

'KEEP OUT' SIGNS: THE ROLE OF DETERRENCE IN THE COMPETITION FOR RESOURCES[†]

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To explain resource heterogeneity, past research focuses on how rivals' resources are hidden from firms and firms accordingly have difficulties accessing them. We argue that resource heterogeneity may also arise when firms are deterred from a technological space upon being shown what resources rivals already possess within that space. To illustrate this deterrence effect, we use patent reexamination certificates, which indicate strategic stakes within a technological space without materially disclosing additional details of the underlying technologies and hence avoid the confounding effect of attracting competition through disclosure. We demonstrate how rivals' reexamination certificates within a technological space induce a firm to subsequently allocate less inventive effort in that space, based on two mechanisms—indications of rivals' developmental speed and exclusionary ability. We further develop these two mechanisms by arguing that the deterrence effect is stronger when rivals' speed is enhanced by their downstream capabilities, or when rivals' exclusion is enhanced by their litigation experiences. Findings suggest that a firm's path of resource accumulation evolves through avoidance of rivals' paths, and deterrence may constitute a viable alternative theory of resource heterogeneity. Copyright © 2010 John Wiley & Sons, Ltd.

INTRODUCTION

A resource's value-creation is inextricably tied to its uniqueness (Barney, 1991). Often, the less similar resources that competitors have, the more value a firm can extract from its own resources. Existing explanations for why we may observe some firms having unique resources tend to focus on how these resources are *hidden* from, and thus inaccessible to, competitors. Arguments largely center on how resources have tacit and 'sticky' nature with

time compression diseconomies or causal ambiguities that thwart competitors' replication attempts (Lippman and Rumelt, 1982; Dierickx and Cool, 1989; McEvily and Chakravarthy, 2002), or how resources are protected from competitors by isolating mechanisms such as secrecy (Cohen, Nelson, and Walsh, 2000; Dushnitsky and Shaver, 2009), complex interdependence (Rivkin, 2000), or other organizational features (Liebeskind, 1996).

However, from a conceptual standpoint, a firm's resources can be unique not only when competitors are unable to observe or understand these resources but also when competitors can observe though are deterred from creating similar resources. In fact, classical studies of deterrence in product markets typically rely on the principle that a firm may deter competitors by actively *showing* its stakes in the production rather than hiding them, with a credible

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threat that it will be in the firm's best interest to act in a manner unprofitable for competitors should they enter the product market (Schmalensee, 1978; Dixit, 1980; Porter, 1980). Yet, is this deterrence principle, based on demonstrating firms' stakes in a particular activity, applicable in the competition for resources? Despite extensive research on this topic within product markets, to date we lack both theory and evidence of whether and how such deterrence may occur in the process of resource accumulation. The main hindrance is that indicating a firm's resource to competitors often comes hand in hand with disclosing details of the resource, which ironically attracts competitors rather than deters them (see Arrow, 1971). Even when the resource in question is technology-based and legally protected by patents (Gilbert and Newberry, 1982), in reality competitors often learn technical details via the patents and invent around them (Lieberman and Montgomery, 1988; Cohen *et al.*, 2000). This paradox of disclosure is so prevalent that most theories of disclosure explicitly model the leakage of technical details as a cost that firms necessarily incur when they signal their technological resources for other benefits (Bhattacharya and Ritter, 1983; De Fraja, 1993; Polidoro, 2006; James and Shaver, 2009). Because the literature to date lacks a suitable context that separates *disclosure of details that attract competitors* from *indication of firms' stakes that deter competitors*, we have thus far been hindered from recognizing a potentially major role that deterrence plays in firms' competition for resources.

In this paper, we examine more closely this deterrence role using a special context—issuance of patent reexamination certificates—that helps isolate the deterrence effect from the confounding disclosure effect. Patent reexamination is a process whereby the United States Patent and Trademark Office (USPTO) reviews the validity of a previously issued patent and awards a certificate if the patent survives such review, without materially increasing the details of the patented technology revealed to the public. Recent studies in the field of intellectual property (IP) have made significant progress in understanding reexamination and its corresponding process of patent opposition in Europe (Graham *et al.*, 2002; Hall and Harhoff, 2004), especially in regard to the attributes of reexamined patents. Building on their insights, we identify reexamination

certificates as indications of strategic stakes in particular technological resources that are parsed out from incremental disclosure. Strategic stakes refer to the resources deployed in pursuit of competitive advantage that are crucial in building strategic positions (Somaya, 2003). In examining these reexamination certificates, our focus is on the deterrent message inherent in these certificates and received by the observing firm. Using this context allows us to formally establish that these indications of resources do indeed carry a deterrence component, albeit often obscured by the opposing disclosure component that exists in many other settings.

Importantly, the use of this context also allows us to uncover mechanisms underlying the deterrence effect. We examine two mechanisms—speed and exclusion—that are not based on the typical retaliatory threats underlying deterrence in product market (Porter, 1980). Speed deters through indicating lead time in the development of resources, with the embedded message being that it is too late for other firms to follow suit even if they are capable of doing so. Exclusion deters through indicating exclusivity of resources, which forewarns other firms that they will not be able to develop similar resources into marketable products even if they are usually efficient in doing so. Speed and exclusion have been used, often separately, as mechanisms to explain why some firms are better at appropriating returns (e.g., Lieberman and Montgomery 1988; Cohen and Klepper, 1996; Lee *et al.*, 2000), although their differences are seldom highlighted. Yet the distinction between them is important. In this paper's context, each leads to different boundary conditions and interpretations regarding when deterrence may be credible or potent. For instance, in the memory chip market where speed is typically crucial and exclusion of competitors from the core technologies is difficult, the extent of deterrence will likely vary differently with development speed than with exclusionary abilities.

Advocating deterrence as a theory of resource heterogeneity is an ambitious though potentially meaningful goal. We take a modest but important first step here of tracing how indications of rivals' strategic stakes influence the way firms allocate their inventive efforts. This constitutes a first cut at demonstrating the deterrent nature of resources. Within the context of the U.S. communication equipment industry, we show that rivals' reexamination certificates within a technological

space induce a firm to subsequently allocate less inventive effort in that space. We refer to technological space as an area of potential research and development (R&D) investments where the resultant inventions have similar nature and usage. A helpful albeit simplistic way to depict this core idea is to draw an analogy to 'keep out' signs that we often see erected on physical properties: they induce others to stay away, often without incrementally revealing what lies within these properties. We further develop the two abovementioned mechanisms by arguing that the main deterrence effect is accentuated when rivals have strong downstream capabilities, either absolute or relative to the focal firm, which enhance speed of development, or when rivals have greater litigation experiences that enhance exclusion. Findings provide strong support for contingencies involving downstream capabilities, and weak support for the contingency involving litigation experiences. Altogether, our propositions and findings suggest an alternative view of resource accumulation in which a firm's path evolves through avoidance of rivals' paths, and that deterrence may indeed constitute a viable theory of resource heterogeneity.

THEORY AND HYPOTHESES

The study of how firms allocate inventive effort has received substantial attention in the literature, in large part because this strategic decision helps account for what resources firms create and, accordingly, how they perform (Grant, 1996). Factors driving this decision can be broadly classified as being internal or external to the firm. Internal factors include: constraints in product systems inducing firms to allocate R&D effort toward resolving these constraints (Ethiraj, 2007), performance-aspiration gaps motivating subsequent R&D investments (Chen and Miller, 2007), and exhaustion of internal opportunities prompting firms to search in science for new innovative directions (Ahuja and Katila, 2004). The 'localness' and path-dependent nature of search also inherently push firms to explore in a familiar vicinity and to allocate inventive effort toward where they had previously invested (Cyert and March, 1963; Helfat, 1994).

Other than internal factors, external considerations also dictate where firms allocate their

inventive efforts. The process of firms considering external factors may be depicted as follows: inventions often occur through recombining existing components (Fleming and Sorenson, 2004); they tend to build on common technological paradigms (Tushman and Anderson, 1986), and cumulatively improve upon prior inventions (Green and Scotchmer, 1995).¹ Given this cumulative nature, when a firm evaluates the prospect of R&D investment within a technological space, it values the whole stream of potential inventive opportunities that may subsequently arise, not just the single first-generation or initial invention in the space. The fewer such innovative opportunities within each space, the lower will be the present value of investment. This process can be used to describe instances where firms adopt a technical standard only when uncertainty is low (Lieberman and Asaba, 2006), such that they are reasonably assured of reaping value from their future innovations building on this standard. Likewise, firms may choose not to follow the industry leader if the lead time is too substantial (Lippman and McCardle, 1987) and the leader has captured sufficient opportunities such that the value of remaining opportunities along that trajectory is not worth the firms' investments.²

Laying out this process helps us see how rivals' strategic stakes within a technological space reduce a firm's allocation of inventive effort in that space. Strategic stakes refer to assets that are deployed in pursuit of competitive advantage (Somaya, 2003) that are crucial in building rivals' strategic positions (Teece, Pisano, and Shuen, 1997). An example would be Microsoft's investments in creating and securing its Windows operating system technologies, in terms of IP, patents protecting this IP, human capital, physical assets, and so forth. Noteworthy characteristics are that they are valuable and of strategic importance to these rivals. They constitute key components necessary for future developments or secondary innovations to occur within that technological space. Rivals,

¹ For instance, technologies or products with multiple generations, such as wireless technologies or drugs, tend to build on common platforms with similar scientific principles and have functional attributes that are incrementally superior (for examples, see Tushman and Anderson, 1986; Fleming and Sorenson, 2004; Polidoro, 2006).

² The winner-takes-all scenario commonly depicted in the patent race literature (De Fraja, 1993) can be represented as an extreme case, where there are no subsequent innovative opportunities following the first technology.

being unwilling to accept competition within the commercial space of these strategic technological positions, would commonly have devoted substantial effort in developing these technologies and garnered significant IP rights for the purpose of exclusion. These rivals' investments limit the stream of inventive opportunities that a firm can further exploit, and thus lower the firm's present value of investing R&D effort here by reducing both the expected value of subsequent innovations and certainty of appropriating this value. All else being equal, rivals' strategic stakes render a technological space less attractive to a firm.

While the preceding argument is conceptually straightforward, it is often difficult in practice for a firm to detect where rivals' strategic stakes might lie, due to the inherent uncertainties embedded within the technological space. Beyond the broad-stroke observation of rivals' overall investments in particular technologies, it is typically unclear to a firm what the details of these investments are, or how they bolster rivals' strategic positions, or which investments are of greater importance to rivals.³ Patents—a common instrument through which the firm can observe rivals' technologies—only provide an incomplete trail, as rivals sometimes opt for secrecy to protect these technologies (Arora, 1997; Cohen *et al.*, 2000). Even for patented technologies, figuring out their precise 'stakes,' that is boundaries of legal claims, can be a daunting task (Merges and Nelson 1990).⁴ Also, it is not always clear to a firm from looking at rivals' patents, how rivals have used the underlying technologies, what products rivals are developing based on these technologies, and how close rivals are in launching these products. Furthermore, most patents have low value (Hall, Jaffe, and Trajtenberg, 2005), and figuring out which

ones represent rivals' strategic stakes versus which are incidental is not a straightforward exercise. In sum, when a firm assesses the attractiveness of a technological space, it faces uncertainties regarding what strategic stakes rivals may hold within, or what commitments they have made in the space. Consequently, the calculations of type and volume of outputs rivals are generating from this space is complex, and hence the firm cannot easily determine its own (negative) payoff of entry. Thus, deterrence here will likely operate differently than that described in classic models of deterrence in product markets (Eaton and Lipsey, 1979; Dixit, 1980).

Moreover, even if rivals' strategic stakes are somehow individually observable, the firm may yet be unable to process and recognize rivals' activities in all relevant technological space. With bounded rationality, a firm often lacks the capacity to consider all possible contingencies before arriving at 'optimal' solutions (Cyert and March, 1963). Rather, its detection of rivals' strategic stakes in particular technological space will likely depend on triggers of managerial attention toward that space, as is consistent with longstanding research on how managerial attention determines the direction of firm growth (Penrose, 1959) and the relevant environment for scanning (Hambrick, 1982).

Amid these uncertainties and constraints on managerial attention, the firm attends to available indications of rivals' strategic stakes. Akin to signals that reduce information asymmetry (Bhattacharya and Ritter, 1983; James and Shaver, 2009), these indications provide information about where rivals' strategic stakes lie, rather than details about what they are. In essence, they act like 'keep out' signs 'staked out' on the technological space. Specifically, they indicate rivals' abilities to appropriate returns through two mechanisms—speed and exclusion. The first mechanism—speed—refers to rivals' lead time and the faster rate at which they can develop current technologies and capture future innovative opportunities. In competitive settings, speed of process development and product launch is crucial (Pisano, 1994; Lee *et al.*, 2000), especially when new products involve a high buyer switching cost that indirectly rewards first-to-market (Farrell and Saloner, 1986). With lead time arising from prior investments in core technologies, rivals are often further along the learning curve of these technologies

³ For instance, while it may be easy to observe that IBM is investing heavily in nanotechnologies through its high-profile US\$1.9bil nanoelectronics manufacturing consortium in 2004, a firm outside the consortium is likely to face considerable uncertainties when assessing the details of the projects, identifying human capital assigned to these projects, understanding how IBM is applying nanotechnology knowledge gained from these projects in its businesses, or recognizing which of these projects are of greater strategic importance to IBM.

⁴ In practice, the search for 'claimed space' by existing patents is a highly complex process. To date, there is no standardized algorithm to retrieve a full set of relevant patents for a technology in any prespecified space or field of use. Precise boundaries of patent protection depend on the nuances of language and words used in the claims texts, and hazy doctrines of equivalence frequently have to be invoked to establish patent infringements in courts.

and operate at lower costs (Lieberman and Montgomery, 1988), which they can exploit to fund competitive pricing attacks against the firm. Even without retaliatory threat, the standard Stackelberg model suggests that the firm, being later in the game, is relegated to smaller production volumes and lower profits. Strategic stakes in the form of prior investments in specialized human capital (e.g., scientists), machineries, and knowledge stock in related technologies further enhance the speed at which these rivals can create further innovations based on current technologies (Cohen and Levinthal, 1990; Doraszelski, 2003). Note that the advantages that speed confers to rivals do not rely on the (in)ability of the firm to operate with these technologies.

The second mechanism—exclusion—refers to rivals' abilities to exclude the firm from operating in the technological space. Exclusion occurs when rivals own scarce resources or key know-how that are central to the technological space and that exhibit some characteristics of 'rival goods' (i.e., rivals' use of these know-how impose cost to the firm's use of the same know-how). An example would be highly specialized skills possessed by a rival's key scientist, who can only work at one place at a time (in which case the cost of the firm's use is infinite). A common form of exclusion is enforcement of legal rights through IP instruments like patents (Gilbert and Newberry, 1982; Somaya, 2003). When core technologies are patented by rivals, these rivals can legally exclude the firm from using these technologies, or demand payment for their use (through licensing fees or cross-licensing) in a way that is unprofitable for the firm (Ziedonis, 2004). Prior to investment, the firm often faces uncertainty regarding what these scarce resources are that may be crucial. Without knowing what the core technologies are, the firm cannot tell with certainty if it has been excluded from these technologies by rivals. When venturing into a technological space, the firm subsequently encounters minefields that explode only later in the development (Rivette and Kline, 2000). *Ex ante*, the firm can however infer that rivals are likely to own these key resources, when it detects signs that rivals have invested in significant stakes within the technological space. Note that rivals' abilities to exclude are not eroded even if the firm can move down a learning curve or bring a product to market quickly.

Before establishing a deterrence effect based on the above mechanisms, it is pertinent to discuss a fundamental issue with indications of firm resources: very often they mark the presence as well as disclose technical details of these resources. This 'double-edged sword' nature is prevalent in many forms of indications such as press releases describing R&D efforts and findings, academic publications detailing new scientific principles, patents describing compositions and claims of innovations, code sharing in software programming, and the list goes on. While indicating presence of resources deters competitors as we described, disclosing details often attracts competitors as they can now replicate these resources more easily (see Arrow, 1971). In this paper's context, indications of where rivals' strategic stakes lie may also disclose what these stakes are in terms of the nature of rivals' prior investments and developed technologies. Researchers typically do not disentangle this duality, but instead acknowledge its existence and model the concurrent disclosure as firms' cost. They show that firms disclose their innovations and reduce their informational advantages over competitors so that they can raise financing at better terms (Bhattacharya and Ritter, 1983; James and Shaver, 2009), gain benefits of increased diffusion such as network externalities or reputation enhancements (Harhoff, Henkel, and von Hippel, 2003), positively influence key institutional constituents (Polidoro, 2006), secure legal protection (through patents) over a limited period of time, and so on. However, the fact that an opposing disclosure effect often concurrently exists does not nullify the validity of the deterrence effect. Rather, which effect dominates the other is likely to depend on the individual situations. For the purpose of illustrating deterrence, it is important to minimize if not control for the disclosure effect. We discuss how we do so with our choice of empirical context in the following.

Patent reexamination

We believe reexamination certificates constitute credible indications of rivals' strategic stakes in technological space but do not materially increase the disclosure of details of these stakes. Reexamination begins when the USPTO is asked to review the validity of an issued patent in light of previously unconsidered prior art and/or questions regarding the scope of the patent claims

(Merges, 1999; Graham *et al.*, 2002). This procedure was put in place as part of the Government Patent Policy Act of 1980 (the Bayh-Dole Act) to provide low-cost means of resolving questions of validity as an alternative to litigation. Either the patent holder or a third party may seek an *ex parte* reexamination.⁵ As shown in Table 1, on average patent owners and third parties generate approximately 43 percent and 55 percent of the reexamination requests, respectively, with remaining requests made by the commissioner of the USPTO.

Within three months of the request, USPTO determines whether a substantial ‘new question of patentability’ exists prior to ordering a reexamination.⁶ On average, USPTO grants reexamination to 89 percent of requests (Stacy, 1997). Following that, the patent owner may respond to the new questions of patentability. For third-party requests, if the patent owner responds, the third party is given a last opportunity to present arguments to the USPTO regarding the patent’s validity.⁷ USPTO then conducts the reexamination in a similar fashion as its initial examination with the patent owner. At its conclusion, including any appeals, the original patent’s claims will be canceled, affirmed, or amended. Only the patent owner may appeal any ruling in *ex parte* reexaminations. The patent owner generally receives a reexamination certificate (see Table 2), which heightens the presumption of validity of the patent in question. While this process may result in some amendments of patent claims so as to make them patentable in view of the new prior art cited by the challenger (Krebs and Bohner, 2004), no part of this process allows any party to broaden the scope of the patent’s claims (Graham *et al.*, 2002).

Of interest to this paper is the information embedded in these reexamination certificates. Recent studies have provided insights on the attributes of reexamined patents that are useful for our purpose. First, reexamined patents tend to be valuable (Hall and Harhoff, 2004; Graham *et al.*,

⁵ As part of the American Inventors Protection Act of 1999 (Public Law 106–113 (11/29/99)), Congress created a separate *inter partes* reexamination procedure that allowed for greater third party participation. Since our sample range ends at 1999, this *inter partes* procedure is not applicable to our study.

⁶ This determination is to prevent reopening of issues deemed settled in the original examination. If the USPTO determines that there is no substantial new question, such a determination is final and nonappealable.

⁷ The patent owner may choose not to respond, so as to limit the third party’s participation.

Table 1. Patent reexamination history at the U.S. Patent and Trademark Office

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Reexamination requests	297	307	392	359	379	392	418	376	350	385	318
By patent owner	124	141	167	147	150	138	194	157	168	173	137
By third party	172	165	168	211	227	253	223	215	178	181	172
Commissioner request	1	1	57	1	2	1	1	4	4	31	9
Percentages											
By patent owner	41.80%	45.90%	42.60%	40.90%	39.60%	35.20%	46.40%	41.80%	48.00%	44.90%	43.10%
By third party	57.90%	53.70%	42.90%	58.80%	59.90%	64.50%	53.30%	57.20%	50.90%	47.00%	54.10%
Commissioner request	0.30%	0.30%	14.50%	0.30%	0.50%	0.30%	0.20%	1.10%	1.10%	8.10%	2.80%

Source: USPTO annual reports

Table 2. Patent reexamination outcomes

	Owner requester	Third-party requester	Commissioner initiated	Overall
All claims confirmed	19%	28%	19%	24%
All claims cancelled	8%	13%	13%	11%
Certificate issued with at least one claim change	73%	59%	68%	65%

Source: Stacey (1997)

2002). Third-party requests often arise as defense against the patent owner's allegation of infringement of its key patented technologies. Likewise, a patent owner often requests reexaminations of its key patents in preparation for litigation against an alleged infringer. As such, the protected technologies underlying reexamination are nontrivial and important to the patent owners (rivals), and likely indicate their strategic stakes in the technological area. Reexamination mostly occurs in areas with high technical and market uncertainty (Hall and Harhoff, 2004), suggesting that functioning of these protected technologies cannot be easily observed, and hence reexamination certificates are useful in helping the observing firm locate rivals' key investments. As mentioned earlier, even though reexamination may entail some tweaking of the claims, it does not change the patent scope or description of the underlying technologies in the patent. Thus, reexamination certificates, while they indicate where rivals' strategic stakes lie, disclose at most immaterial if not zero incremental details of the underlying technologies to the public. Finally, for requests by patent owners, as reexamination may result in cancellation of patent rights, patent owners tend to only subject stronger patents to reexamination, which enhances the credibility of the underlying deterrence component.

In sum, rivals' reexamination certificates credibly indicate rivals' strategic stakes without revealing incremental details about them in environments where these indications are likely useful to a firm. Accordingly, by indicating that there are likely fewer opportunities left in that technological space, based on the mechanisms described in the earlier section, they induce the firm to allocate less inventive effort in that space. With that, we arrive at the first hypothesis.

Hypothesis 1: The greater the indications of rivals' strategic stakes within a technological space via patent reexamination certificates

issued to rivals in that space, the less a firm will subsequently allocate inventive effort in that space.

We have invoked both mechanisms of speed and exclusion to establish this main deterrence effect in Hypothesis 1. We now separately demonstrate the mechanisms with corresponding contingency effects. Recall that the mechanism of speed conveys a message to the firm that it is 'too late to follow suit,' as rivals are likely faster in exploitation and bringing products based on these core technologies to market, as well as in capturing subsequent innovative opportunities arising from these technologies. A key factor that could accentuate or retard such rivals' abilities is their downstream capabilities. Rivals' existing production systems allow them to quickly test and implement technologies and generate a high volume of resultant products to spread fixed cost rapidly and capture market share within a short period of time (Cohen and Klepper, 1996). As development typically involves considerable trial and error (see Macher and Boerner, 2006), rivals with access to production activities in multiple areas are better able to find the appropriate experimental setting to test the feasibility of prototypes and thereby reduce the time needed for rework. Product market and distribution abilities further speed up rivals' identification of appropriate market and product launch (see Nerkar and Roberts, 2004).

Furthermore, rivals' production capabilities create scale economies that feed back into the R&D activities and help rivals capture subsequent innovative opportunities (Panzar and Willig, 1981; Helfat, 1997). Production experience enables rivals to identify and understand production problems that can be solved with subsequent innovations. In the spirit of experiential learning (Baum, Li, and Usher, 2000), product market capabilities help identify related market needs that remain unmet and guide future innovative directions. Because

rivals' downstream capabilities enhance their speed of exploiting existing technologies and capturing subsequent innovative opportunities, when a firm observes them (e.g., production systems and market presence) together with the aforementioned indications, the deterrence effect through the mechanism of speed tends to be accentuated.⁸

Hypothesis 2a: The greater rivals' downstream capabilities, the more that indications of their strategic stakes within a technological space via patent reexamination certificates issued to them in that space will subsequently reduce a firm's inventive effort in that space.

The preceding hypothesis builds on rivals' attributes in absolute terms, that is downstream capabilities that enhance rivals' speed. While it adequately illustrates the mechanism of speed, it does not fully capture all aspects of the indicated advantage that speed confers to rivals, as it does not incorporate the focal firm's relative attributes. Looking closely at how speed is explicated earlier, we see that much of the advantages of speed contain elements of relativity between rivals and the focal firm. Being first-to-market to exploit subsequent buyer switching cost (Farrell and Saloner, 1986), operating at lower cost by being further along the learning curve (Lieberman and Montgomery, 1988), and generating higher production volume by being first in the Stackelberg model, all implicitly suggest that the focal firm realizes its rivals are not just fast, but faster than itself. Accordingly, other than rivals' absolute level of downstream capabilities, how these downstream capabilities compare to the focal firm's own downstream capabilities will affect the focal firm's assessment of whether it is too late to subsequently allocate inventive effort in a technological space populated by these rivals.

⁸ A potential challenge is that downstream capabilities enhance the exclusion component in the deterrence effect rather than the speed component. This would be true in special circumstances where these downstream capabilities are unique and necessary, such that rivals' ownership of them precludes the focal firm from operating in the technological space. However, these circumstances do not correspond with what we theorize here, and indeed do not reflect what we subsequently measure. Additional assumptions would be needed to establish that rivals' downstream capabilities, such as production skills, cannot be replicated by the focal firm, and there is no reason to believe that these assumptions are in general true.

Hypothesis 2b: The greater rivals' downstream capabilities relative to the focal firm's downstream capabilities, the more that indications of their strategic stakes within a technological space, via patent reexamination certificates issued to them in that space, will subsequently reduce a firm's inventive effort in that space.

The mechanism of exclusion works by indicating to a firm that rivals' strategic stakes in the technological space will likely impose prohibitive costs to the firm, if it decides to allocate inventive effort in that space. One form of prohibitive costs is the penalty of infringing on these rivals' patents, when the firm creates new technologies, products, or processes that are substantively similar to, or that are materially based on the protected technologies (Cooter and Rubinfeld, 1989; Somaya, 2003). Even if rivals' patent claims do not literally match the elements of the firm's infringing device, under the 'doctrine of equivalents,' a court may still find that rivals' patented inventions and the firm's allegedly infringing device or process are sufficiently equivalent in what they do and how they do it to warrant a finding of infringement. Remedies for infringement can include injunctions, orders to deliver up or destroy infringing articles, and compensation for damages suffered by rivals (patent owners) or profits made by the firm (accused infringer). The process of defending an infringement suit itself is costly (Bhagat, Brickley, and Coles 1994). According to the American Intellectual Property Law Association, the median cost for a patent litigation can often exceed \$2 million and easily reach \$4 million (AIPLA, 2003).⁹ Other forms of litigation costs include time and effort needed to produce extensive documentations for defense, as well as potential reputation damages (Lerner, 1995).

The likelihood of a firm incurring such costs increases with rivals' litigation experiences. *Ex ante*, it is not always apparent to either the firm or rivals whether a firm has indeed infringed upon rivals' patents. The precise coverage of rivals' patent claims depends on the interpretation of courts, which varies across districts. Infringement suits often last for extended periods of time, as

⁹ In one particular instance, according to securities filings, Research in Motion, the makers of BlackBerry, spent more than \$15 million defending the recent infringement lawsuit brought by NTP Inc.

the parties debate over boundaries of legal rights and deliberate on doctrines of equivalents. Rivals' experiences at managing litigation enhance their abilities to detect infringements, navigate the different courts and corresponding processes, manage settlements, and so forth, which in effect increase the likelihood that the firm will incur litigation costs when it infringes on these rivals' patents (Siegelman and Waldfoegel, 1999). This notion is in line with prior research showing that firms pay attention to competitors' litigation abilities (Ordoover, 1978; Hylton, 1990; Lerner, 1995), and that the ability to litigate varies with firm characteristics (Lanjouw and Schankerman, 2004). Thus, when a firm expects subsequent exclusion from areas where rivals have built up significant strategic stakes, the greater these rivals' litigation experiences, the stronger the deterrence effect becomes.¹⁰

Hypothesis 3: The greater rivals' litigation experiences, the more that indications of their strategic stakes within a technological space, via patent reexamination certificates issued to them in that space, will subsequently reduce a firm's inventive effort in that space.

Our proposed theory is by no means the only possible theory of deterrence in firms' competition for resources. The central proposition here rests on indications of rivals' strategic stakes, and is intended to be applicable across different types of resources. In a more specific setting where resources are protected by IP rights, one may imagine a related type of deterrence at work through indications of rivals' willingness and abilities to defend their 'protected turfs,' without hints of whereabouts of rivals' strategic stakes. These indications may deter by warning the focal firm of potentially costly infringements should it tread on *any* of these rivals' 'protected turfs' *in general*, and do not need to convey rivals' speed of exploiting these resources or their abilities to exclude the focal firm from specific technological space

¹⁰ Note that rivals' litigation experiences, just like their downstream capabilities, are themselves observable by the firm prior to reexamination. The emphasis in these contingency effects (Hypotheses 2a, 2b, and 3) is not on rivals' downstream capabilities or litigation experiences per se, but rather on how they accentuate the deterrence effect of reexamination by highlighting the nature of rivals that have built up strategic stakes in these identified locations.

because of their prior investments in this space. In other words, only the exclusion component exists, and it pertains to specific rivals rather than to a particular technological space. Hypotheses 1 and 3 are not helpful in differentiating these two related forms of deterrence, as reexaminations may alternatively be construed as reflections of rivals' willingness and abilities to sue (Hypothesis 1), which are accentuated when these rivals are litigious by nature (Hypothesis 3). However, this alternative deterrence theory does not explain Hypotheses 2a and 2b, since it is not apparent how rivals' willingness and abilities to sue become more deterrent with greater downstream capabilities. The validity of Hypotheses 2a and 2b would demonstrate that reexamination deters in ways other than by indicating rivals' willingness and abilities to sue, and lends support to our proposed theory of deterrence with strategic stakes.

The deterrence theory can also be further sharpened by recognizing that when indications of strategic stakes lead to heterogeneous investment patterns across firms (similar to Hypothesis 1), it may not only be deterrence at work as we described. When the focal firm detects the whereabouts of rivals' strategic stakes, it may stay away, not because of the two proposed deterrence mechanisms, but because of an inherent quest for differentiation (Porter, 1980). This quest is rational, as uniqueness of resources helps the focal firm create a competitive advantage over its rivals (Barney, 1991), and is likely to exist alongside our proposed deterrence theory. However, their separation becomes more apparent in the contingency effects (Hypotheses 2a, 2b, and 3). The focal firm's urge to be different, which is not driven by rivals' deterrence, should be relatively independent of these rivals' abilities to exploit resources quickly or exclude the focal firm.

While uncertainty plays a crucial role in our propositions—indications of rivals' strategic stakes are valuable only because the focal firm is uncertain about where rivals' strategic stakes are in the first place—it presents yet another complication. Even when these indications are stripped of incremental details about the underlying resources, they may still attract the focal firm when it is uncertain about where opportunities lie. In other words, these indications could ironically reveal to the focal firm where its rivals have discovered valuable opportunities. Comprehensively separating this attraction effect from deterrence may yield

further insights about strategic responses to rivalry during a firm's search for resources, but will likely require a different research design. Constrained by the scope of this paper, we acknowledge that this attraction effect opposes but does not invalidate our deterrence theory. Rather, it poses higher hurdles for empirical validation of Hypothesis 1. Conceptually, the discussion on contingency effects also steers us away from this complication, toward a clearer focus on our deterrence theory.

METHODS

Data and sample

We empirically examine our hypotheses in the context of the U.S. communication equipment industry (Standard Industrial Classification [SIC] codes 366 and 367) from 1990 to 1999. We choose this industry primarily because firms' decisions in allocating inventive effort are nontrivial in this setting. Firms' R&D intensities are among the highest across all industries (Fransman, 2002).¹¹ The wide variety of technologies used in this domain¹² makes the allocation decision all the more important for resource-constrained firms. The rapid pace of technological change in this industry also results in substantial uncertainties regarding where technological opportunities reside, such that firms are likely more reliant on indications of attractiveness of prospective R&D investments.

As a proxy for technological space, we use the main technology class created by the USPTO. The USPTO groups related technologies into classes based on the criterion that subject matters have similar functions, uses, or technological principles, so as to ease the search for prior arts in the grant process. By defining technological space on the basis of these similarities, we orientate toward technologies' 'use' rather than 'origin' (Griliches, 1990), which is suited for our test of whether

prior exploitation of technologies within a particular area affects a firm's assessment of remaining opportunities. Our unit of analysis is the firm(i)-class(j)-year(t), namely, each observation captures firm i's allocation of inventive effort in technology class j in year t, as a function of patent reexamination certificates issued to rivals within class j in the prior year.

Since reexamination records are classified by USPTO's technology class, we define our sampling frame according to technology class rather than SIC codes. We compile 89 classes that are related to the communication equipment industry based on the National Bureau of Economic Research (NBER) concordance files. We then remove the inactive classes, by dropping those with 10 or less patents across the sampling period, so as to remove likely irrelevant components from the firms' choice sets. The corresponding reexamination records are matched to the NBER database according to the assigned patent numbers.¹³ Reexaminations are not unusual in this setting: there were 4,607 certificates issued within the sample. It is possible that some unobservable class-specific nature of technology may render reexamination difficult or unnecessary within a class. To minimize such instances, we exclude classes that did not experience any reexamination throughout the sampling period. We then gather all publicly listed firms that existed in the year prior to the start of our sampling range, and that had patented in at least one of the classes over the sample range. Firms in the communications industry sometimes purchase technologies instead of develop them in-house.¹⁴ We restrict our analysis to firms that have more than 10 patents across all classes over the sampling period, so as to rule out firms that are inactive in creating new technologies. Even though the selected classes all relate to the communication equipment industry, it is probably unrealistic to assume that all classes constitute

¹¹ Fransman (2002) reports that R&D expenses as percent of sales in 1999 for Cisco, Ericsson, and Nortel were 18.7, 14.5, and 13.9 percent, respectively. Equivalent figures for pharmaceutical firms like Roche, Glaxo Smithkline, and Smithkline Beecham, which are among the most R&D-intensive firms across industries, were 15.5, 14.4, and 10.8 percent, respectively.

¹² For example, for telecommunication applications alone, related technologies include circuit switch and signaling systems, data transmission systems, customer premise equipments like servers and routers, communication protocol connecting networks, network technologies like Ethernet and voice-data convergence technologies (Green, 2000).

¹³ This procedure does not capture instances where ownership of reexamined patents have changed between patent grant and reexamination certificate issuance, which may affect our analysis if ownership of these patents happened to be transferred to the firm i. However, these incidences are likely to be infrequent. When they do occur, we believe they work against our ability to identify the deterrence effects of reexamination, since the technological space in which firm i is issued a reexamination certificate is likely an area in which the firm is actively investing.

¹⁴ Over our sampling period, the network and carrier firms, for example, the 'Baby Bells,' AT&T, Qwest, MCI WorldCom, and so on mostly engage in little R&D themselves, but instead purchase new technologies from the communication equipment firms (Fransman, 2002).

relevant investment opportunities for each firm, especially given the wide varieties of technologies involved. To better capture the individual set of classes that each firm would have invested in, we remove classes that it did not patent in at all across all years.¹⁵ The resultant sample consists overall of 75 technology classes and 253 firms.

We obtain text records of reexamination certificates from the REEXAM database (in Lexis-Nexis), which documents all U.S. reexamination certificates issued since 1981 and their corresponding patent numbers. Litigation records are obtained from LitAlert (Derwent), which contains text records of patent litigation cases in the United States, with information on associated patent numbers, filing dates of the lawsuits, USPTO-assigned technology classes, identities of plaintiffs and defendants, and so on. Data on firm characteristics are collected from Compustat, and patent-related data are obtained from the NBER patent database (see Hall, Jaffe, and Trajtenberg, 2001).

Variables

In line with recent research (e.g., Ethiraj, 2007), we use patent count as an indication of firms' inventive efforts. Using patent-based measures presents various well-known challenges. Firms' propensities and motives to patent differ greatly across industries, such that an outright cross-industry study may result in inaccurate comparisons (Cohen *et al.*, 2000). Restricting our study to a single industry helps mitigate this problem, since factors driving such differences in patenting propensities are likely stable within the industry (Griliches, 1990). While patent count has been criticized for being an imperfect measure of innovative output

(Trajtenberg, 1990), it remains a fairly reliable indicator of inputs of inventive effort (Hausman, Hall, and Griliches, 1984; Cohen *et al.*, 2000), and is reasonably correlated with R&D investments (Trajtenberg, 1990) and corporate technological strength within a particular area (Narin, Noma, and Perry, 1987).¹⁶

We measure the dependent variable—*Inventive effort*_{ijt}—as the number of patents firm *i* applied for in class *j* in year *t* that are subsequently granted.¹⁷ Instead of scaling this dependent variable by a denominator of firm *i*'s inventive effort across all classes in year *t*, we include this denominator as a control variable. This bypasses the problem of the dependent variable in a firm year summing to one (Katz and King, 1999), and allows us to use count models.

To capture indications of rivals' strategic stakes within a technological space, we use the number of reexamination certificates issued to firms other than firm *i* in class *j* in year *t*−1 (*Reexamination*_{nonijt−1}). This measure excludes instances where patents are subjected to but fail the reexamination process, which is appropriate as our predictions are based on the issued reexamination certificates per se and not the underlying patents. Moreover, patents that fail reexamination tend to be protecting technologies that are of lower value in the first place (Hall and Harhoff, 2004), which typically do not correspond with rivals' strategic stakes.

For downstream capabilities of rivals who are issued the reexamination certificates in class *j*, we measure the average 'product, plant, and equipments' (PPE) across these firms at year *t*−1 (*Rivals' downstream capabilities*_{nonit−1}). Fixed production assets like plants and equipment often

¹⁵ Dropping classes in our sample selection procedure, while serving purposes as described, may themselves create selection issues. First, inactively patented classes that are dropped may represent technological areas with low patentability, which would correspond with low incidence of reexamination. Second, dropped classes with zero reexamination throughout the sample range may contain rivals with strong patents that are hard to challenge, and hence a firm tends not to subsequently allocate inventive effort here to avoid infringements. Third, dropped classes for firm *i*, which firm *i* has not patented in throughout the sample range, may represent technological areas with strong rivals and that are seldom contested via reexamination. Excluding these scenarios from our sample may have biased the findings spuriously in favor of our predictions. We suppress each of these three criteria individually and together, and rerun all subsequent analyses. Results remain fully robust.

¹⁶ The observation that not all innovations are patented (Cohen *et al.*, 2000) may pose a problem, if somehow indications of rivals' strategic stakes systematically induce firms to bypass patenting as a protection mechanism and adopt secrecy instead for their innovations, so as to obfuscate potential infringements. Also, one may argue that reexamination incidences worsens firms' prior assessment about the strength of IP rights, and therefore induce them to bypass patenting. However, recent studies have argued the opposite: upon creating innovations, it is precisely in these situations that firms tend to actively seek patents in order not to be 'fenced in' subsequently (Ziedonis, 2004). Consequently, it is not clear that, given a particular level of innovation, there is a systematic bias in firms' patenting propensities that arise from observing rivals' reexamination certificates.

¹⁷ Measuring counts of granted patents at their application dates rather than grant dates more accurately traces the firm's inventive activities due to the time lag between application and grant dates.

require time for setup and also for employees to become accustomed to their use before bringing the yield rates to desirable levels. Consequently, firms with prior investments in these production assets tend to be able to implement subsequent productions at faster speeds. The presence of fixed assets also reflects the extent of firms' learning about other production activities, which further enhances subsequent speed (Pisano, 1994).

Similarly, we measure the litigation experiences of rivals with reexamination certificates as the average number of litigation cases initiated by these firms in the two years prior to year $t-1$ (*Rivals' litigation experiences*_{nonit-1}). The litigation process is typically time-consuming, costly and tedious, requiring much knowledge and experience of the parties involved such as familiarity with the process of detecting infringements, variability in interpretation of patent laws across jurisdictions, objective of the lawsuit (damages, injunction, and so forth), settlement procedures, and so on. Even if litigation activities are outsourced, the firms are not absolved from involvement. Managers and researchers need to establish relationships and coordination with law firms. As litigation often involves counter lawsuits of infringements, they also need to participate in time-consuming depositions and produce the necessary documents in defense against accusations such as willful infringements. Experiences with prior lawsuits enable rival firms to build the abilities to manage the complex litigation process (Lerner, 1995).

In our analysis, we control for potentially endogenous factors, both at the individual firm and technological class levels. We include the total inventive effort of the focal firm across all relevant technological space (*Total inventive effort*_{it}) with a measure of total patent counts for firm i in year t . This method achieves a similar effect as defining the dependent variable as a proportion of overall inventive effort allocated to a particular technological space. The focal firm with greater abilities to appropriate returns, via speed or exclusion, may be more inclined to allocate inventive effort despite indications of rivals' strategic stakes. We control for these abilities of the focal firm with PPE of firm i in year $t-1$ (*Downstream capabilities*_{it-1}) and number of litigation cases firm i initiated in the two years prior to year $t-1$ (*Litigation experiences*_{it-1}). Firms operating in particular classes with a high frequency of

reexamination may also be more cash constrained, so that they lack the capacity to conduct inventive activities. We account for this 'deep pockets' factor with firm i 's cash and short-term investments in the previous year (*Cash*_{it-1}). To capture instances where R&D-intensive firms are investing more in new technological frontiers with low prior patenting (and hence reexamination) incidences, we add firm i 's R&D expense in the prior year (*R&D*_{it-1}). Large firms may invest greater inventive effort in general, and at the same time focus on technologically stable areas with few challenges of patent validity (via reexamination). We add firm size, measured as the logarithm of the number of employees in year $t-1$ (*Log(firm size)*_{it-1}). High incidences of reexamination may arise when technological space is 'crowded'; and firm i may allocate low inventive effort because opportunities are lacking, not because it reacts to the rivals' deterrence as indicated by reexamination per se. In these situations, rivals should also be investing low inventive efforts. We control for this potential source of endogeneity by including the inventive effort (patent count) of firms other than firm i in class j in year $t-1$ (*Rivals' inventive effort*_{nonijt-1}). Rivals that are cash-rich or large and hence more litigious (Lanjouw and Schankerman, 2001) may themselves deter firm i , while at the same time be more inclined to challenge each other's patent validity via initiating reexaminations. We accordingly control for the average cash and short-term investment (*Rivals' cash*_{nonit-1}) and average firm size as measured by the logarithm of employment (*Rivals' log(firm size)*_{nonit-1}) of firms other than firm i in the previous year. To account for other unobservable technology class characteristics and intertemporal heterogeneity, we include technology class and year dummies.

Model specification

As the dependent variable is a count of non-negative integers, linear estimation models would not be appropriate since the assumption of homoskedastic and normally distributed errors is violated. Following prior literature (e.g., Hausman *et al.*, 1984), we use Poisson-based models where the expected number of patents in class j at year t is assumed to be an exponential function of the independent and control variables. Using the Lagrange Multiplier test from Cameron and Trivedi (1998), we found overdispersion in our data and reject the

Table 3. Descriptive statistics

	Variable	Obs.	Mean	Std. dev.	Min.	Max.
A	Inventive effort _{ijt}	20459	2.04	7.30	0	184.00
B	Reexamination _{nonijt-1}	17460	1.93	2.27	0	19.00
C	Total inventive effort _{it}	20459	82.38	195.46	0	1338.00
D	Downstream capabilities _{it-1}	14610	8.65	16.81	0	78.17
E	Litigation experiences _{it-1}	16980	0.30	0.91	0	9.00
F	Cash _{it-1}	12821	3.77	7.49	0	139.27
G	R&D _{it-1}	16411	6.32	12.75	0	70.36
H	Log(firm size) _{it-1}	14580	2.46	1.85	-4.61	5.92
I	Rivals' inventive effort _{nonijt-1}	17214	694.43	509.48	3	2626.00
J	Rivals' downstream capabilities _{nonit-1}	17214	13.78	8.63	0	71.63
K	Rivals' litigation experiences _{nonit-1}	17214	0.42	0.36	0	4.00
L	Rivals' cash _{nonit-1}	17214	4.27	2.56	0	59.28
M	Rivals' log(firm size) _{nonit-1}	17214	2.92	0.67	-1.82	5.92

use of a pure Poisson model. Instead, we use the negative binomial model primarily for all our analyses, allowing for robust standard errors to help correct for serial correlation and heteroskedasticity (Wooldridge, 2002). To ensure that our findings are not driven by specific distributional assumptions for the error term in this model, we check for robustness with the random-effects Poisson model, which similarly relaxes the unity ratio assumption between mean and variance and instead allows the variance to grow (Hausman *et al.*, 1984). As a further attempt to capture unobserved firm-specific capabilities that enable certain firms to identify and invest in relatively new technological space with low prior patenting and reexamination activities, we also run both the fixed-effect negative binomial and fixed-effect Poisson models.

FINDINGS

Table 3 reports the descriptive statistics. On average, each firm faces about two reexamination certificates issued to other firms within a technology class in a year. Within our sample, it is also common for a technology class not to have any reexamination certificates issued in a given year (428 out of 750 class years). Based on the low correlations of $Reexamination_{nonijt}$ with other firm and class attributes reported in Table 4, there is no sign that the observations are systematically selected into class year with high or low incidences of reexamination, at least along these known attributes. We trace total reexamination certificates issued in our sample classes over time and do not detect any clear trends across years. Thus, at first glance, the

reexamination data does not exhibit symptoms of selection issues driven by macro forces, or technology class and firm attributes. Figure 1 plots firms' inventive effort against reexamination certificates issued in the prior year. The negative association it reveals is in line with our central prediction that reexamination certificates deter a firm's subsequent allocation of inventive effort. While this association does not demonstrate causality, it nonetheless provides a comforting basis on which to build our analysis.

Table 5 reports results for the full sample analysis. Column 1 contains the baseline negative binomial model with robust error using only the control variables. As expected, firms with larger overall inventive effort ($Total\ inventive\ effort_{it}$) or larger firms ($Log(firm\ size)_{it-1}$) tend to invest greater inventive effort in each technology class. In Column 2, we add the variable of interest— $Reexamination_{nonijt-1}$. Including this variable significantly increases the explanatory power of the model. Its coefficient is significantly negative (z-statistic -9.2), suggesting that more reexamination certificates issued to rivals in a particular technology class induce a firm to subsequently allocate less inventive effort in the class. This result supports Hypothesis 1. An alternative explanation may be that, despite the various firm-level controls, some unobserved firm attributes are driving the firm to seek out technological areas with low reexamination incidences. We account for the time-invariant subset of these attributes using a fixed-effect negative binomial model in Column 3. Coefficient of $Reexamination_{nonijt-1}$ remains significantly negative (z-statistics -18.3). We then test for the robustness of this finding to different

Table 4. Pair-wise correlations

Variables	Correlations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	
A Inventive effort _{ijt}	1													
B Reexamination _{nonij,t-1}	-0.07*	1												
C Total inventive effort _{it}	0.42*	-0.12*	1											
D Downstream capabilities _{it-1}	0.25*	-0.10*	0.66*	1										
E Litigation experiences _{it-1}	0.11*	-0.05*	0.23*	0.16*	1									
F Cash _{it-1}	0.09*	-0.06*	0.28*	0.35*	0.10*	1								
G R&D _{it-1}	0.29*	-0.11*	0.75*	0.90*	0.14*	0.47*	1							
H Log(firm size) _{it-1}	0.20*	-0.09*	0.51*	0.67*	0.15*	0.39*	0.69*	1						
I Rivals' inventive effort _{nonijt-1}	0.10*	0.26*	-0.08*	-0.10*	-0.05*	-0.05*	-0.12*	-0.11*	1					
J Rivals' downstream capabilities _{nonit-1}	-0.03*	-0.16*	0.08*	0.13*	0.06*	0.09*	0.12*	0.09*	-0.32*	1				
K Rivals' litigation experiences _{nonit-1}	-0.01	-0.06*	0.04*	0.04*	0.14*	0.01	0.04*	0.04*	-0.15*	0.43*	1			
L Rivals' cash _{nonit-1}	0.06*	-0.13*	0.09*	0.09*	0.02*	0.14*	0.10*	0.04*	-0.05*	0.18*	0.11*	1		
M Rivals' log(firm size) _{nonit-1}	-0.10*	-0.14*	0.07*	0.10*	0.06*	0.05*	0.11*	0.14*	-0.35*	0.73*	0.29*	0.15*	1	

* Pair-wise correlation significant at 5%.

distributional assumptions of the error term with both the random-effects and fixed-effect Poisson models in Columns 4 and 5, and find significant results for *Reexamination_{nonijt-1}* (z-statistics -18.9 and -18.7, respectively). It is also possible that firms react not only to reexaminations occurring in the previous year (t-1), but rather to all relevant reexaminations in the recent past. We include two-year and three-year lagged reexamination certificates in each of the above models, test for the joint significance of all three lags, and find significant results at five percent level across all models. Thus, we are reasonably confident that our empirical findings support Hypothesis 1.

The remaining hypotheses describe how the characteristics of rivals that are awarded reexamination certificates, either independently or relative to the focal firm, affect the strength of deterrence. We focus on observations that experience at least one reexamination certificate, and split the sample into 'high' and 'low' groups, along the median of each dimension—*Rivals' downstream capabilities_{nonit-1}* (Hypothesis 2a) and *Rivals' litigation experiences_{nonit-1}* (Hypothesis 3)—and also based on whether *Rivals' downstream capabilities_{nonit-1}* is greater than focal firm's *Downstream capabilities_{it-1}* (Hypothesis 2b). We then run the fixed-effect negative binomial model in Column 3 of Table 5 on the separate groups and report our findings in Table 6. Because of reduced sample size in this split-sample analysis, we have to drop the technology class dummy variables.¹⁸

Columns 1 and 2 report results for the 'low' and 'high' groups of downstream capabilities, respectively. *Reexamination_{nonijt-1}* is significantly negative in the 'high' group (Column 2, z statistic -2) but not in the 'low' group (Column 1, z-statistic -1.33), suggesting that the deterrence effect is present only when rivals that are issued these certificates have greater downstream capabilities, which supports Hypothesis 2a. To formally test this difference across groups, we calculate the marginal effects at the respective mean levels of

¹⁸ This reduces our ability to capture unobserved class-specific factors that may drive firm i to allocate inventive effort in class j. However, we still control for all other firms' inventive effort in class j in the prior year through the variable *Rivals' inventive effort_{nonijt-1}*, which should capture these unobserved factors to a large extent, based on the rationale that such unobserved attractiveness of class j to firm i would similarly attract other firms to class j as well.

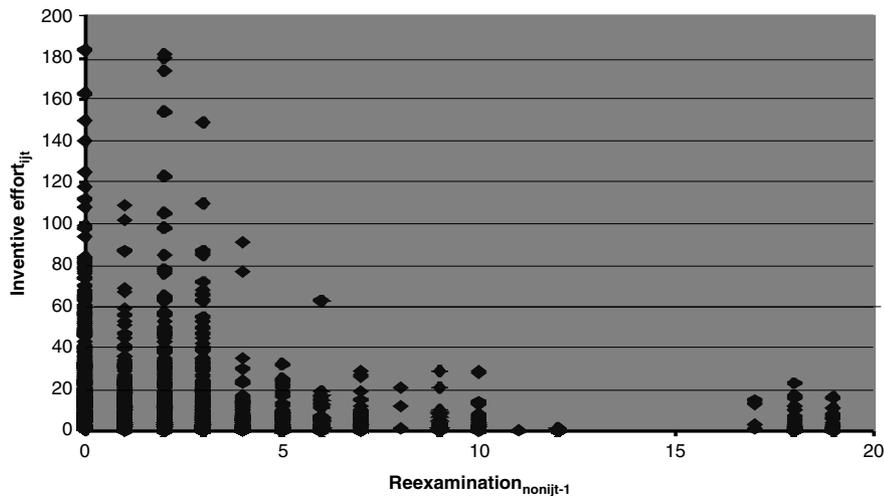


Figure 1. Firm’s inventive effort against rivals’ patent reexamination certificates

$Reexamination_{nonijt-1}$ for each group and conduct a t-test for their difference (Penner-Hahn and Shaver, 2005).¹⁹ Note that it is more appropriate to compare marginal effects rather than coefficients across groups, since a comparison of coefficients may be misleading due to the nonlinearity of the estimator if observations for each group lie in sufficiently different parts of the curve. T-test reveals that the marginal effect of $Reexamination_{nonijt-1}$ is significantly more negative in the ‘high group’ than that in the ‘low’ group (t-statistic 23.62), which further supports Hypothesis 2a.

Similarly, the next two columns report findings for groups where rivals’ average downstream capabilities are (Column 3) less than or equal to, and (Column 4) higher than, the focal firm’s downstream capabilities. $Reexamination_{nonijt-1}$ is insignificant in Column 3 (t-statistic -0.01), while somewhat significant (at 10%) in Column 4 (t-statistic -1.67), which is arguably meaningful given the one-tailed nature of the test. A t-test of marginal effects across groups, however, strongly confirms this difference (t-statistic 20.11), that is, the deterrence effect is significantly stronger when rivals have greater downstream capabilities than

the focal firm. We interpret these findings as relatively strong support for Hypothesis 2b.

Columns 5 and 6 contain results for the ‘low’ and ‘high’ groups of rivals’ litigation experiences, respectively. We see that $Reexamination_{nonijt-1}$ is significantly negative in the ‘high’ group (z-statistic -9.07), but not in the ‘low’ group (z-statistic -1.48), which suggests that rivals with stronger litigation experience are the ones whose reexamination certificates carry a deterrence effect. This is in line with Hypothesis 3. However, we are unable to validate such difference in strengths of deterrence effects via a t-test of marginal effects between the two groups (t-statistic 0.05). We interpret these findings conservatively as only weak support for Hypothesis 3. We rerun the above analyses with each of the alternative models described in Table 5 to check for robustness to model specifications, and find substantively similar results.

DISCUSSION

We further examine alternative explanations for our main findings. First, unobserved firm capabilities may have helped some firms identify inventive opportunities (correlated with high firm i’s patenting) in areas not previously populated by rivals (correlated with low reexamination). Arguably, these capabilities may evolve within a firm over time, such that they are not captured by fixed-effect models. However, this interpretation is not

¹⁹ Calculations of t-statistics follow the standard formula of dividing the difference in marginal effects across the two groups by $[(var_1^2/n_1)+(var_2^2/n_2)]^{1/2}$, where var is variance, n is sample size, and subscript denotes group. Variance of marginal effect is $Q'VQ$, where Q can be calculated by taking the first derivatives of the marginal effect by the coefficient estimates β , and V is the variance-covariance matrix of β .

Table 5. Full-sample regression analysis

	Negative binomial with robust errors (1)	Negative binomial with robust errors (2)	Fixed-effect negative binomial (3)	Random-effects Poisson (4)	Fixed-effect Poisson (5)
Reexamination _{nonijt-1}		-0.111*** (-9.20)	-0.178*** (-18.30)	-0.0831*** (-18.90)	-0.0824*** (-18.70)
Total inventive effort _{it}	0.00387*** (21.90)	0.00382*** (21.40)	0.00062*** (3.85)	0.00283*** (32.30)	0.00270*** (30.30)
Downstream capabilities _{it-1}	-0.00451 (-1.40)	-0.00427 (-1.37)	-0.0189*** (-6.54)	-0.00422* (-1.77)	-0.00328 (-1.35)
Litigation experiences _{it-1}	0.0735*** (3.82)	0.0681*** (3.62)	-0.0236 (-1.64)	-0.00312 (-0.37)	-0.00967 (-1.13)
Cash _{it-1}	0.00732** (2.39)	0.00778** (2.50)	-0.00589* (-1.91)	0.00390 (1.58)	0.00488* (1.90)
R&D _{it-1}	-0.00424 (-0.73)	-0.00437 (-0.77)	0.00767 (1.59)	-0.000252 (-0.08)	-0.00683** (-2.02)
Log(firm size) _{it-1}	0.0799*** (5.49)	0.0806*** (5.49)	0.0594*** (3.20)	0.249*** (9.43)	0.471*** (12.8)
Rivals' inventive effort _{nonijt-1}	0.000165 (1.35)	0.000225* (1.82)	0.000126 (1.55)	0.00016*** (4.17)	0.00016*** (4.12)
Rivals' downstream capabilities _{nonit-1}	-0.00982* (-1.77)	-0.00982* (-1.79)	-0.00991** (-2.31)	-0.0153*** (-5.12)	-0.0152*** (-5.11)
Rivals' litigation experiences _{nonit-1}	-0.0492 (-0.62)	-0.119 (-1.50)	0.0266 (0.43)	0.226*** (5.47)	0.226*** (5.46)
Rivals' cash _{nonit-1}	0.0335*** (2.60)	0.0302** (2.33)	0.0114 (1.25)	0.0247*** (4.24)	0.0242*** (4.16)
Rivals' log(firm size) _{nonit-1}	-0.126* (-1.92)	-0.122* (-1.82)	-0.0464 (-0.98)	-0.0600* (-1.90)	-0.0604* (-1.91)
Year control	yes	yes	yes	yes	yes
Tech class control	yes	yes	yes	yes	yes
Constant	-1.006** (-2.13)	-1.942*** (-4.27)	-2.589*** (-5.72)	-2.385*** (-5.92)	
Observations	11393	11393	11389	11393	11389
Log-likelihood	-16386.31	-16286.76	-15510.15	-23002.36	-22152.57

Notes: *** p<0.01, ** p<0.05, * p<0.1. Dependent variable: Invent effort_{ijt}. Robust z statistics are shown in parentheses. Analyses include year and technology class dummy variables.

consistent with findings in Table 6, since the firms' capabilities at identifying opportunities in 'uncrowded' areas should not vary with rivals' characteristics in the 'crowded' areas that these firms are avoiding. Nonetheless, we test this alternative explanation, using the rationale that if such capabilities are driving our findings, then reexamination should have no deterrence effect in 'uncrowded' areas identified by these capabilities. We use *Rivals' inventive effort_{nonijt-1}* as a proxy for 'crowdedness' and split the sample into two groups—'low' and 'high'—based on this measure. We then run the fixed-effect model for the 'low' group and find *Reexamination_{nonijt-1}* to still be significantly negative (z-statistic of -8.11). We fine-tune the definition of the 'low' group

by splitting the sample into five and 10 groups separately. *Reexamination_{nonijt-1}* remains significantly negative in the 'low' group in both instances (z-statistics -2.22 and -9.45, respectively). Thus, our main findings are not likely driven by unobserved firm capabilities.

Second, unobserved exhaustion of technological opportunities within a class as a whole may lead to more reexaminations and lower overall patenting. Class dummies do not fully capture such exhaustion if it occurs during but not throughout our sample range within a class. However, *Rivals' inventive effort_{nonijt-1}* should partially capture this, since with exhaustion other firms will similarly reduce their inventive efforts. Also, exhaustion does not

Table 6. Split-sample regression analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Low rivals' downstream capabilities _{nonit-1}	High rivals' downstream capabilities _{nonit-1}	Rivals' downstream capabilities _{nonit-1} <= focal firm	Rivals' downstream capabilities _{nonit-1} > focal firm	Low rivals' litigation experience _{nonit-1}	High rivals' litigation experience _{nonit-1}
Reexamination _{nonit-1}	-0.0207 (-1.33)	-0.0352* (-2.00)	-0.000311 (-0.01)	-0.0175* (-1.67)	-0.0186 (-1.48)	-0.397*** (-9.07)
t-test of difference in marginal effects across models		23.62		20.11		0.05
Total inventive effort _{it}	0.00223*** (4.12)	0.00090* (1.80)	0.00277** (2.53)	0.000641 (1.47)	0.00112 (2.83)	0.00331*** (4.65)
Downstream capabilities _{jit-1}	-0.0186 (-1.54)	-0.0315*** (-3.10)			-0.0282*** (-3.30)	-0.00698 (-0.36)
Litigation experience _{jit-1}	0.0616 (1.39)	-0.0616 (-1.04)	-0.171 (-1.16)	-0.0202 (-0.51)	-0.0130 (-0.33)	-0.208** (-2.00)
Cash _{it-1}	-0.00718 (-0.48)	-0.0199** (-2.42)	0.0521* (1.66)	-0.0203** (-2.27)	-0.0149** (-2.11)	0.0393* (1.84)
R&D _{it-1}	0.00638 (0.31)	0.0206 (1.23)	-0.0144 (-0.66)	0.0308 (1.11)	0.0164 (1.17)	0.0134 (0.41)
Log(firm size) _{it-1}	0.178*** (2.75)	0.0968 (1.37)	0.185 (0.62)	0.0703 (1.49)	0.119** (2.42)	0.0990 (0.62)
Rivals' inventive effort _{nonit-1}	0.000155 (1.37)	0.000169 (1.21)	0.000298 (1.39)	0.000320*** (4.85)	0.000316*** (4.20)	-0.0422*** (-8.98)
Rivals' downstream capabilities _{nonit-1}					-0.00586 (-0.51)	-3.854*** (-8.93)

Table 6. Split-sample regression analysis (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
	Low rivals' downstream capabilities _{nonit-1}	High rivals' downstream capabilities _{nonit-1}	Rivals' downstream capabilities _{nonit-1} <= focal firm	Rivals' downstream capabilities _{nonit-1} > focal firm	Low rivals' litigation experiences _{nonit-1}	High rivals' litigation experiences _{nonit-1}
Rivals' litigation experiences _{nonit-1}	-0.0444 (-0.13)	-0.155 (-0.70)	-0.0384 (-0.05)	-0.190 (-1.11)		
Rivals' cash _{nonit-1}	0.0363 (0.53)	0.051* (1.87)	0.147* (1.87)	0.0661*** (3.39)	0.0735*** (3.57)	12.54*** (8.75)
Rivals' log(firm size) _{nonit-1}	-0.668*** (-4.41)	-0.561*** (-4.53)	-0.700** (-2.56)	-0.464*** (-5.90)	-0.420*** (-4.87)	30.35*** (8.51)
Year control	yes	yes	yes	yes	yes	yes
Constant	-1.091* (-1.78)	-0.0456 (-0.08)	-1.900 (-1.05)	0.0761 (0.24)	-1.347*** (-4.01)	-161.0 (-0.13)
Log-likelihood	-1221.42	-1433.56	-258.64	-2696.63	-2346.37	-383.53

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Dependent variable: invent effort_{ijt}. z statistics are shown in parentheses. Estimation model is fixed-effect negative binomial. Analyses include year dummy variables.

explain findings in Table 6, as its effect should not vary with rivals' characteristics. We adopt a rationale that if exhaustion is driving our main finding, then reexamination should have no effect on patenting where exhaustion is less likely occurring. We create a proxy for exhaustion, with the average age of patents cited by patents in class j at year t , based on the reasoning that building on older patents reflects fewer remaining opportunities. We then split the sample into 'low' and 'high' groups by this proxy and run regression on the 'low' group as before. We find $Reexamination_{nonijt-1}$ to remain significantly negative (z-statistics of -10.88). Refining the 'low' group by splitting the sample into five and 10 groups yields robust results (z-statistics -4.99 and -3.04 , respectively). Hence, our main findings are not likely driven by technological exhaustion.

Third, the significance of $Reexamination_{nonijt-1}$ may arise from the focal firm reacting to the nature and motives of requests for reexaminations rather than to the certificates per se. However, we believe this is unlikely, primarily because these requests are not public information and typically are not observed by the focal firm prior to the issue of certificates. Notwithstanding this argument, we may potentially isolate the effect of requests so as to extract the focal firm's reaction to certificates by showing that the effect of $Reexamination_{nonijt-1}$ persists across different natures of requests.²⁰ Requests by firm i are likely made to remove entry barriers into the technological space or disarm infringement suits launched by the patent owner against firm i . Both indicate firm i 's interest in allocating inventive effort in that space, which is contrary to our prediction and does not explain our findings. This narrows down the set of potential endogenous requests to those by all parties other than firm i , some of which are made in anticipation of, or in response to, litigation. These litigation-related requests express patent owners' intentions to fend off infringers, and it may be these deterrent intentions that the focal firm is reacting to, rather than the associated certificates. We identify

²⁰ Alternatively, we may demonstrate that the effect of $Reexamination_{nonijt-1}$ does not vary across identity of requesters, or show that requests that do not eventually transpire into certificates have no effect on the focal firm. Unfortunately, the Patent and Legal Administration Office (overseeing reexaminations) and the Electronic Resource Center (managing data) within the USPTO denied us the information on requesters necessary to conduct these tests, on the basis that such information is nonpublic.

a litigation-related reexamination as one where its underlying patent was involved in litigation filing between the year before ($t-1$) and the year after ($t+1$) the reexamination, and split $Reexamination_{nonijt-1}$ into two variables—litigation-related and non-litigation-related. Using the fixed-effect model, we find that these two variables both remain significantly negative, either in separate models (z-statistics -8.25 and -12.65 , respectively) or together (z statistics -5.22 and -11.62 , respectively). This suggests that over and above the nature of requests, the certificates themselves carry a deterrence message.²¹

We also revisit the competing notion of 'deterrence without indicating strategic stakes,' that is, reexamination certificates may be conveying to the focal firm that rivals are willing and able to defend against infringements rather than indicating rivals' strategic stakes as we had theorized. As discussed earlier, while Hypothesis 3 (rivals' litigation experience) cannot tease apart these two related forms of deterrence, Hypotheses 2a and 2b (rivals' downstream capabilities) help differentiate our theory about strategic stakes. In fact, findings from the split-sample analyses, by showing stronger support for Hypotheses 2a and 2b than for Hypothesis 3, suggest that deterrence with strategic stakes is more relevant at least within this setting, and that exclusion is not the only component at work. Nonetheless, we further challenge our proposed theory by questioning if rivals' downstream capabilities in Hypotheses 2a and 2b merely reflect rivals' sizes, and that large or cash-rich rivals may deter the focal firm (Lanjouw and Schankerman, 2004), especially when combined with indications of rivals' willingness to deter (through reexaminations). However, turning back to Table 5, we see that $Rivals' cash_{nonit-1}$ is, in fact, significantly positive across most models, providing no support for deterrence (the positive coefficients may indicate that operating in profitable areas makes these rivals cash-rich, which attracts rather than deters firm i). $Rivals' log(firm size)_{nonit-1}$ is only significantly negative at 10 percent across most models, and even then we cannot determine if the focal firm is

²¹ Another possible challenge is that when a third party enters a technological space and requests reexaminations, it is such entry per se, and not the certificates, that affects firm i . However, it is not clear why such new entry would uniformly deter firm i , or would not, in fact, signal remaining opportunities within this technological space and hence attract firm i . Thus, we do not believe that such entry systematically affects firm i 's subsequent action.

avoiding large rivals, or if technological areas with greater opportunities (and hence soliciting greater investment efforts) tend to be explored by smaller firms. We further attempt to salvage this opposing deterrence theory by picking a favorable condition for rivals' size or cash to deter firm i —when they are coupled with rivals' extensive litigation experiences in Column 6 of Table 6—but we still see that *Rivals' cash*_{nonit-1} and *Rivals' log(firm size)*_{nonit-1} remain significantly positive (opposite of deterrence). Hence, we conclude that there is no evidence here supporting the opposing deterrence theory that reexamination is only deterring by indicating rivals' willingness and abilities to sue in general.

While we focus on production-related assets for rivals' downstream capabilities, as measured by PPE, we stress that the contingency effect of downstream capabilities conceptually spans beyond production-related assets. The aforementioned mechanisms through which production-related assets accentuate speed (e.g., enabling high-volume production, testing and experimentation, feedback and new problem identification) also apply to other downstream capabilities such as sales, retailing, or other forms of marketing expertise, and long-standing alliances with distributors or retailers that allow efficient information flows and coordination of rapid product implementations. It may be fruitful for future research to explore and compare equivalent effects of these other downstream capabilities. In particular, with respect to rivals' relationships with other downstream firms, we may yet obtain interesting insights by investigating if the strength of these downstream capabilities will cross firm boundaries to accentuate these rivals' ability to deter the focal firm.

CONCLUSIONS

The central message in this paper is that firms can be deterred from a technological space upon being *shown* what resources rivals already possess within that space. This suggests an approach to understanding resource heterogeneity that is fundamentally different from that used in the literature, which is based on how rivals' resources are *hidden* from firms. To illustrate this deterrence effect, we use patent reexamination certificates that indicate strategic stakes within a technological space without materially disclosing additional details of

the underlying technologies. This context helps minimize the confounding disclosure effect often associated with indications of resources, that is, attracting competition through disclosing details. We demonstrate that rivals' reexamination certificates within a technological space induce a firm to subsequently allocate less inventive effort in that space based on two mechanisms—speed and exclusion. We further develop these two mechanisms by arguing that the deterrence effect is stronger when rivals' speed is enhanced by their downstream capabilities, or when rivals' exclusion is enhanced by their litigation experience. We find strong results showing that the main deterrence effect is accentuated when rivals have greater downstream capabilities, both in absolute terms and relative to the focal firm, and weak results showing that rivals' litigation experience accentuates the deterrence effect.

We believe our propositions reach the heart of the 'paradox of disclosure' that is prevalent in the strategy literature. When the object of interest involves firm resource or some other form of firm's strength, should the firm reveal such strength? While there are many instances where the firm may choose to do so, such as to facilitate financing or influence key constituents (Bhattacharya and Ritter 1983; Polidoro 2006), the well-known disclosure paradox points out a troubling cost—disclosing details attracts competitors and facilitates imitation (Arrow, 1971; James and Shaver, 2009). Yet, when discussing this dilemma between disclosure and nondisclosure, we often neglect another fundamental paradox that precedes it. Even though revealing a firm's strength often attracts competitors through disclosing details, sometimes such revelation may deter competitors instead by indicating an exhaustion of remaining opportunities as we explain in this paper. This idea of 'deterrence via staking out one's territory' is indeed intuitive, and parallels established theories of deterrence (Dixit, 1980; Porter, 1980). Without accounting for this deterrence effect, it is not clear that the cost of disclosure—attraction of competitors—always prevails. We have by no means resolved this paradox here. By minimizing the disclosure component through our empirical context, we merely attempt to show the existence of the deterrence effect that runs counter to the well-known disclosure effect. This highlights nuances to the relationship between disclosure and competitors' reactions that may have

been missed, and we hope that future research will disentangle and resolve this paradox.

Our treatment of the two mechanisms—speed and exclusion—represents preliminary explorations of their implications. They are different from the typical deterrence mechanisms that rely on some form of retaliatory threat. Both mechanisms have been used in prior literature as micromechanisms of appropriation from the perspective of the focal firm itself. However, the prospect that such ability of a firm to appropriate returns (through speed or exclusion) may be indicated to competitors, and accordingly may affect competitors' behavior, has seldom been discussed. A potential implication is that the full extent of appropriation goes beyond merely observing how much the focal firm is able to use the technologies and generate products from them. Rather, it includes the preemption of competitors when competitors recognize the focal firm's abilities to appropriate returns. Hence, downstream assets may do more than help firms appropriate returns to technologies quickly and survive technological change (Tushman and Anderson, 1986; Mitchell, 1989); they also strengthen any indication of the firm's speed of appropriation to competitors and accordingly deter them from competing. Likewise, a firm's litigation suit against one competitor may deter other competitors as well by enhancing the message that the firm can exclude them from a particular market. Furthermore, the relationship between the two mechanisms warrants deeper examination. How effective is deterrence via indicating speed when a firm's ability at exclusion increases or decreases, and vice versa? When do firms choose to bolster one mechanism over the other? While we acknowledge the importance of these questions, we are constrained to focus on our main objective of demonstrating the deterrence effect. These remaining unanswered questions are worthy of future pursuit.

While we focus only on contingencies that illustrate the corresponding two mechanisms, there are conceivably others that affect the strength of deterrence. Other attributes of rivals may similarly condition the credibility of the deterrence messages, such as rivals' experience in the technological field, their status, their influence over key institutional constituents, and so forth. Moreover, the precise message conveyed probably depends much on the context within which the message is sent, and messages may be differentially appropriate

depending on that context. Also, in our analysis, the characteristics of the focal firm play only minor roles. Yet, more could be learned if we unpack the types of receiving firms to identify how they may react differently. For instance, one could plausibly imagine capable firms to be less sensitive to deterrence messages, suggesting that incumbents already have a significant lead. While these contingencies are not directly related to the main thrust of this paper, they are nonetheless interesting extensions that will help complete our understanding of how deterrence operates in the resource landscape.

The findings of this paper also generate practical concerns. From a firm's perspective, reexamination is much less costly than litigation. To the extent that reexamination deters competitors from creating technologies or products that infringe upon the focal firm's patents, reexamination may constitute a viable alternative to litigation. More generally, a comparison of effectiveness and cost of litigation and reexamination is needed to inform whether a firm should litigate upon competitors' infringement, or preemptively deter competitors from infringing via reexamination. From a public policy perspective, the process of reexamination was put in place to ensure the quality of issued patents (which has been challenging in recent years due to the increasing workload of patent examiners; see Hall and Harhoff, 2004). The larger backdrop is that high-quality patents contribute toward achieving the appropriate balance between providing adequate rewards to inventors and stifling future innovations by others. However, a deterrence effect of reexamination would tip this balance by discouraging future innovations. Furthermore, one may question whether the two deterrence mechanisms imply different degrees of welfare loss, as speed may suggest that more efficient firms should rightly monopolize a technological space, whereas exclusion does not guarantee the monopolist will develop the technologies in a welfare-maximizing way. A comprehensive assessment of welfare implications is beyond the scope of this paper and, indeed, is not our focus. We leave this to specialists in the field of welfare economics who are more capable of further inquiries here.

Ultimately, this paper is about firms' processes of resource accumulation, and their according growth and performance. By mapping a firm's inventive-effort allocation as a function of indications of its rivals' strategic stakes, we in essence

highlight that the path of searching for new resources is not just guided by the firm's internal constraints, its needs for new opportunities, or some form of internal impetus (Ahuja and Katila, 2004; Chen and Miller, 2007). Rather, external constraints matter too as a firm may meander in its search partly to avoid its rivals. This observation is important as such meandering search patterns may have resulted in firms being heterogeneous in the resource landscape. While we do not empirically examine heterogeneity per se, it is our hope that this first-cut demonstration of deterrence will spur future research toward establishing deterrence as a meaningful theory of resource heterogeneity.

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