Dedicated Institutions	2.030	-5.927
	(6.068)	(8.999)
Constant	-5.480**	-17.570**
	(1.354)	(2.357)
Model Chi-squared	52.17***	87.78***
Wald Chi-squared vs. Restricted Model	4.902*	3.503+
Log Pseudolikelihood	-.271.63	-.435.43

^a *n* = 1,363. Robust standard errors adjusted for within firm variation in parentheses; Year fixed effects omitted.

+*p* < 0.010, **p* < 0.050, ***p* < 0.010, ****p* < 0.001

Table 3: Fixed Firm-effects Ordinary Least Squares Estimations of the Effects of Patents Based on Emergent Inputs on the *Amount of Funding- Alliance Partners' Purchases* and the *Amount of Funding- Open Market Purchases*

Variables	Model 1	Model 2
	DV: Amount of Funding-Alliance Partners	DV: Amount of Funding-Open Market Purchases
Patents Based on Emergent Technologies	0.198+ (0.111)	-0.137* (0.064)
Number of Financial Analysts	-0.003 (0.033)	-0.012 (0.041)
R&D Intensity	-0.065 (0.108)	-0.074 (0.362)
Drug Project Diversity	0.341 (0.643)	0.431 (0.589)
IPO Dummy	0.323 (0.521)	0.381 (0.337)
Firm Size	0.255 (0.196)	1.027** (0.328)
Proportion of Equity	46.982** (14.664)	13.150** (1.643)
Total Alliances	0.040 (0.063)	-0.028 (0.107)
Drug on Market Dummy	0.287 (0.657)	-0.425 (0.318)
Total R&D Funds	0.000+ (0.000)	
Total Upfront Funds	0.000** (0.000)	
Liquidity	-0.745 (0.627)	0.892 (0.636)
Leverage	0.041 (0.045)	-0.106** (0.019)
Dedicated Institutions	-1.501 (5.980)	-2.854 (3.759)
Constant	-4.022 (3.677)	-7.295 (5.838)
Model F	3.373***	13.36***
F test: Restricted & Unrestricted Models	3.193+	4.540*
R-squared	0.275	0.321

^a $n = 1,363$. Robust standard errors adjusted for within firm variation in parentheses; Firm and year fixed effects omitted.

+ $p < 0.010$, * $p < 0.050$, ** $p < 0.010$, *** $p < 0.001$

Support is found for H1a in Model 2, Table 2. Here, the coefficient of the Number of Patents Based on Emergent Technologies is negative and significant (-0.182; $p > 0.10$). A Wald test comparing this model to a model with controls only (3.503; $P < 0.10$) shows inclusion of Patents Based on Emergent Technologies enhances the descriptiveness of our empirical models. Support is found for H1b in Model 2, Table 3. Here, the coefficient of the Number of Patents Based on Emergent Technologies is negative and significant (-0.137; $p > 0.05$). An F test comparing this model to a model containing only control variables (4.450; $p < 0.05$) suggests inclusion adds significant explanatory power to our empirical models

Support is found for H2a in Model 1, Table 2. In this model, the coefficient for the Number of Patents based on Emergent Technologies is positive and significant (0.083; $p > 0.05$). A Wald test comparing this model to a model containing only control variables (4.902; $p < 0.05$) suggests inclusion enhances explanatory power of this model. Support is found for H2b in Model 1, Table 2. The coefficient for the Number of Patents Based on Emergent Technologies is positive and significant (0.182; $p > 0.10$). An F test comparing this model to a model without the variable (3.503; $p < 0.10$) suggests inclusion enhances the explanatory power of to our empirical models.

Implications and Conclusions

We set out to examine how a firm's patenting activity affects its abilities to raise cash from two broad groups of investors – open market and alliance partners. We discussed how patents inputs provide unique insights into the firm's knowledge creating capabilities, reducing some uncertainties for external investors. We drew upon the biopharmaceutical industry to examine our hypotheses as this industry derives upon externally sourced funding for knowledge creation. We argued and found evidence patents built upon emergent technologies are viewed differently by the two types of investors. We found open market investors were less likely to invest in emergent technologies and invested less when they did. Conversely alliance partner investors would be more appreciative of the opportunities new technology inputs present, thus, more likely to invest in firms using emergent technologies and invest more.

Our study is important as many research-intensive firms lack or lack access to needed external funding. Our findings imply that various investors have different motivations to invest in the knowledge creating firm. Open-market investors are more wary of emergent technologies and the risk associated with investing in uncertain futures. Conversely, alliance partners have unique insights into the industry and the potential future benefits of being on the leading edge of technology. Technological breakthroughs are key to high knowledge intense industries and the opportunity to be a part of a new breakthrough does not come often. Alliance partners clearly have access to more insights of technology trajectories within the industry, yet they will also succumb to analysts' concerns with emergent technologies. Thus, firms using more established technology inputs are likely to be more successful in obtaining needed funding from open-market investors. On the other hand, research intensive firms utilizing emergent technology inputs are more likely to find needed funding from an alliance partner rather than an open-market investor.

Our study is not without limitations. First, we focused on only one industry, which allowed us to generate precise unique data, yet may limit the generalizability of our findings. Future research might examine various knowledge intensive industries and incorporate private firms to increase the robustness of our results. Our study should be of interest to managers as well as management scholars. Knowledge creation is key to many industries and the ability to fund such activities is often difficult. Understanding how various investors make investment decisions should provide management with new tools to obtain external equity.

Our study provides new insights into the motivating factors of two broad types of investors as well as a critical external influencer to those investors. We provide additional understanding as to when more established firms benefit from patenting when attempting to raise external capital, and when they do not. Rather than examining patent counts or citations, given the importance of new technologies, we focused on patents which are based on "emerging technologies," as groundbreaking technology is key to competitive advantage in knowledge intense industry. We focused on the creation of new knowledge, and unlike other commonly used measures of patent effectiveness, the concept of emerging technologies encompasses the novelty of the patent on which that technology is based.

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