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Seek and you shall find: the role of exploitive and explorative search in a biotechnology firm's patent claims

RESEARCH ARTICLE

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Abstract

Patents are widely recognized to provide legal protections to a firm's inventions. However, such protections are dependent upon claims that delineate the exclusive rights of the patent. This study examines theoretically and empirically the role of exploitive and explorative search on a firm's patent claims in the biotechnology industry. We argue that firms are subject to 'boundedly rational' behaviors where firms are unable to cite their patent's prior art and therefore are unable to identify with their patent's novel claims. A firm's exploitive and explorative search is offered as a solution to overcoming such bounded rationality. We argue and find that a biotechnology firm's exploitive and explorative search has an inverted u-shaped relationship to a firm's patent claims. A key contribution of this study is that a firm's citation behavior is not only attributed to strategic and legal motivations, but also be to behavioral explanations.

Keywords: patent claims, exploitive and explorative search, innovation
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1. Introduction

Patents are widely recognized to provide legal protections to a firm's inventions. Such protections are dependent upon claims that delineate the exclusive rights of a patent (Li *et al.*, 2014). Patent claims are primarily assessed on the basis that the patented invention demonstrates a novelty and non-obviousness to a 'prior technological art' (Jaffe and de Rassenfosse, 2017; Lampe, 2012; Li *et al.*, 2014; Sampat, 2010). Such prior art is comprised of citations made to previous inventions which the patented invention is built upon. Empirical studies have shown that the number of citations made to this prior art is positively correlated with the probability that a patent's novel and non-obvious claims will stand up in court (Jaffe and de Rassenfosse, 2017; Lampe, 2012). This is because citations 'immunize' the patented invention from being invalidated by the prior technological art (Lampe, 2012).

Although there are strong legal incentives to disclose all 'relevant' prior art, there is nevertheless, considerable variability in the scope or breadth of this search. For instance, behavioral explanations have found that applicants tend to favor an 'exploitive' search by citing prior art that is closely related to a firm's patented inventions (Quintana-García and Benavides-Velasco, 2008; Rosenkopf and Nerkar, 2001). This is because proximal technologies are easier to relate to than more distant technological arts (Li *et al.*, 2014; Quintana-García and Benavides-Velasco, 2008). Yet, patent studies have also shown that an applicant can engage in an 'explorative' search where the citing of more distant technological arts can promote a combination of technological experiences that cannot be readily recognized by an exploitation of local experiences (e.g. Ahuja and Lampert, 2001).

While the behavioral concepts of exploitation and exploration offer important insights to understanding the scope of an innovator's search, the role of exploitive and explorative search in explaining a patent's claims remains surprisingly limited (Jaffe and de Rassenfosse, 2017; Li *et al.*, 2014). The current treatment of search has been used to explain a firm's ability to innovate new experiences (Ahuja and Lampert, 2001; Quintana-García and Benavides-Velasco, 2008; Rosenkopf and Nerkar, 2001), but not the identification of claims that are central to a patent's economic value. In particular, patent researchers (Lemley, 2001; Marco *et al.*, 2016; Sampat, 2010) have recognized a trend of increasing patent applications where patent applicants are increasingly vulnerable to a 'rational ignorance' (Lemley, 2001). With this ignorance, applicants are unable to fully assess their patent's relevant patent art. Overcoming this ignorance is important because it undermines a firm's ability to make novel / non-obvious claims that are innovatively different from a patent's prior technological art. Hence, since the assertion of a patent's claims is dependent upon a search of a patent's prior art, it stands to reason that exploitive and explorative search should play an important role in influencing an applicant's ability to discover its patent's claims. As a result, this motivates the following research question: how does a firm's exploitive and explorative search influence a firm's discovery of its patent claims?

The objective of this study is to theoretically and empirically examine this research question. In developing this study's theoretical model, we appeal to a 'behavioral' or descriptive approach to explaining a firm's citing behavior. We argue that a firm's 'rational ignorance' (Lemley, 2001) can be explained by a 'bounded rationality' (March, 1978; Simon, 1955, 1956, 1957). With this study, bounded rationality involves limits in a firm's ability to identify with its patent's relevant prior art, where such limits preclude a firm from identifying with its patent's novel claims. To overcome this bounded rationality, a central argument of this study is that a firm's citing behavior is influenced by an exploitive and explorative search. This search distinctly influences a firm's ability to claim novel inventions that are 'innovatively different' (Collins and Wyatt, 1988; Li *et al.*, 2014) from its patent's prior technological art. To empirically examine this citing behavior, biotechnology patent application data was drawn from the United States Patent and Trade Office (U.S.P.T.O.). In using Poisson, negative binomial, and two-stage least squares (2SLS) FE panel estimations, we find that a biotechnology firm's exploitive and explorative search has a positive yet diminishing effect (i.e. inverted u-shaped relationship) to its patent's claims.

In organizing the development of this study, its definitions, assumptions, and units of observation are first outlined. To contrast this study's behavioral explanation from other developments, insights from 'value creation approaches' are then examined (Grimaldi *et al.*, 2015; Jaffe and de Rassenfosse, 2017; Li *et al.*, 2014). The tenets of behavioral research involving the concepts of bounded rationality, exploitation and exploration are introduced (Levinthal and March, 1993; March, 1978, 1991; Simon, 1955, 1956, 1957). Hypotheses relating a firm's exploitive and explorative search to its patent claims are formulated. The data, measures, and methods used to empirically examine these hypotheses are discussed. A discussion of this study's results follows. Lastly, we conclude with this study's contributions and implications to patent research.

Specifically, by addressing this study's research question, this study offers two important contributions to patent research. First, as the primary purpose of a patent application is to demonstrate how a claimed invention is 'innovatively different' from a prior technological art, we argue and empirically show that exploitative and explorative search introduce an important source of novelty and non-obviousness to a firm's patent claims. Second, as the economic value of a patent, especially in the biotechnology industry, resides in the legal standing of a firm's patent claims (e.g. Allison *et al.*, 2003), exploitation and exploration offer a means to validate a firm's patent claims. This validating role has not been addressed in value creation approaches. As a result, this study offers a unique behavioral extension to value creation explanations.

2. Conceptual developments

2.1 A preface to the conceptual model

We define a patent claim as a technical statement that delineates the scope of an applicant's exclusive rights and defines the legal basis for determining the infringement of patents (Grimaldi *et al.*, 2015; Li *et al.*, 2014). More generally speaking, claims define what the inventor considers to be the scope of her invention or technological territory that she claims is hers to control by suing for infringement (Merges and Nelson, 1990). Central to the assertion of these patent claims is that the applicant '... shows how the claimed invention relates to, but is innovatively different from what was already public knowledge (i.e. prior art), and his/her task is to identify his/her work either related to but significantly different from, or else a useful step towards a new invention or use of the invention' (Collins and Wyatt, 1988).

Due to the legal nature of a patent's claims, we assume that unlike other measures of patent value, such as a patent's forward citations (e.g. Hall *et al.*, 2001; Jaffe and de Rassenfosse, 2017), patent claims attribute the value of a patent to its exclusivity rights in protecting an applicant's innovations from infringement by others (Lampe, 2012; Li *et al.*, 2014; Sampat, 2010). Such patent claims are examined from the standpoint of a firm's applicants (Lampe, 2012) where claims are defined at the firm-level. This unit of observation is consistent with patent analysis research (Lampe, 2012; Quintana-García and Benavides-Velasco, 2008; Tseng *et al.*, 2011).

3. Literature review of patent search: value creation approach

Since the search of a patent's prior art is central to a firm's patent claims, developments in the value creation approach have offered varied insights to explaining a firm's citing behavior. Most notably, the value creation approach seeks to explain the strategic and legal motivations in a firm's citing behavior and how a patent's connections to its prior art influences the economic and/or strategic value of a patent (Grimaldi *et al.*, 2015). In explaining the strategic aspects of this value creation approach, Lampe (2012) finds that firms have a strategic incentive to omit or withhold citations of its patent's prior art, because this omission increases a firm's ability to assert their patent claims. For instance, Lampe (2012) describes: 'if patent B cites patent A, it implies that patent A represents a piece of previously existing knowledge upon which patent B builds, and over which B cannot have a claim ...'. In order to assert a firm's patent claims, Criscuolo and Verspagen (2008) thus argued that firms '...have an incentive not to cite patents unnecessarily, as it may reduce their claims to novelty of the invention and therefore affect the scope of the monopoly rights granted by the patent'.

This strategic omission can offer benefits where the firm can create 'patent fences' that obstruct competing firms from gaining access to key technologies and/or improve a firm's negotiating position in generating licensing revenues (Ziedonis, 2004). In addition to such strategic explanations, value creation approaches have argued that there are legal motivations in explaining a firm's citing behaviors. From a legal standpoint, the patent laws in U.S.P.T.O. dictate that a firm's patent applications be subject to a 'duty of candor' where firms are legally obligated to disclose any documents or prior technological art that have a material bearing to a patent's claim (Allison and Lemley, 1998; Allison *et al.*, 2003; Li *et al.*, 2014; Sampat, 2010). A firm that fails to fully disclose this prior art will be interpreted by the U.S.P.T.O. as legal grounds to invalidate a firm's claims to novelty. Hence unlike strategic explanations, Allison *et al.* (2003) argued and found that firms have a strong legal motivation to include citations of prior art, because 'citing more prior art will make a patent more valuable in litigation, as it is much harder to prove a patent is invalid if the patent office has already considered it and rejected the relevant prior art.'

Although these strategic and legal motivations introduce competing explanations to a firm's citing behavior, value creation approaches have argued that the 'discreteness and complexity' of a patented technology can offer a resolution to these explanations (e.g. Cohen, 2010; Cohen *et al.*, 2000; Sampat, 2010; Ziedonis, 2004). Discrete technologies are typically observed in the biotechnology industry where the commercialization of drugs and chemicals products are based on a limited number of 'discrete or separately patentable elements' (Cohen, 2010; Cohen *et al.*, 2000; Sampat, 2010; Ziedonis, 2004). Studies have shown that the biotechnology industry relies on discrete patents for obtaining exclusivity rights to their investments in R&D (Sampat, 2010). Under such discrete product settings, there is a strong legal incentive to fully disclose the prior art, because it develops stronger legal claims of novelty and non-obviousness that can be used to defend against cases of infringement (Allison *et al.*, 2003; Sampat, 2010). In contrast, complex technologies are found in electronic products that consist of many interconnected patentable elements (Cohen, 2010; Cohen *et al.*, 2000; Sampat, 2010; Ziedonis, 2004). With this complexity, the firm does not have control over all patentable elements and thus patents are not used as means of proprietary control (Sampat, 2010; Ziedonis, 2004). Patents are instead used as a legal means to strategically negotiate cross-licensing agreements and to gain favorable licensing terms (Cohen, 2010; Sampat, 2010). With these strategic negotiations, a patent applicant is more likely to strategically withhold the disclosure of the prior art (Ziedonis, 2004). This is because a full disclosure can render a firm's patents subordinate to the claims of another firm's patents to which introduce the potential for hold-up in licensing agreements (Ziedonis, 2004). Hence, while strategic and legal motivations offer competing explanations of a firm's citing behavior, the discreteness and complexity of the patented technology appear to influence the relative importance of these explanations. For instance, Sampat (2010) and other studies (Cohen *et al.*, 2000) have found that while firms are strategically motivated to withhold their citations, firms in discrete product industries, such as biotechnology, engage in a significantly greater search of prior art than complex industries.

While the discreteness/complexity of a patented invention offers an important contextual understanding to value creation approaches, the challenge facing this body of work is that it does not sufficiently recognize limits in a firm's ability to cite its patent's prior art (Lemley, 2001; Sampat, 2010). The reality faced by patent applicants, as well as patent examiners, is that they have limited time and resources to search its patent's relevant prior art. For instance, Sampat (2010) shows that applicants fail to even identify their own previous patents and many fail to even engage in 'cursory searches of prior art'. Such difficulties are further complicated by the observations made by the then former assistant secretary of commerce and commissioner of the U.S.P.T.O. where he had noted that since 2002 there has been a 'dramatic increase in the number of patent applications...' (Marco *et al.*, 2016). With this growth, Lemley (2001) argues that patent applicants are subject to a 'rational ignorance' where firms are unable to fully assess its patent's relevant prior art (see also Marco *et al.*, 2016) and thus face increasing difficulties substantiating their patent's novel claims. Hence, in spite of its contributions to patent research, the challenge with value creation approaches is that it does not sufficiently account for this 'rational ignorance' in a firm's citing behaviors.

3.1 Behavioral theory of the firm

In order to develop a better understanding of a firm's 'rational ignorance', this study argues that value creation approaches can benefit from the insights of behavioral research. Behavioral research, especially those rooted in the behavioral theory of the firm (Cyert and March, 1963; Levinthal and March, 1993; March, 1978, 1991; Simon, 1957), have been a seminal influence to management scholarship (Argote and Greve, 2007). A key distinction of this body of research is that it seeks to offer a descriptive or behavioral account of how a firm actually behaves, as opposed to offering a prescriptive or normative explanation of how a firm should behave (March, 1978). Most prescriptive or normative explanations are premised on a model of rational choice where economic agents face few, if any, information or cognitive limits in their ability to pursue rational aims (March, 1978). More specifically, rational choice models operate on the full knowledge assumptions that the firm has a well-defined objective function (i.e. maximization of profits) where the state of available alternatives (i.e. range of output) and an understanding of their consequences (i.e. influence to a firm's average cost) are well specified or known (March, 1978; Simon, 1957). The task of the rational economic agent is to evaluate these available alternatives in terms of their expected future consequences, at least probabilistically, and then choose those actions that will fulfill the firm's objectives. While management research has long challenged the full knowledge assumptions of rational economic models (Argote and Greve, 2007; Cyert and March, 1963; Simon, 1957; Seth and Thomas, 1994), March (1978) has argued that the normative or prescriptive view of rational economics has on 'balance, done more good than harm'. March (1978) however does appeal for a greater need to understand the merits of a practical account to decision making where he argues: 'I think there is good sense in asking how the practical implementation of theories of choice combines with the ways people behave when they make decisions, and whether our ideas about the engineering of choice might be improved by greater attention to our descriptions of choice behavior'. This appeal to realism forms the core tenet of behavioral research (Argote and Greve, 2007) where a firm's behavior is described not in terms of the full knowledge assumptions of the rational economic agent, but rather in terms of limits in a firm's ability to engage in rational decision making (Cyert and March, 1963; Simon, 1957). Such limits to a firm's rationality has been described by the behavioral concept of 'bounded rationality' (Simon, 1957) where it refers to:

> 'The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectivelyrational behavior in the real world or even for a reasonable approximation to such objective rationality' (Simon, 1957).

Bounded rationality underscores a departure from the full knowledge assumptions of the rational economic agent where a firm faces limits in its ability: 'to anticipating or considering all alternatives and all information' (March, 1978, p. 592), and to evaluate the consequences from a limited set of alternatives (e.g. March, 1978; Simon, 1957). In that, a firm's behavior is no longer one of evaluating the consequences of a known or well specified set of alternatives (March, 1978). But instead, a firm's behavior is explained by a search for alternatives that are less than fully known where an understanding of their consequences is at best incomplete (March, 1978). Hence, while both behavioral and rational economic models share a common focus that a firm pursues rational aims, the distinction with behavioral research is that a firm's ability to pursue such rational aims is dependent upon a firm's search to overcome limits with its bounded rationality (e.g. Cyert and March, 1963; Levinthal and March, 1993; March, 1978, 1991).

Search has thus become a defining feature of behavioral research where the concepts of exploitive and explorative search have been the subject of much theoretical and empirical examination (e.g. Argote and Greve, 2007; O'Reilly and Tushman, 2013). In defining this search, March (1991) describes:

> 'The essence of exploitation is the refinement and extension of existing competencies, technologies and paradigms... The essence of exploration is experimentation with new alternatives'.

Exploitation involves a local or 'problematic' search for solutions that are in close proximity to a firm's existing domain of expertise (Cyert and March, 1963). This exploitive search involves learning from others that share similar experiences (Cohen and Levinthal, 1990; Levinthal and March, 1993). Firms engage in this exploitive search, because by learning from the experiences of similar others, it increases a firm's efficient use of its established technologies, assets and experiences. Such efficiency improvements reinforce a firm's exploitative search in subsequent periods (March, 1991). As a result, firms have a general tendency to engage in exploitive search, because they introduce local or proximal solutions that reinforce a firm's established experiences and competitive advantage (Ahuja and Lampert, 2001; March, 1991; Quintana-García and Benavides-Velasco, 2008; Rosenkopf and Nerkar, 2001). Yet, the challenge with this exploitive search is that a firm's commitment to its established competencies prohibits the firm from adapting to changing environmental conditions (Levinthal and March, 1993; March, 1991). Behavioral researchers have argued that an exploration of distant solutions is important to discovering new solutions, experiences and competencies. Such explorations enable a firm to overcome its past commitments and improve a firm's ability to adapt. For instance, empirical studies have shown that explorative search increases the discovery of radical or breakthrough innovations and increases a firm's ability to adapt to new technological developments (Ahuja and Lambert, 2001).

By drawing on the behavioral concepts of bounded rationality and, in particular exploitive and explorative search, these concepts offer a descriptive appeal to explaining a firm's citing behavior. We argue that the limits surrounding a firm's 'rational ignorance' (Lemley, 2001; Marco *et al.*, 2016) can be directly rooted in the behavioral concept of bounded rationality. Specifically, we argue that a firm's citing behavior is subject to a 'bounded rationality' where firms not only face limits in their ability to assess all the relevant prior art (i.e. the space of patent alternatives), but as a result are limited in their ability to relate this prior art to substantiating their patent's novel claims (i.e. understanding the consequences of citing the relevant prior art). Since search is a response to overcoming limits in a firm's bounded rationality (Cyert and March, 1963; March, 1978, 1991), we argue a firm's exploitive and explorative search (March, 1991) can provide an important solution to overcoming a firm's rational ignorance.

To elaborate on this search, exploitation involves a local search of those cited patents that share a similar technological domain as those of a firm's patented inventions. Patent analysis studies have argued that firms tend to cite patents that are technologically similar to a firm's patented inventions. This is because firms tend to exploit scientific inventions that are similar to their own (Li *et al.*, 2014). For instance, Quintana-García and Benavides-Velascos' (2008) define a firm's 'exploitive competence' by patents that include one or more citations that are closely related to a firm's existing innovations. Similar to Quintana-García and Benavides-Velasco (2008) (see also Nerkar and Roberts, 2004), we argue that exploitation increases a firm's citation of patents that are similar to the technologies of a firm's patented inventions. However, unlike Quintana-García and Benavides-Velasco (2008), we argue that exploitation enables the firm to identify opportunities to differentiate its claimed inventions from those of its cited patents. For instance, according to Deephouse's (1999) strategic balance hypothesis, firms engage in a search of local/similar experiences, because they offer opportunities to differentiate themselves from the members of its local group. That is, a firm's exploitive search enables the firm to understand the state of those patented inventions that are closely related to a firm's patented inventions. This localized understanding subsequently offers the firm the means to differentiate its patented inventions from its local members. By engaging in this exploitative search, a firm's exploitation can overcome limits in its bounded rationality. This is because as exploitation increases a firm's ability to identify with the relevant prior art of its local group, this localized understanding enables the firm to differentiate its patented inventions from its local group. This differentiation thus overcomes limits in a firm's ability to identify novel claims amongst the patented inventions of this local group.

In addition to exploitation, exploration is defined by a distant search for cited patents that do not share the same technological domain as that of a firm's patented invention. A firm's exploration of cited patents is argued to increase a firm's ability to understand how a firm's claimed inventions relate to a broader technological setting in ways not possible with an exploitive search. In particular, according to innovation research, a firm's exposure to diverse technological domains enable the firm to identify novel ways to recombine their inventions with others (Dahlin and Behrens, 2005; Gavetti *et al.*, 2005; Piao and Zajac, 2016). Such recombinations offer a type of novelty that is non-obvious (Dahlin and Behrens, 2005; Hargadon and Sutton, 1997). For instance, innovation studies that draw on analogical reasoning (Dahlin and Behrens, 2005; Gavetti *et al.*, 2005; Hargadon and Sutton, 1997) show that a firm's broader exposure to their technological environments enable the firm to form analogies or inferences to distant technological domains. These analogies enable a firm to combine distant technologies or experiences that are not possible with a local search (Hargadon and Sutton, 1997; Piao and Zajac, 2016). Since exploration increases the breadth or scope of a firm's search of its prior art, exploration increases a firm's ability to engage in such analogical inferences. Such analogical inferences enable a firm to discover non-obvious ways of combining existing inventions and thus increasing a firm's ability to discover novel patent claims (see Dahlin and Behrens, 2005; Piao and Zajac, 2016). Hence, like exploitation, exploration also overcomes limits with a firm's bounded rationality. However unlike exploitation, exploration overcomes a firm's bounded rationality by not only offering a broader search of its prior art. But this exploration also enables a firm to overcome limits in its ability to discover novel claims by revealing non-obvious ways of combing distant or seemingly unrelated patented inventions.

While exploitive and explorative search offer distinct roles in discovering a firm's patent's novel claims, behavioral researchers have argued that an excessive reliance on exploitive/explorative search can result in diminishing return effects (e.g. Ahuja and Lampert, 2001; March, 1991). However, unlike prior explanations, we argue that an increasing reliance on exploitative search increases the number of cited inventions that are potentially similar to those of a firm's patented inventions. This increasing similarity can diminish a firm's ability to identify novel claims amongst a firm's locally searched group. Furthermore, an excessive reliance on exploration can also result in such diminishing return effects. However, unlike exploitation, studies of innovation (Hargadon and Sutton, 1997) have argued that an invention is more likely to stand out if it was introduced in a space of common or similar experiences. Yet, when a firm engages in an explorative search over many or distant technology domains, the novel or non-obvious associations claimed by a firm's patented invention is less likely to stand out against this broader space of patented inventions. Hence, when a firm engages in excessive explorations, the firm will face increasing difficulties in identifying non-obvious combinations that are novel. Given the discrete nature of the biotechnology industry, we hypothesize the following behavioral hypotheses:

H1: a biotechnology firm's exploitive search of its prior art has an inverted u-shape or diminishing effect to the number of its patent claims.

H2: a biotechnology firm's explorative search of its prior art has an inverted u-shape or diminishing effect to the number of its patent claims.

4. Data and sample

To empirically examine this study's hypotheses, the BioScan database was used to identify this study's sample of biotechnology firms. BioScan is widely recognized for its comprehensive coverage of firms in this industry (Ng, 2011a,b; Ng *et al.*, 2006;). In drawing from this BioScan sample, we included firms that have submitted patent applications to the U.S.P.T.O. where the intellectual property protections surrounding a firm's patented inventions are subject to U.S. patent laws and regulations. This sample consists of a panel of 337 biotechnology firms that span periods from 1993 to 2005. Of particular note, many of the years in this sample period has been marked by a significant growth in the number of patent applications. For instance, the total number of patent applications grew from 4,689 in 1993 to a peak of 8,837 in 2001. In subsequent years, the number of patent application had declined to 5,722 in 2005. As most of this sample period has been driven by a growth in patent applications, firms in this study's sample are likely to be subject to the limits of 'rational ignorance' (Lemley, 2001, Marco *et al.*, 2016) or bounded rationality and thus offers a unique opportunity to examine the exploitive and explorative search described in this study. With this sample period, the U.S.P.T.O. patent application data was then supplemented with other data involving a biotechnology firm's R&D expenditures, total assets, and age. This data was collected from the Mergent and Hoover Online database.

4.1 Dependent variable

While forward patent citations are commonly used as a measure of patent value, the value of a patent is attributed to its claims of novelty and non-obviousness (Allison *et al.*, 2003; Jaffe and de Rassenfosse, 2017; Li *et al.*, 2014). In industries, such as biotechnology, a patent's reported claims are an important source of value, because they serve as the basis for a biotechnology firm's legal protections (e.g. Cohen, 2010). To measure such claims, the U.S.P.T.O. database reports the number of claims filed by a firm's applications. The number of claims – *Claims* – is measured by aggregating the number of claims made by a firm's patents. This total number of claims is aggregated on a yearly basis and is used in patent research (e.g. see also Allison and Lemley, 1998)

4.2 Independent variables

The *Exploitation* and *Exploratio*n search variables were constructed by leveraging the technological classifications of the U.S.P.T.O. database. According to the U.S.P.T.O., a firm's patent applications and its cited patents are classified into more than 400 technological classes. A firm's exploitation is measured by counting the number of technological classes that are common between a firm's patent applications and that of its cited patents. Exploration is measured by counting the number of technological classes that are not common between a firm's patent applications and that of its cited patents. This construction of the exploitation and exploration search variables follows the approach used in Rosenkopf and Nerkars' (2001) study of the optical disk drive industry. However, unlike their study as well as more recent examinations (Belderbos *et al.*, 2010), we are the only study that has used all 400+ of the U.S.P.T.O. technological categories. We offer one of the most extensive representations of exploitive/explorative search found in patent citation studies to date. To account for the diminishing effects of these search variables, the $Exploitation^2$, and $Exploration^2$ variables were included. This also corrects for possible omitted variables bias as well as specification bias (Papageorgiadis and Sharma, 2016).

4.3 Control variables

Several variables that can impact a firm's patent claims*,* were introduced as controls in the analysis. We included the log of research and development expenditures – *log(R&D)* – (in US dollars), because innovation studies have commonly used this as a measure of a firm's knowledge stock (Cohen, 2010). This stock of knowledge is used to develop new patents and thus can influence the development of a firm's patent claims. We also included the log of firm's age – *log(Age)* – and the log of firm's total assets – *log(Total Assets)* – to control for experiential learning curve and size effects (Blundell *et al.*, 1999; Cohen, 2010). We argue that older firms may have accumulated greater experiences in assessing the relevant prior art and thus may influence their ability to identify novel claims in their patented inventions. Furthermore, firms with greater assets are more likely to allocate resources in assessing the prior art where such allocations may benefit from scale effects in the assessment of novel claims. In addition, since firms with more patents are more likely to assert a greater number of novel claims, we controlled for a firm's total number of patents – *Patent*s. This *Patent* variable was constructed by aggregating on a yearly basis, a firm's total number of patents.

5. Estimation methods and results

5.1 Empirical methods

As our firm-level data is sampled over multiple yearly observations, we employ panel econometric techniques (Josephson *et al.*, 2016). Panel data models offer advantages in controlling for firm-level heterogeneity and dynamic relationships among observations (Josephson *et al.*, 2016; Wooldridge, 2002). In particular, since our dependent variable, *Claims*, is a count variable, a fixed-effect (FE) Poisson estimation approach can be used in examining our panel data. Poisson count estimations are commonly used in the patent citation literature (Hall *et al.*, 2001; Jaffe and de Rassenfosse, 2017) where it assumes an equi-dispersion in the mean and standard deviation of the count variable. In using the Likelihood-ratio test of Alpha in Stata 15.0, this test draws on the conditional mean and conditional variance of the *Claims* variable (conditional on explanatory variables) (Wooldridge, 2002). The X^2 statistic for the Likelihood-ratio test of Alpha is 4.4e+05. With this test, we reject the null hypothesis that the Alpha parameter is 0 where there is equi-dispersion or no overdispersion in the *Claims* variable.

In the presence of overdispersion, a common approach is to use the conditional FE negative binomial model of Hausman *et al.* (1984) (hereafter HHG). However, Allison and Waterman (2002) argue that the HHG approach does not offer a 'true fixed effects model'. The HHG approach uses an individual's total counts to condition out the fixed effects in the likelihood function. By including the overdispersion parameter in this likelihood function, Allison and Waterman (2002) show that it does not condition out this individual fixed effect. Allison (2009) suggests that, while a FE Poisson model suffers from problems of overdispersion, a FE Poisson model is estimated by a conditional maximum likelihood function that eliminates the individual fixed effect. Guimarães (2008) continues this discussion and argues that the conditional maximum likelihood estimator of the negative binomial regression with fixed effects removes the individual fixed effects only when those effects are related to the individual parameter of overdispersion. In order to develop a true FE model, we follow Allison and Waterman (2002) recommendation where they argue that a FE Poisson model that adjusts for the standard errors for overdispersion can be used. Specifically, to adjust for this overdispersion, Wooldridge (2002) showed that a FE Quasi-Maximum Likelihood (QML) Poisson estimator can be used to produce consistent estimates. For purposes of robustness, this study utilizes both the FE QML Poisson model and HHG FE negative binomial estimations. These estimations were respectively implemented by using the xtpqml (Simcoe, 2008) and xtnbreg commands in Stata 15.

In addition, previous studies point out that panel regression methods can be prone to non-stationarity and endogeneity biases (Josephson *et al.*, 2016; Lavie *et al.*, 2011; Luo and Bhattacharya, 2009; Wooldridge, 2002). In line with the previous literature, Fisher-type unit root test was employed (Josephson *et al.*, 2016). The result of the unit root test indicates that the dependent variable, *Claims*, is stationary (*Claims*: inverse X^2=4,794.49, P<0.01). With respect to problems of endogeneity, a firm's exploitive and explorative search can be potentially influenced by a firm's characteristics. A firm's R&D expenditures (e.g. Cohen and Levinthal, 1990) and diversity of technical expertise (e.g. Quintana-García and Benavides-Velasco, 2008) have been correlated with a firm's search. In particular, Quintana-García and Benavides-Velasco (2008) study had argued and found that a firm's exploitive and explorative search was positively influenced by a firm's diversity of technical expertise.

5.2 Two-stage least square approach

To control for such endogeneity, a 2SLS approach was used where these firm-level characteristics – a firm's R&D expenditures (i.e. *log (R&D)*) and diversity of technical expertise (*DIV*) – were chosen as instruments for a firm's exploitive and explorative search. A firm's diversity of technical expertise is measured by examining the diversity of its patent's technology classes, *DIV*. *DIV* is measured by a Herfindahl-Hirshman Index (HHI) (Quintana-García and Benavides-Velasco, 2008). The HHI is computed by taking the ratio or shares, S_i, of a patent that has been assigned to technology class *i* to all patents held by the firm. *DIV* is then computed by subtracting 1 from the sum of the square of these patent shares where *DIV* is computed as $DIV = 1 - \sum_i S_i^2$. In interpreting this variable, large values of *DIV* denote a greater level of technical diversity. A firm's exploitation and exploration are then individually regressed on these instrumented variables – *log (R&D)* and *DIV* – along with the following controls: *log (Age)*, *log (Total Assets), Patents.* The predicted values, $\widehat{Exploitation}$ and $\widehat{Exploitation}$, from these first stage estimations are then used as predictors in the second stage estimation. In order to control for a firm's true fixed effects (Allison and Waterman, 2002), a FE QML Poisson estimation using the xtpqml command was used for this 2SLS approach.

6. Results

The descriptive statistics for all co-variants and their correlations are shown in Table 1[1]. In particular, while some of the independent variables are highly correlated, a Variance Inflation Factor (VIF) score test was conducted to examine potential issues of multi-collinearity. In using all the explanatory variables (i.e. model 6 in Tables 2 or 3), the mean VIF had a value of 7.11 which is less than the recommended value of 10. Multi-collinearity thereby does not appear to be a significant issue. Tables 2 and 3 respectively presents in a hierarchical fashion the FE results for the Poisson and negative binomial estimations. For instance, model 1 in Table 2 (FE Poisson) and Table 3 (FE negative binomial) report the regression results of our control variables. The coefficient estimate for a firm's total assets – *Log* (*Total Assets)* – was negative and significant for the Poisson estimation (-0.0378, $P<0.05$), but not for the negative binomial estimation (-0.0201, $P>0.1$). The R&D expenditure variable – *Log (R&D)* – was positive and significant (0.320, $P<0.001$), while the age variable – *Log (Age)* – was not significant (-0.0887, $P>0.1$) in the Poisson estimation. For the negative binomial estimation, the R&D expenditure[2] – *Log (R&D)* – and age – *Log (Age)* –were significant and were respectively positive (0.362, $P<0.001$) and negative (-0.0714, $P<0.05$). Of particular interest to this negative binomial estimation is that a firm's discovery of novel claims appear to decline with the firm's age. This is consistent with the myopic tendencies described in behavioral research (e.g. Ahuja and Lampert, 2001; Levinthal and March, 1993; March, 1991). With respect to the remaining control variable, the patents variable – *Patents* – was positive and significant for both the Poisson (0.00646, $P<0.001$) and negative binomial (0.00569, $P<0.001$) estimations and thus the inclusion of this variable was appropriate.

In examining our main variables of interests, models 2 and 3 in Table 2 (Poisson) respectively show the effects of the *Exploitation* and $Exploitation^2$ variables on a biotechnology firm's patent claims. Model 2 shows that the coefficient estimate *Exploitation* has a positive and significant effect to a firm's claims (0.0543, $P<0.001$). This suggests that an exploitive search of the prior art appears to have an effect that is distinct from the myopic influences of a biotechnology firm's age – *Age* (Levinthal and March, 1993). In examining its diminishing effects model 3 shows that $Exploitation^2$ was negative and significant (-0.00132, $P<0.001$). Such diminishing effects suggest limits in a biotechnology firm's ability to differentiate their patent claims in its local search. In examining the negative binomial estimations, model 2 in Table 3 also show that *Exploitation* has a significant positive effect (0.0927, $P<0.01$) where model 3 also shows that $Exploitation^2$ has a significant diminishing effect (-0.00462, $P<0.001$). Hence, hypothesis 1 cannot be rejected. This is an important finding because to the best of our knowledge, we are the first to report Deephouse's (1999) strategic balance argument in a patent setting.

[1] See Supplementary Table 1A for a list of representative firms from the BioScan sample.
[2] Since R&D intensity (R&D expense / Total assets) can influence a firm's citation behavior (Lin and Chen, 2005), we experimented by replacing a firm's R&D expenditure and total assets with this variable in the FE Poison and negative binomial estimation. This variable however was not significant. Results are available on request.

Table 1. Descriptive statistics and correlations.[a]

	Variable	**Mean**	**Std. Dev.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Claims	92.23	794.79	1						
2	Exploration	2.45	8.86	0.6449*	1					
3	Exploitation	1.40	7.28	0.8504*	0.7765*	1				
4	Total assets[b]	3.35e+7	1.06e+9	-0.0000	-0.0023	0.0074	1			
5	R&D[b]	6,330	4.82e+03	0.0681*	0.0462*	0.0708*	0.1321*	1		
6	Age	27.92	34.75	0.1508*	0.2060*	0.2109*	0.2661*	0.2853*	1	
7	Patents	6.78	55.65	0.9320*	0.6126*	0.8720*	0.0108	0.0645*	0.1577*	1

[a] Significant at $*P<0.05$.

[b] In millions of US dollars.

Table 2. Fixed-effect Poisson regression models. Standard deviations are in parentheses.[a]

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log (Total Assets)	-0.0378*	-0.0579***	-0.0513***	-0.0452**	-0.0473***	-0.0550***
	(0.0207)	(0.0201)	(0.0193)	(0.0176)	(0.0163)	(0.0175)
Log (R&D)	0.320***	0.319***	0.191***	0.299***	0.232***	0.165***
	(0.0782)	(0.0634)	(0.0692)	(0.0550)	(0.0654)	(0.0579)
Log (Age)	-0.0887	-0.0583	0.0903	-0.185	-0.190	-0.0133
	(0.135)	(0.126)	(0.153)	(0.121)	(0.132)	(0.125)
Patents	0.00646***	0.00389***	0.00490***	0.00576***	0.00531***	0.00449***
	(0.00154)	(0.00114)	(0.00107)	(0.00148)	(0.00128)	(0.00108)
Exploitation		0.0543***	0.132***			0.105***
		(0.0113)	(0.0139)			(0.0119)
Exploitation^2			-0.00132***			-0.00104***
			(0.000327)			(0.000281)
Exploration				0.0161***	0.0485***	0.0304***
				(0.00455)	(0.0104)	(0.00650)
Exploration^2					-0.000285***	-0.00016***
					(0.000100)	(5.47e-05)
Observations	3,309	3,309	3,309	3,309	3,309	3,309
Number of firms	337	337	337	337	337	337

[a] Significant at * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

In examining hypothesis 2, the Poisson estimations in models 4 and 5 of Table 2 respectively show the coefficient estimates *Exploration* and *Exploration*^{2}. In model 4, the coefficient of *Exploration* was positive and significant (0.0161, $P<0.001$). Model 5 shows that the diminishing effect of exploration, *Exploration*^{2}, was negative and significant (-0.000285, $P<0.001$). These results were also robust to negative binomial estimations. In Table 3, models 4 and 5 respectively show that *Exploration* was positive and significant (0.0238, $P<0.001$) and their diminishing effects, *Exploration*^{2}, was negative and significant (-0.000947, $P<0.001$). Hypothesis 2 thereby cannot be rejected. These findings build on Ahuja and Lampert's (2001) patent study of the US chemicals industry. They found that exploration has a positive yet diminishing effect on a chemical firm's breakthrough innovations. This study's shows that this positive yet diminishing effect also extends to a biotechnology firm's patent claims. This is an important observation. In that, while exploration has been widely associated with a firm's breakthrough/radical innovations (Ahuja and Lampert, 2001), exploration has not been associated with the discovery of those novel claims that are pre-requisite to a firm's breakthrough/radical innovations.

Although we did not hypothesize the joint influence of exploitative and explorative search, the Poisson estimates in model 6 of Table 2 examines their joint influence. Model 6 shows that *Exploitation* and *Exploration* were positive and significant (respectively 0.105, $P<0.001$ and 0.0304, $P<0.001$). Similarly, in Table 3, the negative binomial estimates in model 6 also show that *Exploitation* and *Exploration* were positive and significant (respectively 0.170, $P<0.001$ and 0.0733, $P<0.001$). *Exploitation* and *Exploration* thereby appear to have a mutually reinforcing influence to a firm's patent claims. To further examine these joint effects, an inter-level significance test (Hilbe, 2011) was used where it rejects the null hypothesis that the effect of exploration is equal to the effect of exploitation (X^2=57.50, $P<0.01$). This suggests that while both exploitation and exploration jointly influence biotechnology firm's claims, *Exploration* has less of an effect on these claims than *Exploitation*. This is consistent with behavioral research where, due to limits on bounded rationality, exploitation tends to be favored over a firm's exploration (Levinthal and March, 1993). With respect to examining the diminishing effects of exploitation and exploration, the Poisson estimations

Table 3. Fixed-effect negative binomial regression models. Standard deviations are in parentheses.[a]

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log (Total Assets)	-0.0201	-0.0293	-0.0481***	-0.0175	-0.0230	-0.0353**
	(0.0178)	(0.0185)	(0.0151)	(0.0182)	(0.0178)	(0.0159)
Log (R&D)	0.362***	0.309***	0.256***	0.330***	0.190***	0.193***
	(0.0251)	(0.0251)	(0.0224)	(0.0249)	(0.0238)	(0.0229)
Log (Age)	-0.0714**	-0.0272	-0.176***	-0.154***	-0.0869***	-0.223***
	(0.0334)	(0.0336)	(0.0315)	(0.0336)	(0.0336)	(0.0310)
Patents	0.00569***	-0.00363***	0.00482***	0.00404***	0.00320***	0.00502***
	(0.000231)	(0.000739)	(0.000442)	(0.000236)	(0.000299)	(0.000414)
Exploitation		0.0927***	0.265***			0.170***
		(0.00504)	(0.00646)			(0.00909)
Exploitation^2			-0.00462***			-0.00346***
			(0.000150)			(0.000183)
Exploration				0.0238***	0.108***	0.0733***
				(0.000910)	(0.00357)	(0.00490)
Exploration^2					-0.000947***	-0.000758***
					(5.44e-05)	(6.58e-05)
Constant	-6.539***	-5.686***	-4.243***	-5.931***	-3.920***	-3.438***
	(0.213)	(0.218)	(0.229)	(0.217)	(0.226)	(0.237)
Observations	3,309	3,309	3,309	3,309	3,309	3,309
Number of firms	337	337	337	337	337	337

[a] Significant at ** P<0.01, *** P<0.001.

in model 6 show that *Exploitation^2* and *Exploration^2* were significant and negative (respectively -0.00104, P<0.001 and -0.000168, P<0.001). The negative binomial estimations of model 6 show a similar finding where *Exploitation^2* and *Exploration^2* were also negative and significant (respectively -0.00346, P<0.001 and -0.000758, P<0.001). While behavioral research has viewed exploitation and exploration as competing search processes (Levinthal and March, 1993), these results suggest that they have a mutually positive yet diminishing effect to a biotechnology firm's claims.

6.1 Two-stage least square estimations

To account for problems of endogeneity, we utilized the 2SLS FE Poisson estimation where the results are reported in table 4. Model 1 shows the estimates of the first stage estimation where the instrumented variables, *DIV* and *log (R&D)*, have a positive and significant influence to a firm's exploitation (respectively 3.58e-12, P<0.001 and 0.143, P=0.001). Model 2 shows a similar finding where *DIV* and *log (R&D)* variables have a positive and significant influence to a firm's exploration (respectively 1.84e-12, P<0.001 and 0.160, P<0.001). The significant values for these instrumented variables suggest the presence of endogeneity and thus warrants the use of 2SLS approach[3]. In using the predicted values from model 1 $\widehat{Exploitation}$ and model 2 $\widehat{Exploitation}$, model 3 shows the estimates of the second stage. In model 3, the control variables, total assets – *log (Total Assets)* –and age – *log (Age)* – were not significant (respectively -0.0101, P>0.1 and 0.0368, P>0.1), while the patents – *Patents* – was significant (0.00754, P<0.001). Models 3 show that the estimates on the $\widehat{Exploitation}$ and $\widehat{Exploitation^2}$ were significant (respectively 5.468, P<0.001 and -0.820, P<0.001). In model 4, the estimates on the $\widehat{Exploitation}$ and $\widehat{Exploitation^2}$ were also significant

[3] Due to space limitations, a control function approach was also used where the residuals from the first stage estimations were significant when these residuals were used as regressors in the second stage. This also indicates the presence of endogeneity. Results are available on request.

Table 4. Two-stage least square fixed-effects Poisson regression models. Standard deviations are in parentheses.[a]

Variables	**Model 1 Exploitation**	**Model 2 Exploration**	**Model 3 Claims**	**Model 4 Claims**	**Model 5 Claims**
DIV	3.58e-12***	1.84e-12***			
	(5.75e-13)	(5.27e-13)			
Log (R&D)	0.143***	0.160***			
	(0.0308)	(0.0397)			
Log (Total Assets)	-0.000678	0.0133	-0.0101	-0.0232	-0.00575
	(0.0159)	(0.0228)	(0.0234)	(0.0380)	(0.0308)
Log (Age)	-0.110**	0.115	0.0368	-0.393**	0.0579
	(0.0450)	(0.0852)	(0.0897)	(0.188)	(0.224)
Patents	0.00277***	0.00237***	0.00754***	0.00647***	0.00763***
	(0.00107)	(0.000760)	(0.00244)	(0.00198)	(0.00234)
$Expl\widehat{oitati}on$			5.468***		5.488***
			(0.777)		(1.104)
$Expl\widehat{oitati}on^2$			-0.820***		-0.811***
			(0.169)		(0.218)
$Expl\widehat{oitati}on$				6.976***	0.0158
				(0.981)	(1.790)
$Expl\widehat{oitati}on^2$				-0.744***	-0.0163
				(0.135)	(0.220)
Observations	2,117	2,115	2,117	2,117	2,117
Number of firms	299	298	299	299	299

[a] Significant at ** $P<0.01$, *** $P<0.001$.

(respectively 6.976, $P<0.001$ and -0.744, $P<0.001$). Hence, when controlling for endogeneity, hypotheses 1 and 2 cannot be rejected. However, when examining the joint effects of exploitation and exploration, model 5 shows that the $Expl\widehat{oitati}on$ and $Expl\widehat{oitati}on^2$ variables were no longer significant (respectively 0.0158, $P>0.1$ and -0.0163, $P>0.1$).

7. Conclusions

By drawing on the behavioral concepts of bounded rationality, exploitation and exploration, this study offers a descriptive or behavioral account of a firm's citing behavior. We argue that a firm's 'rational ignorance' is driven by a 'bounded rationality' where a firm faces limits in its ability to fully assess its patent's relevant prior art. A consequence of this bounded rationality is that the firm is unable to fully substantiate its patent's novel claims. A central argument of this study is that a firm's exploitive and exploitive search offer distinct solutions to overcoming such bounded rationality. Exploitation offers a local search of a firm's patent's prior art. This local search enables the firm to differentiate its patented inventions from its local group and thus overcoming limits in a firm's ability to identify with its patent's novel claims. Exploration overcomes a firm's bounded rationality by not only offering a broader search of its prior art. But, this exploration also enables a firm to overcome limits in its ability to discover novel claims by revealing non-obvious ways of combing distant or seemingly unrelated patented inventions. To empirically examine this citing behavior, a FE Poisson, negative binomial, 2SLS panel estimations were conducted in the biotechnology industry. We found that a firm's exploitive and explorative search have a positive yet diminishing effect (i.e. inverted u relationship) to discovering its patent's claims. By appealing to this behavioral explanation, this study offers three contributions/insights to patent research.

First, over the last 50 years, behavioral or descriptive approaches to decision making have had a long-standing influence to management research (Argote and Greve, 2007) where calls have been made to incorporate such considerations into agribusiness settings (Ng and Siebert, 2009). Given the discrete nature of biotechnology, we argue that bounded rationality not only offers a descriptive or realistic appeal to a firm's citing behavior, but a firm's efforts to overcome such limits can inform the rational decision making approaches of patent research. For instance, while determining the optimal length or time of a patent's protection has been the subject of much examination by industrial organizational researchers, Klemperer (1990) argued that the examination of the 'optimal width of patent protections' is an important but neglected consideration in patent research. Klemperer (1990) developed a rational decision making model where the firm optimizes the length as well as the width of a patent's protection. A firm optimized its patent length and width by minimizing the present value of the patent's social costs subject to the discounted value of a firm's profits. This optimization is based on the assumption that the relevant prior art in determining the width or scope of a patent's protections is fully known or well specified. Yet, as shown by this study, the number of patent applications in the biotechnology has grown significantly where firms are likely to face a 'rational ignorance' (see also Lemley, 2001; Marco *et al.*, 2016) or bounded rationality in identifying with their patent's prior art. We argue a firm's exploitative and explorative search can play an important role in rational decision models where the optimization of a firm's patent width may need to be optimized with respect to a firm's exploitive and explorative search. Such efforts to incorporate behavioral insights into rational decision models is important. This is because in order to develop models that are managerial relevant, these decision models need to reflect the computational and information limits faced by management (Simon, 1957). This is in fact the goal and purpose of behavioral research (Cyert and March, 1963; March, 1978; Simon, 1957) and hence the contribution of this study is in offering an explanation of a firm's citing behavior that aspires to this goal.

Second, and perhaps more pragmatically speaking, this study offers insights that are managerially relevant to value creation approaches. Strategic explanations contend that there is an incentive not to cite patents, because it will reduce a firm's claims to novelty and thus affecting the scope of a patent's monopoly rights. While on the other hand, legal explanations contend that a full disclosure of the prior art increases the validity of a patent's novelty and thus reducing incidences of patent infringement. For managers who seek to assert protections to their patented inventions, we think exploitation and exploration offer a clear managerial lesson that differs from either of these explanations. Relative to strategic explanations, exploitive and explorative search offer a patent protection where a firm does not engage in the withholding of its prior art. This is because to do so would increase the threats of patent infringement and invalidate the novelty of a firm's inventions. Hence, exploitive and explorative search favors the legal explanations found in value creation research. However, unlike legal explanations, there are limits in a firm's bounded rationality where there is a cost associated with such search. In that, despite legal obligations to cite the relevant prior art (i.e. a duty of candor), a firm cannot realistically search all the relevant prior art without exacting a cost to a manger's time, attention and efforts (e.g. Lemley, 2001). This study empirically shows that there are diminishing returns to a firm's search. This is a managerially relevant finding, because given limits in a manager's ability to search the prior art, these diminishing effects suggest, in a loose sense, that managers can optimize the extent of their search. In particular, as the cost of a patent application is significantly influenced by the extent of the search of its prior art (Lemley, 2001), such diminishing effects have a clear managerial lesson. Namely, searching too little (i.e. strategic withholding of prior art) or too much (legal requirements to cite due to a duty of candor) may not be optimal when seeking to identify a patent's novel claims. Hence, the contribution of this study to value creation approaches is that by appealing to a behavioral approach to explaining a firm's citing behavior, it offers insights that are relevant to the decision realities faced by the manager. This study argues that exploitive and explorative search are not only important to asserting a patent's protections, but their diminishing effects offer a prescription on how managers should behave in ways that fall between the strategic and legalist explanation of value creation research.

Third, while the data limitations of this study preclude a direct examination of any particular segment of the biotechnology industry, this study nevertheless provides some insights to understanding the role of patents in the agribusiness industry, especially that of the plant biotechnology sector. Patent applications in plant biotechnology firms have witnessed substantial increases, especially in corn, rice soybean and wheat commodities (Chan, 2006). Amongst developed countries (i.e. Australia, Europe, Canada, Brazil *etc*.), the US plant biotechnology industry remains the leader in gene, variety and method patent applications (Chan, 2006). This trend reflects a basic structural change in the agricultural biotechnology industry where innovations through the patenting of plant and related technologies are a key driver of economic growth and profit. The approval and granting of such patent applications is likely to be an important driver in developing a plant biotechnology firm's leadership into the 21st century. In particular, although there are many other considerations that impact patent approval, patent applications that demonstrate novel claims to the prior art are more likely to gain patent approval than those that do not (Allison *et al.*, 2003). Hence, we argue that as innovation in genomic advances will become an increasing driver to the leadership and success of plant biotechnology firms (e.g. CRISPR gene editing techniques), firms that engage in an exploitive and explorative search of their prior art may increase their chances of patent approval. Such search will not only enable these firms to capitalize on their investments in plant biotechnology research, but as a result better position themselves for market leadership. Future research is called for to examine such aspects of exploitive and explorative search.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2018.0097.

Table A1. Representative firms from the BioScan sample.

References

Ahuja, G. and C.M. Lampert. 2001. Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal* 22(6-7): 521-43.

Allison, J.R. and M.A. Lemley. 1998. Empirical evidence on the validity of litigated patents. *American Intellectual Property Law Association Quarterly Journal* 26: 185-269.

Allison, J.R., M.A. Lemley, K.A. Moore and R.D. Trunkey. 2003. Valuable patents. *Georgetown Law Journal* 92: 435-495.

Allison, P.D. 2009. *Quantitative applications in the social sciences: fixed effects regression models*. SAGE Publications, Thousand Oaks, CA, USA. DOI: https://doi.org/10.4135/9781412993869

Allison, P.D. and R.P. Waterman. 2002. Fixed-effects negative binomial regression models. *Sociological methodology* 32(1): 247-265.

Argote, L. and H.R. Greve. 2007. A behavioral theory of the firm – 40 years and counting: introduction and impact. *Organization Science* 18(3): 337-349.

Belderbos, R., D. Faems, B. Leten, and B. Van Looy. 2010. technological activities and their impact on the financial performance of the firm: exploitation and exploration within and between firms. *Journal of Product Innovation Management* 27 (6): 869-82.

Blundell, R., R. Griffiths and J. Van Reenen. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *Review of Economic Studies* 66(3): 529-54.

Chan, P.H. 2006. International patent behavior of nine major agricultural biotechnology firms. *AgBioForum* 9(1): 59-68.

Cohen, W.M. 2010. Fifty years of empirical studies of innovative activity and performance. handbook of the economics of innovation. In: *Handbook of the economics of innovation*, edited by B. Hall and N. Rosenberg. Elsevier North Holland, Amsterdam, the Netherlands.

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

Cohen, W., R. Nelson and J. Walsh. 2000. *Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not)*. Working paper no. 7552. National Bureau of Economic Research, Cambrdige, MA, USA. Available at: https://tinyurl.com/yc2lbhao.

Collins, P. and S. Wyatt. 1988. Citations in patents to the basic research literature. *Research Policy* 17(2): 65-74.

Criscuolo, P. and B. Verspagen. 2008. Does it matter where patent citations come from? inventor vs. examiner citations in European patents. *Research Policy* 37(10): 1892-1908.

Cyert, R.M. and J.G. March. 1963. *A behavioral theory of the firm*. Prentice-Hall, Englewood Cliffs, NJ, USA.

Dahlin, K.B. and D.M. Behrens. 2005. When is an invention really radical?: defining and measuring technological radicalness. *Research Policy* 34(5): 717-37.

Deephouse, D.L. 1999. To be different, or to be the same? it's a question (and theory) of strategic balance. *Strategic Management Journal* 20(2): 147-66.

Gavetti, G., D.A. Levinthal and J.W. Rivkin. 2005. Strategy making in novel and complex worlds: the power of analogy. *Strategic Management Journal* 26(8): 691-712.

Grimaldi, M., L. Cricelli, M. Di Giovanni and F. Rogo. 2015. The patent portfolio value analysis: a new framework to leverage patent information for strategic technology planning. *Technological Forecasting and Social Change* 94: 286-302.

Guimarães, P. 2008. The fixed effects negative binomial model revisited. *Economics Letters* 99(1): 63-66.

Hall, B.H., A.B. Jaffe and M. Trajtenberg. 2001. *The NBER patent citation data file: lessons, insights and methodological tools*. Working paper no. 8498. National Bureau of Economic Research, Cambridge, MA, USA. Available at: https://tinyurl.com/yav8tw4f.

Hausman, J., B.H. Hall and Z. Griliches, Zvi. 1984. 'Econometric models for count data with an application to the patents-R&D relationship.' *Econometrica* 52(4): 909-938.

Hargadon, A. and R.I. Sutton. 1997. Technology brokering and innovation in a product development firm. *Administrative Science Quarterly* 42(4): 716-749.

Hilbe, J.M. 2011. *Negative binomial regression*. Cambridge University Press, Cambridge, UK.

Jaffe, A.B. and G. De Rassenfosse. 2017. Patent citation data in social science research: overview and best practices. *Journal of the Association for Information Science and Technology* 68(6): 1360-74.

Josephson, B.W., J.L. Johnson and B. J. Mariadoss. 2016. Strategic marketing ambidexterity: antecedents and financial consequences. *Journal of the Academy of Marketing Science* 44(4): 539-54.

Klemperer, P. 1990. How broad should the scope of patent protection be? *RAND Journal of Economics* 21(1): 113-130.

Lampe, R. 2012. Strategic citation. *Review of Economics and Statistics* 94(1): 320-33.

Lavie, D., J. Kang, and L. Rosenkopf. 2011. Balance within and across domains: the performance implications of exploration and exploitation in alliances. *Organization Science* 22(6): 1517-38.

Lemley, M.A. 2001. Rational ignorance at the patent office. *Northwestern University Law Review* 95(4): 1-34.

Levinthal, D.A. and J.G. March. 1993. The myopia of learning. *Strategic Management Journal* 14(S2): 95-112.

Li, R., T. Chambers, Y. Ding, G. Zhang and L. Meng. 2014. Patent citation analysis: calculating science linkage based on citing motivation. *Journal of the Association for Information Science and Technology* 65(5): 1007-17.

Lin, B-W. and J-S. Chen. 2005. Corporate technology portfolios and R&D performance measures: a study of technology intensive firms. *R&D Management* 35(2): 157-170.

Luo, X. and C.B Bhattacharya. 2009. The debate over doing good: corporate social performance, strategic marketing levers, and firm-idiosyncratic risk. *Journal of Marketing* 73(6): 198-213.

March, J.G. 1978. Bounded rationality, ambiguity, and the engineering of choice. *Bell Journal of Economics* 9(2): 587-608.

March, J.G. 1991. Exploration and exploitation in organizational learning. *Organization Science* 2(1): 71-87.

Marco, A.C., J.D. Sarnoff and G. DeGrazia. 2016. *Patent claims and patent scope*. Economic working paper no.2016-04. USPTO, Alexandria, VA, USA. Available at: https://doi.org/10.2139/ssrn.2825317.

Merges, R.P. and R.R. Nelson. 1990. On the complex economics of patent scope. *Columbia Law Review* 90(4): 839-916.

Nerkar, A. and P.W. Roberts. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical Industry. *Strategic Management Journal* 25(89): 779-99.

Ng, D. 2011a. Thinking outside the box: an absorptive capacity approach to the product development process. *International Food and Agribusiness Management Review* 14(3): 67-94.

Ng, D. 2011b. Absorptive link: an absorptive capacity and alliance approach to biotechnology product success. *Journal of Chain and Network Science* 11(1): 31-47.

Ng, D. and J. Siebert. 2009. Toward better defining the field of agribusiness management. *International Food and Agribusiness Management Review* 12(4): 123-142.

Ng, D., J. Unterschultz and E. Laate. 2006. The performance of relational ties: a functional approach in the biotechnology industry. *Journal on Chain and Network Science* 6(1): 9-21.

O'Reilly, C.A. and M.L. Tushman. 2013. Organizational, ambidexterity: past, present and future. *Academy of Management Perspectives*. 27(4): 324-338.

Papageorgiadis, N. and A. Sharma. 2016. Intellectual property rights and innovation: a panel analysis. *Economics Letters* 141: 70-72.

Piao, M. and E.J. Zajac. 2016. How exploitation impedes and impels exploration: theory and evidence. *Strategic Management Journal* 37(7): 1431-47.

Quintana-García, C. and C.A. Benavides-Velasco. 2008. Innovative competence, exploration and exploitation: the influence of technological diversification. *Research Policy* 37(3): 492-507.

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

Sampat, B.N. 2010. When do applicants search for prior art? *The Journal of Law and Economics* 53(2): 399-416.

Seth, A. and T.H. 1994. Theories of the firm: implications for strategy research. *Journal of Management Studies* 31(2): 165-192.

Simcoe, T. 2008. *XTPQML: stata module to estimate fixed-effects Poisson (quasi-ml) regression with robust standard errors. Statistical Software Components S456821*. Boston College Department of Economics, Chestnut Hill, US.

Simon, H.A. 1955. A behavioral model of rational choice. *Quarterly Journal of Economics* 69: 99-118.

Simon, H.A. 1956. Rational choice and the structure of the environment. *Psychological Review* 63: 129-138.

Simon, H.A., 1957. *Models of man: social and rational; mathematical essays on rational human behavior in society setting.* Wiley, New York, NY, USA.

Tseng, F-M., C-H. Hsieh, Y-N. Peng and Y-W. Chu. 2011. Using patent data to analyze trends and the technological strategies of the amorphous silicon thin-film solar cell industry. *Technological Forecasting and Social Change* 78(2): 332-45.

Wooldridge, J.M. 2002. *Econometric analysis of cross section and panel data*. MIT Press, Cambridge, MA, USA.

Ziedonis, R.H. 2004. Don't fence me in: fragmented markets for technology and the patent acquisition strategies of firms. *Management Science* 50(6): 804-820.