GETTING AHEAD BY FALLING BEHIND: A SET THEORETIC MODEL OF SEARCH-BASED COMPETITION

DOUGLAS P. HANNAH

Department of Management Science and Engineering

Stanford University

473 Via Ortega, Stanford, CA, 94110

dphannah@stanford.edu

HENNING PIEZUNKA

Department of Management Science and Engineering

Stanford University

473 Via Ortega, Stanford, CA, 94110

piezunka@stanford.edu

July 14, 2014

We are grateful for the very helpful comments from Oliver Alexy, Kathleen Eisenhardt, Riitta Katila, Rory McDonald, and the seminar participants at Stanford University. We have received generous financial support from the Stanford Technology Ventures Program, the Sloan Research Project on the Economics of Knowledge Contribution and the Institute for Research in the Social Sciences at Stanford University.

GETTING AHEAD BY FALLING BEHIND: A SET THEORETIC MODEL OF SEARCH-BASED COMPETITION

How do firms succeed against superior competitors? In search, firms compete to identify resource combinations that are both valuable and exclusive. Acquiring idiosyncratic resources is, thus, a central activity in search-based competition. But while resource acquisition clearly benefits the acquiring firm, the impact of this action on other firms is less clear. We develop a set theoretic model to address this gap. Contrary to prior research, we find that firms can benefit from competitors' resource extensions. Moreover, we show this finding to have counterintuitive strategic implications: under certain conditions, firms should actually remain resource-inferior. We contribute to the literature on search by illuminating a means by which resource-inferior firms can compete against resource-superior competitors and by identifying attention as a differentiating strategy in search-based competition.

INTRODUCTION

How can firms succeed against resource-superior competitors? In their search for innovation, firms try to identify valuable and exclusive resource combinations to increase their performance (Greve and Taylor, 2000; Katila and Chen, 2008). As firms compete in search, they take actions to differentiate themselves from competitors (Katila, Chen, and Piezunka, 2012; Toh and Polidoro, 2013; Wang and Shaver, forthcoming). One such action is adding idiosyncratic resources, which increase the number of potential unique resource combinations (Ahuja and Katila, 2004; Katila and Ahuja, 2002). While prior research has established the benefit of such additions for firms themselves (Katila and Ahuja, 2002), the optimal response to these additions on the part of a firm's competitors is less clear. In particular, a firm that finds itself rendered resource-inferior in this way has two options: It can either *catch up*, trying to close the resource gap, or it can *stay behind*, embracing inferiority and attempting to succeed despite its disadvantageous position.

In *catching up*, the firm adds the same resources as its competitor in an effort to recreate a state of resource equality between the firms. The advantages of this strategy are twofold: First, catching up extends the firm's resources and, thus, increases the number of resource combinations that can be identified (Baumann and Siggelkow, 2013; Katila and Ahuja, 2002). Second, it may allow the focal firm to learn from its competitor's pioneering efforts through knowledge spillovers (Katila and Chen, 2008). The strategy also has a disadvantage: Catching up results in the two firms competing head-to-head to identify valuable combinations within the same search space, which can lead to rapid exhaustion of technological opportunities (Podolny, Stuart, and Hannan, 1996; Swaminathan, 1996). In their study of the robotics industry, for example, Katila and Chen (2008) find that firms that simultaneously search the same space as their competitors tend to introduce less novel products. Pacheco-de-Almeida and Zemsky (2012) similarly illustrate how a resource-inferior firm's (AMD) efforts to catch up to its resource-superior competitor (Intel) actually reduced the performance of both firms.

An alternative strategy is to *stay behind*. In this approach, rather than attempting to recreate the original state of resource equality, the focal firm stays behind in a state of resource inferiority. This was the strategy implemented by Nintendo in its ongoing competition with Sony and Microsoft: As the latter developed superior resources in terms of graphics capability and branded content, Nintendo chose to develop games using older hardware and internally developed content. Research has found that firms with limited resources can be successful even when faced with resource-superior competitors. Garud and Karnoe (2003) find, for example, that Danish wind turbine makers succeed against resource-superior competitors by focusing on incremental improvements to existing technology. More generally, staying behind may encourage firms to reevaluate existing resources and recombine them in novel ways (Baker and Nelson, 2005; Katila and Shane, 2005). The disadvantage of the strategy is that the firm is constrained to a smaller set of resource combinations, all of which might also be found by the resource-superior firm. Thus, although the literature has identified ways in which resource-inferior firms may succeed, it is not clear when a firm might *prefer* to be resource-inferior – that is, if and when it would prefer to stay behind, even when catching up is feasible.

With this in mind, we ask, *how should a firm respond when its competitor adds new resources?* Two issues, in particular, complicate the decision faced by the focal firm. First, neither the impact of a competitor's resource extension on the performance of the focal firm nor the mechanism by which this impact occurs is clear. Thus, it is difficult to predict from existing theory when a resource-inferior firm will succeed in the search for innovation against its resource-superior competitor. Second, the conditions under which each strategy is preferable – or even if these strategies comprise the full repertoire of possible responses for the resource-inferior firm – are similarly unclear. Moreover, evidence suggests that both strategies may succeed (or fail). Both Nintendo and Sega stayed behind with respect to Microsoft in the game console market, but only Nintendo succeeded as a console manufacturer. Similarly, Apple's advances in smartphones prompted both Blackberry and Samsung to catch up, but Blackberry failed while Samsung thrived. The question of how to best respond to a competitor's resource addition is thus a very real one.

To address this question, we develop a formal set-theoretic model that depicts two firms competing to identify valuable resource combinations. A formal model has two distinct advantages with respect to our research question. First, formal modeling allows us to precisely specify the structure of interdependence between the competing firms, as well as the payoffs associated with certain actions (Chatain and Zemsky, 2007; Csaszar and Siggelkow, 2010). This facilitates the development of theory that is simultaneously precise and transparent (Adner *et al.*, 2009). Second, our approach allows us to explore concepts that are difficult to capture empirically, such as search space and attention. We thus contribute to a growing body of work that builds on earlier empirical and simulation-based studies (e.g., Katila, 2002; Levinthal, 1997) through formal models (Adner and Zemsky, 2006; Csaszar, 2012; Pacheco-de-Almeida and Zemsky, 2012).

This study contributes to the research on competition in search. While prior work has generally focused on how firms gain access to, defend, or benefit from positions of resource superiority (Capron and Chatain, 2008; Obloj and Capron, 2011; Polidoro and Toh, 2011), we take the perspective of the resource-inferior firm. Surprisingly, we find that a competitor's addition of resources can actually make a focal firm more innovative, even in the absence of spillovers between the firms. We illuminate the mechanism by which this occurs, as well as the conditions under which it holds. In particular, we demonstrate that a competitor's resource addition may cause it to overlook valuable combinations that it would have otherwise identified, and that these *oversights* allow the focal firm to identify exclusive resource combinations despite its resource inferiority. This finding has implications for research on the strategy of resource-constrained firms. Prior work finds that firms should differentiate their search efforts by adding unique resources (Greve and Taylor, 2000; Katila and Chen, 2008; Katila *et al.*, 2012; Wang and Shaver, forthcoming). We demonstrate that even when a firm's search space is entirely subsumed by its competitor's – that is, when it is classically undifferentiated – the inferior firm's *focused attention* can be a differentiating factor. Building on this insight, we explore a range of strategies available to the focal firm that may allow it to succeed against a superior competitor and identify the conditions under which each strategy is optimal. We thus contribute to a better understanding of competitive interaction in search-based competition.

BACKGROUND

Competition in search and differentiation

Firms compete in their search for innovation. Competition makes it difficult for firms to identify exclusive and valuable resource combinations by increasing the number of firms searching. Prior research has thus found that the innovativeness of competing firms (that is, the number of exclusively identified resource combinations) decreases to the degree of overlap of their search spaces (that is, the set of all possible resource combinations that can be formed from the focal firm's resources). Podolny, Hannan and Stuart (1996) find, for instance, that semiconductor manufacturers with overlapping search spaces are more likely to fail. Similarly, Katila and Chen (2008) find that robotics manufacturers who draw on the same patents as their competitors launch fewer and less innovative products. Katila, Chen, and Piezunka (2012) find that entrepreneurial firms that attempt to develop products for markets with well-established incumbents fail to do so. Given the bleak outlook that exists when firms search the same spaces as their competitors, firms look for ways to differentiate.

One action firms take to differentiate is adding idiosyncratic resources – that is, resources not held by their competitors. By adding resources, firms make more resource combinations possible and thus extend their search space; moreover, by adding idiosyncratic resources, they ensure that these new combinations are not accessible to their competitors. This increases their ability to exclusively identify valuable combinations. In their study of radio broadcasters, Greve and Taylor (2000) find that firms actively seek uncontested search space by experimenting with program content and formats not in use by local competitors. Katila and Chen (2008) illustrate the benefits of such a strategy by showing that firms in the global robotics industry that reduced search space overlap with competitors (measured in terms of patents cited) increased their innovativeness. Given the importance of idiosyncratic resources to firm innovativeness, a rich body of work has developed exploring how firms develop, defend and benefit from such resource positions (Capron and Chatain, 2008; Katila and Ahuja, 2002; Laursen, 2012; Obloj and Capron, 2011; Polidoro and Toh, 2011; Wang and Shaver, forthcoming).

But while prior research has established the advantages of adding idiosyncratic resources, it is less clear how a firm should respond to a *competitor's* addition. Although, in such a case, a focal firm might potentially add its own idiosyncratic resources, there may be scenarios in which the firm is unable to do so. The firm may, for example, lack sufficient capital or capability to develop its resources internally (Baker and Nelson, 2005; Katila and Ahuja, 2002), or its resources may simply be dwarfed by those of its competition (Katila *et al.*, 2012). Moreover, adding idiosyncratic resources of its own does not even address its inferiority with respect to the competitor's recently added resources. A firm in this situation is thus left with two choices: to catch up or to stay behind.

The unresolved dilemma between catching up and staying behind

One strategy is to catch up. While creating idiosyncratic resources (and thus reaching resource superiority) might not be feasible, firms can catch up by adding the same resources as their resource-superior competitors and, thus, eliminate the resource gap. Catching up to resource-superior competitors may be easier than adding idiosyncratic resources due to interorganizational learning and spillovers. A clear benefit of catching up is that the focal firm increases its resources. Even if these resources are not idiosyncratic, they allow for the creation of more resource combinations (i.e., an extension of the resource space). To the extent that the added resources are likely to generate valuable combinations (that is, to the extent that they exhibit complementarity), their addition also makes more *valuable* combinations available (Harrison *et al.*, 2001; Inkpen, 1996). Fang (2011) finds for instance that the innovativeness of Chinese manufacturing firms increases in the degree of complementarity between their resources and those they add through alliances with Western firms. Thus, catching up has the advantage of being a viable way to increase a firm's possible resource combinations. However, catching up also has disadvantages. Adding resources may be costly. Moreover, as firms catch up and eliminate the resource gap, their search space comes to perfectly overlap that of their competitor. This may result in a faster depletion of the valuable combinations contained therein, thus limiting the innovativeness of both firms. Katila and Chen (2008) find, for example, that simultaneous search of a shared search space causes both firms to release fewer and less innovative products. From this perspective, catching up is thus likely to incur the costs associated with adding resources without allowing the focal firm to identify additional exclusive resource combinations.

By staying behind, in contrast, firms remain resource-inferior. Staying behind leaves a focal firm with fewer resources and, thus, a smaller search space. Moreover, this search space is a subset of that of the resource-superior competitor. Thus, any resource combination that can be identified by the focal firm is at risk of identification by the competitor, and *exclusive* identification of valuable combinations may, therefore, be difficult. Despite these clear downsides, however, prior research suggests that firms can be extremely successful even when facing resource-superior competitors (Katila *et al.*, 2012; Pacheco-de-Almeida and Zemsky, 2012). Garud and Karnoe (2003) demonstrate, for example, how Danish wind turbine developers were able to succeed against their American counterparts by focusing on the incremental developments that their smaller resource bases allowed. Baker and Nelson (2005) similarly observe that resource-constrained firms were able to create valuable innovations by focusing on novel combinations of the "odds and ends" (2005: 330) they already had. These studies illustrate that firms can succeed despite being resource inferior. However, while firms may succeed despite being resource inferior, it isn't clear when they might *prefer* to remain in such a position.

As a result, the optimal response of a focal firm to a competitor's addition of resources is ambiguous. In particular, it is not clear when the firm should attempt to catch up by adding the same resources and when it may be better served by staying behind and allowing its competitor to pull ahead. Nor is it clear whether these are the only possible responses at the firm's disposal. Under what conditions might one firm be able to "preempt" the other (e.g., by credibly committing to a course of action)? Are there actions that it can take to differentiate its search efforts without adding unique resources? Despite a rich body of work on the benefits of adding idiosyncratic resources (Katila and Chen, 2008; Obloj and Capron, 2011; Podolny *et al.*, 1996), it is unclear how a firm that is unable to do so can succeed against a resource-superior competitor.

The decision to catch up or stay behind is complicated by two additional factors. First, the initial impact of a competitor's resource extension on the search process of the focal firm is unclear. On one hand, it may be that the focal firm is dominated by its competitor's undisputed resource-superiority and is simply "out-searched" by its competitor. On the other hand, it may be that the focal firm continues to thrive despite its inferiority (Katila *et al.*, 2012). In either case, the mechanism that links the search process of one firm to the resources of its competitors has not been thoroughly specified. If a focal firm is able to thrive despite its inferior position, for example, it is not clear how it does so. Thus, it is not possible to predict from existing theory how or when a competitor's resource extension will affect a focal firm.

Second, the factors that govern both the optimal response and the initial impact of a competitor's resource addition are not clear. Although the literature has identified several variables that affect firms' innovativeness in isolation, the roles and relationships between these variables under competition is not clear. In particular, the degree of complementarity between the resources being added and the munificence of the resulting search spaces (Fang, 2011; Klevorick *et al.*, 1995), the level of attention possessed by the firms (Burgelman, 2002; Laursen and Salter, 2006), and the cost of "catching up" to competitors (Katz and Shapiro, 1987) may all affect the optimal response of the focal firm. It is not clear, however, how the variables interact, which variables have primacy over others and through what mechanism they affect the innovativeness of the focal firm. This lack of clarity limits the predictive value of existing findings to real-world situations, which vary simultaneously across multiple dimensions.

To address these issues, we develop a set theoretic model to examine how firms compete in their search for innovation. At the core of our examination is the assumption that firms' attention is finite. The evaluation of any resource combinations in the search space requires attention (Criscuolo, Haas, and George, 2013; Gavetti and Levinthal, 2000; Knudsen and Levinthal, 2007), and organizations can "attend to only a limited number of things at a time" (March and Simon, 1958:151). As a result, there is a tradeoff between the size of a search space and the thoroughness with which it can be searched (Katila and Ahuja, 2002; Laursen and Salter, 2006). When firms are not able to evaluate to all the resource combinations within their search space, they are likely to fail to identify some valuable combinations (Criscuolo *et al.*, 2013; Hansen and Haas, 2001; Martin and Eisenhardt, 2010). In other words, *oversights* occur. We argue that such oversights provide the key to understanding how a firm's innovativeness depends on its competitors and how a firm should respond to competitors' actions.

THE MODEL

The resources possessed by firms consist of distinct elements that can be combined to create valuable resource combinations. Let $L_j = \{1,2\ldots n\}$ denote the set of resource elements possessed by Firm j. Firm j searches for valuable combinations within the search space Q, which is comprised of all pairwise combinations of the elements in L, such that Q = c(L,2). Consider a pharmaceutical firm, which may possess a set of resources in terms of its knowledge of molecules and metabolic pathways (L), which results in a search space (Q) consisting of the various pairings thereof. Let V be the combinations within Q that have value (e.g., those that lead to clinically promising drugs). Trivially, $V \subseteq Q \Rightarrow |V| \leq |Q|$.

Firms engage in a trial-and-error search to identify valuable combinations within their search space. Trial-and-error search is necessary because the specific elements of Q that reside in V (i.e., the identities of the combinations that are, in fact, valuable) are *a priori* unknown to the firm. We model every combination $q \in Q$ as having an equal probability $|V|/|Q|$ of being valuable (i.e., the probability that $q \in V$ is independent of the resource elements that comprise q). Firm j's search process thus consists of selecting a set of arbitrary combinations $X_j \subseteq Q$ and then simultaneously evaluating those combinations for membership in V. This method of search – "sampling opportunities from the pool of technological possibilities" (Levinthal and March, 1981:313) – corresponds to an "off-line" learning process (Gavetti and Levinthal, 2000), in which the selection of resource combinations precedes, and is independent of, their evaluation. For instance, in phenotypic drug discovery, pharmaceutical companies screen vast numbers of molecules against animal cells in a process that is largely trial and error in order to identify those chemicals that have a desirable therapeutic effect. The set of valuable combinations identified is denoted as Y_j, where $Y_j = X_j \cap V$.

Firms' search is constrained by its level of available attention. Let α_j denote the *attention* that Firm j is able to bring to bear in searching for combinations and model α_j denote the number of elements of Q that can be selected and evaluated in a given period: that is, $\alpha_j = |X_j|$. For example, prior to the emergence of high-throughput screening (HTS) techniques in the 1990s, pharmaceutical companies' ability to innovate was constrained by their inability to screen the hundreds of thousands of candidate molecules. HTS effectively increased companies' attention by increasing the number of molecules that could be screened at a time, leading (at least in theory) to the identification of more pharmacologically effective compounds (Thomke, Nimgade, and Pospisil, 1997). The attention of a firm is thus a key determinant of its innovativeness.

Insert Figure 1 and Table 1 about here

However, firms search for combinations that are not only valuable (i.e., members of V), but also exclusive (i.e., not identified by competitors). Consider the case of two firms, which we denote as the focal firm and its competitor. Assume that both firms hold the same set of resource elements (L) and, thus, search over the same search space (Q) for valuable combinations (V) by simultaneously evaluating independent subsets of X_j combinations. For simplicity, we assume that combinations identified by both firms have no value due to later competition between the firms.[1] Each firm thus seeks to maximize the number of valuable combinations that it identifies

[1] This assumption is relaxed in a model extension and is shown to have no qualitative effect on the results.

and its competitor doesn't: formally, $Y_j = (X_j \cap V \setminus X_i)$. Normalizing the value of each element $v \in V$ to one, the expected innovativeness of each firm is then the expected count of valuable elements identified times the expected share of those solutions not identified by the other firm.[2]

Proposition 1: The expected innovativeness of Firm j when $L_j = L_i$ is given by

$E[|Y_j|] = min(\alpha_j|V|/|Q_j|, |V|)\cdot((|Q_i|-\alpha_i)/|Q_i|)^+$.

The intuition underlying Proposition 1 is as follows. The probability that any combination evaluated by the focal firm is valuable is given by |V|/|Q|. The expected number of valuable combinations identified is, thus, the number of combinations evaluated (α_j) times the probability that each is valuable ($|V|/|Q_j|$), up to a maximum of |V|. As both firms search an overlapping search space, however, the probability that any given combination is identified only by the focal firm declines with its competitor's attention. The expected performance of the focal firm is, thus, $min(\alpha_j|V|/|Q_j|, |V|)$ if its competitor is unable to identify any combinations and zero if it is able to identify them all. Note that the ratio $|V|/|Q_j|$ determines the *munificence* of the search space – that is, the share of combinations likely to be valuable. Intuitively, innovativeness increases with the degree of munificence of the search space (Klevorick *et al.*, 1995).

As in all research, we make several assumptions. Some are fundamental to our modeling. First, firms are assumed to engage in trial-and-error search, with the expectation that valuable combinations are distributed uniformly throughout the search space. This could be relevant in contexts where particular resource elements are understood to be more valuable than others *in combination* or where particular areas of the search space are believed to contain more (or more

---

[2] For the sake of notational simplicity, we denote the original set of knowledge elements (L) as L_C when possessed by the competitor and L_F when possessed by the focal firm (and do the same for L'). Thus, $L_C = L_F$, but, at any time, the focal firm may hold L_F', and the competitor may hold L_C. The same applies for Q and Q'. Valuable combinations are particular to a given search space rather than to the firm and are denoted by V and V'.

valuable) combinations. This assumption thus best reflects settings where resource elements need to be combined and where the results of such a combination are not known *a priori*. Our results may, therefore, be particularly applicable to science-driven industries, such as pharmaceutical drug development and biotechnology. Moreover, relaxing this assumption does not necessarily weaken our results. While common knowledge of the location of valuable areas within a search space might prompt firms to follow one another into these spaces, it could also cause a competitor to focus more of its attention on the munificent area, increasing a focal firm's ability to identify combinations exclusively elsewhere.

Second, we model firms' innovativeness as the number of exclusively identified valuable combinations. In reality, firms' innovation performance is subject to a variety of factors well beyond the scope of our model, such as the ability to commercialize identified combinations. Our results thus pertain only to the very first steps of the innovation process: the acquisition of resources and the identification of valuable combinations thereof. Using a count of exclusive combinations as a performance function is a valid assumption in settings where identifying a large quantity and diversity of "promising" combinations is likely to lead to more holistic innovative success, such as in pharmaceutical drug discovery (Thomke *et al.*, 1997). Moreover, although our focus on resource combination discovery as a function of search space and attention limits comparability to existing work, which has largely focused on the *outputs of* rather than the *inputs to* search, we consider it to be one of the strengths of our approach.

Other assumptions are less fundamental to the theory and serve to simplify the analysis. For example, we consider only pairwise combinations of resource elements. In reality, valuable innovations are likely to draw on a variety of resource elements (Wuchty, Jones, and Uzzi, 2007) (Kotha, George, and Srikanth, 2013). Relaxing this assumption, however, would only strengthen our results by exacerbating the effect of additional resource elements on the magnitude of the search space and thus increasing the impact of oversights. Similarly, we initially assume that only *exclusively* identified combinations contribute to innovativeness – that is, those combinations identified by both firms have no value. We explore the impact of this assumption in a model extension. Finally, we assume every exclusively identified combination to have value. Although, in reality, commercialization often poses a substantial challenge to firms, our assumption is a good one given the variety of ways in which value can be derived from discoveries, ranging from licensing (Gambardella and McGahan, 2010) to internal development (Fosfuri, 2006). Moreover, the assumption that every exclusive valuable combination increases a firm's performance may be relaxed to state that each has value *in expectation* without any loss of generality. In other words, not every discovery may be valuable, but each has the potential to be.

Impact on the competitor of becoming resource superior

We first consider the case in which a competitor is presented with an opportunity to extend its resources. In searching for valuable combinations, firms may attempt to differentiate themselves by adding new resource elements (Ahuja and Katila, 2004; Katila *et al.*, 2012). For example, a pharmaceutical company may have the opportunity to extend its library of molecules through a licensing agreement or an acquisition. We first determine the impact of such a move by a competitor on its own expected innovativeness and the conditions under which the competitor will undertake this move. We then determine the impact of the competitor's move on the focal firm and the associated best response.

Assume that the competitor extends its resource set L_C by K elements, resulting in a new resource set L_C' and a corresponding search space Q_C', such that $Qc \subset Qc'$ for $K \geq 1$. Because the focal firm's search is limited to the smaller $Q_F = Q_C$, this gives the competitor two distinct search spaces: the original search space (Q_C), in which every element identified is subject to potential competition from the focal firm, and a new, uncontested space ($Q_C' \setminus Q_F$). Given its larger search space, we refer to the competitor as being (newly) resource-superior. See Figure 2:

Insert Figure 2 about here

The competitor's expected performance following the extension $E[|Y_C'|]$ is a function of the relative sizes of the original and new search spaces ($Q_F = Q_C$, Q_C'), the munificence of each search space ($|V|/|Q_C|$ and $|V'-V|/|Q_C'- Q_C|$) and the attention of each firm (α_C, α_F):

$$E[|Y_C'|] = \mathit{min}(\alpha_C|V|/|Q_C|, |V|)\cdot((|Q_F|-\alpha_F)/|Q_F|)^+\cdot(|Q_C|/|Q_C'|) + \mathit{min}(\alpha_C(|V'-V|)/(|Q_C'- Q_C|), |V'-V|)\cdot((|Q_C'-Q_F|)/|Q_C'|) \quad [1]$$

The move from $Q_C \rightarrow Q_C'$ will increase the competitor's innovativeness if the expected number of exclusively identified combinations increases (i.e., if $E[|Y_C'|] > E[|Y_C|]$). This condition readily reduces to the following form:

$$E[|Y_C'|] > E[|Y_C|] \text{ } \mathit{iff} \text{ } (|V|/|Q_C|)((|Q_F|-\alpha_F)/|Q_F|)^+ \leq |V'|/|Q_C'| \quad [2]$$

In other words, the competitor's innovativeness will increase as long as the munificence of the expanded search space ($|V'|/|Q_C'|$) is greater than the munificence of the original search space ($|V|/|Q_C|$) times the probability that any combination is identified exclusively ($(|Q_F|-\alpha_F)/|Q_F|$). Note that this implies that the competitor's innovativeness will increase even if the munificence of the expanded search space is strictly lower than that of the original search space. In the presence of competition, it may thus be optimal to add new resource elements, even when a firm is unable to fully utilize its current set and even when the additional elements have a lower probability of creating valuable combinations than those in the current set.

Moreover, note that the extension of the competitor's search space changes the identity of the combinations it evaluates (and those valuable combinations it identifies). With a larger search space, the competitor chooses to evaluate the newly available combinations and may, thus, be less likely to evaluate the previously available combinations. In other words, an *attentional shift* takes place. For example, when the US Supreme Court nullified Myriad Genetics' patents on BRCA1 and BRCA2 (two genes associated with breast cancer diagnosis and treatment), the scientific knowledge associated with these genes became available to every firm engaged in cancer diagnostics and treatment. As these other firms focused their (sometimes limited) attention on understanding and implementing BRCA1- and BRCA2-related tests, they did so, at least in part, at the expense of the potentially promising genes they had previously been exploring. Attentional shifts thus lead to *oversights*, defined as combinations that are not identified following a resource extension, but that might have been in its absence.

Oversights are strategically relevant to the competitor in that they decrease the realized value of a resource extension. A resource extension that generates an additional $V' \setminus V$ valuable combinations may not increase the competitor's innovativeness by $|V'| - |V|$, simply because not all combinations will be evaluated (for $\alpha_C < Q_C'$). At the same time, although oversights strictly decrease the performance of the competitor, they represent a valuable opportunity for the focal firm, as the following analysis demonstrates.

Impact on the focal firm of becoming resource inferior

As the competitor extends its search space, the focal firm is left in a resource-inferior state. To determine the optimal response of the focal firm, we first examine the impact of the competitor's extension on the focal firm's innovativeness. To do so, we apply Proposition 1 to calculate the difference between the focal firm's expected innovativeness $E[|Y_F|]$ before and after the competitor's extension (where the competitor's search space is Q_C and Q_C', respectively):

$$\Delta E[Y_F] = min(\alpha_F|V|/|Q_F|, |V|)\cdot(((|Q_C'|-\alpha_C)/ |Q_C'|)^+ - ((|Q_C|-\alpha_C)/ |Q_C|)^+) \qquad [3]$$

Surprisingly, this equation is strictly positive for $\alpha_C < |Q_C'|$ and is zero otherwise. In other words, if a competitor lacks the attention sufficient to evaluate all of the combinations in its extended search space (Q_C'), its extension strictly improves the performance of the focal firm. The rationale is that the competitor's extension shifts its attention and creates oversights in the shared search space (Q_C). As the resource-superior competitor overlooks valuable combinations contained therein, the resource-inferior focal firm is more likely to identify them exclusively. The focal firm's innovativeness thus increases due to the competitor's extension.

Note that the competitor's oversights are the mechanism by which this increase occurs and that the existence of oversights is dependent on the relationship between the attention levels of the two firms (α_C, α_F) and the sizes of their respective search spaces (Q_C', Q_F). In particular, when $\alpha_C \geq |Q_C'|$, the competitor is able to evaluate all possible resource combinations, such that $X_C = Q_C'$ and $V' \subseteq X_C$. Consequently, the competitor does not overlook any resource combinations in the shared space, and the extension does not benefit the focal firm. For $\alpha_C < |Q_C'|$, however, there exists the probability that a valuable combination in V will go unidentified, thus leading to greater oversights. Similarly, oversights increase in both the size of the resource extension (because a larger extension prompts a larger attentional shift on the part of the competitor) and the munificence of the shared search area (because a higher ratio of valuable to non-valuable combinations implies that a given attentional shift leaves a greater number of valuable combinations available for exclusive identification by the focal firm). In other words, the focal firm benefits as long as the competitor's resource extension is large enough to tax its attention and as long as there are valuable combinations to be discovered in the first place. These results are summarized in Proposition 2, as follows:

Proposition 2: Expected oversights E[O] for K additional resource elements.

2.A: Expected oversights: For $\alpha_C \geq Q_C'$, $E[|O|] = 0$. *For* $\alpha_F \geq Q_C$, $E[|O|] = 0$. *For* $\alpha_F < Q_C$ and $\alpha_C < Q_C$, $E[|O|] = \min(|V|,(\alpha_C \cdot |V|)/|Q_C|) \cdot (|Q_C| - \alpha_F)/|Q_F| - \min(|V|, (\alpha_C \cdot |V|)/|Q_C|) \cdot (Q_C/Q_C') \cdot (|Q_C| - \alpha_F)/|Q_F|$.

2.B: Dynamics: Expected oversights $E[|O|]$ *and the ability of the focal firm to benefit from its competitor's resource extension decline with the attention of the competitor* ($\delta E[|O_C|]/\delta\alpha_C < 0$) *and increase with the size of the resource extension* ($\delta E[|O_C|]/\delta K > 0$) *and the munificence of the shared search space* ($\delta E[|O_C|]/\delta(|V|/|Q_C|) > 0$).

Note that it may be possible for the focal firm to benefit even more from the competitor's resource extension than the competitor itself. In fact, as long as the munificence of the extended search space is lower than that of the original and the competitor has insufficient attention to fully search the extended area, the decrease in competition within the shared search space may increase the focal firm's innovativeness more than the addition of the uncontested search space does the competitor's – even when the competitor does not incur any cost to add the additional resource elements. This has substantial strategic implications, as it suggests a counterintuitive means for firms to increase their innovativeness without investing in resources.

Focal firm's response to resource inferiority

We now turn to our primary research question: What is the appropriate response on the part of the now resource-inferior focal firm? Here, neither prior research nor the preceding analysis gives clear insight. Although the focal firm may have gained from its competitor's action – it has gotten ahead by falling behind – the best response to its newfound resource-inferiority is unclear. Should the focal firm *catch up* or *stay behind*?

Consider this choice in the context of two firms in the market for solar photovoltaic cells: Suntech and SunPower. Both firms have substantial expertise in silicon cell technology, but other materials exist. Now, imagine that one of the two firms (e.g., Suntech) adds resources by building a knowledge base around one such alternative material: gallium arsenide. How should the focal firm (e.g., SunPower) respond? It could (1) catch up and extend its resources by building a corresponding knowledge base around the use of gallium arsenide. Doing so would eliminate the resource gap and recreate the original state of resource equality. Alternatively, SunPower could (2) stay behind and simply enjoy a potential increase in its own innovativeness stemming from Suntech's investment, without expanding its own resource set. In the following, we examine whether and when *catching up* or *staying behind* is the optimal action.

Without loss of generality, we assume that there are two distinct sets of resource elements under consideration: the original shared elements (L) and an expanded set, currently possessed only by the competitor (L'), so that $L \subseteq L'$. Each of these sets has a corresponding search space (Q and Q'). The focal firm can choose to either stay behind ($L_F = L \Rightarrow Q_F$) or catch up ($L_F = L' \Rightarrow Q_F'$) to the competitor, and the conditions under which each move is optimal may be determined by comparing the focal firm's expected innovativeness following each action.

To understand which strategy is optimal, we need to explore the complex interplay between the attention of each firm (α_F, α_C) and the munificence of each search space (V/Q, V'/Q'). Consider, first, the case of $\alpha_C < Q_C'$ (the top row of Table 2). When $\alpha_F < Q_F$, the focal firm possesses *insufficient attention* to evaluate all of the combinations in its current search space (left hand side of Table 2). Catching up ($Q_F \rightarrow Q_F'$) is thus optimal whenever the munificence of the extended search space is greater than that of the current search space. In contrast, when $\alpha_F > Q_F'$, the focal firm possesses *excess attention* (right hand side of Table 2). Here, catching up is universally optimal, since it potentially allows for the identification of additional valuable combinations ($V' \setminus V$) without generating oversights by the focal firm (since $\alpha_F \geq Q_F' \Rightarrow X_F = V'$). In the intermediate region ($Q_F < \alpha_F < Q_F'$), the firm might either catch up or stay behind. If the munificence in the extended space is higher ($V'/Q_F' > V/Q_F$), catching up is optimal, but if the munificence is lower ($V'/Q_F' < V/Q_F$), the firm is torn between the need to put its excess attention to use and the fact that, in doing so, it puts itself in a less fertile search space. When $\alpha_C > Q_C'$ (the bottom row of Table 2 and the bottom two graphs in Figure 3), catching up and staying behind are equivalent – and low-performing. This result is driven by the importance of oversights: When the competitor possesses high attention relative to its current search space, it is likely to be able to evaluate all of the combinations therein, thus preventing the focal firm from identifying exclusive combinations of its own.

Insert Table 2 about here

Moreover, note that in each region of Table 2, the mechanism that drives the optimal response differs. When $\alpha_C > Q_C'$, the optimal strategy is dictated by the competitor's excess attention and the subsequent competition it generates for valuable combinations; when $\alpha_F < Q_F$, it is the munificence of the search space that determines optimal response; and when $\alpha_F > Q_F'$, it is the focal firm's attention that plays the governing role.

Insert Figures 3 and 4 about here

What if we relax the assumption that a combination evaluated by both firms ($q \in X_F \cap X_C$) has zero value? If combinations retain their full value, the decision facing the focal firm then approximates that of a single firm searching in isolation, such that $E[Y_F] = min(\alpha_F|V|/|Q|, |V|)$. As Figure 4 illustrates, however, the optimal decision is exactly the same: For $\alpha_F < |Q_F|$, the focal firm will catch up if $|V'|/|Q_F'| > |V|/|Q_F|$; for $|Q_F| < \alpha_F < |Q_F'|$, the focal firm will catch up if $\alpha_F|V'|/|Q_F'| > |V|$; and for $\alpha_F > |Q_F'|$, the focal firm will always catch up. In other words, the degree to which the value of combinations is derived from their exclusive use impacts the performance of each firm, but *not* their optimal strategy.

Expanding the repertoire of potential responses

Thus far, we have focused exclusively on two strategies: *catching up* by adding resources and regaining resource equality and *staying behind* by instead accepting a position of resource inferiority. We now extend the range of potential responses by developing a more extreme version of each. Instead of merely catching up, for example, the focal firm could strive to *leap ahead* and achieve resource superiority of its own by adding, not only the competitor's resources, but additional resources as well. In the preceding example, Suntech (the competitor) extended its search base beyond silicon technology by developing expertise in gallium arsenide solar cells. To leap ahead, SunPower might respond by not only catching up with its own investment in gallium arsenide, but also adding additional materials knowledge (e.g., expertise in cadmium telluride). In contrast, the focal firm might not only stay behind, but actually attempt to *fall further behind* by actively subsidizing its competitor's further resource extension. Here, SunPower might encourage Suntech to develop cadmium telluride technology. This strategy is, in fact, well-documented empirically: IBM regularly publishes patentable technical information to make it available to competitors, for example, and any instance of a company selling one of its divisions to a competitor (e.g., Google selling Motorola to Lenovo) is, in some sense, a subsidization of the competitor's growth in that area.[3]

To examine the focal firm's optimal choice of strategy with all four actions possible – *leaping ahead*, *catching up*, *staying behind*, and *falling further behind* – we expand the preceding analysis. To do so, we assume that there are three distinct sets of resource elements under consideration: the original shared elements (L); an expanded set, currently possessed only by the competitor (L'); and a still larger set (L"), such that $L \subseteq L' \subseteq L''$ and $Q \subseteq Q' \subseteq Q''$. The focal firm's possible actions are, thus, to *stay behind* the competitor ($L_F = L$), to *catch up* to the competitor ($L_F = L'$), to *leap ahead* of the competitor and strive for resource superiority ($L_F = L''$), or to *fall further behind* the competitor by subsidizing the competitor's further resource growth ($L_C = L''$). The results of this analysis are presented in Table 3.

Insert Table 3 about here

It becomes immediately apparent that the strategies that maximize the innovativeness of the focal firm tend to be those that minimize the relative overlap between the competing firms' resource sets – in other words, those that maximize differentiation. As in the preceding analysis, when the competitor possesses very high attention (now $\alpha_C > Q_C''$), the only viable move for the focal firm is to attempt to gain superior resources for itself (bottom row of Table 3). This is

[3] Although the free release of knowledge has been thoroughly examined in management literature, prior work has generally viewed the strategy in terms of spillovers (Harhoff, Henkel, and Von Hippel, 2003), network externalities and standard-setting (Harhoff, 1996; Lim, 2009) or reputational benefits (Allen, 1983). In contrast, our model explicitly excludes these factors, instead illustrating the conditions under which it is optimal to not only disclose proprietary knowledge without direct compensation (see Pacheco-de-Almeida and Zemsky, 2012), but to actually relinquish access to that knowledge, as well.

driven by the fact that, no matter how large the competitor's search space, it possesses enough attention to leave no oversights. When the competitor possesses only moderately high attention ($Q_C' < \alpha_C < Q_C''$), leaping ahead and falling further behind both become viable. Here, the choice between the two is a function of both the focal firm's attention (i.e., its ability to utilize a larger search space) and the relative munificence of each search space.

Moreover, catching up becomes a viable move only when the attention of both firms is low relative to the size of the search space, and the range for which catching up may be optimal decreases with the attention of each firm. When either firm has excess attention, it becomes optimal to differentiate, which the focal firm can accomplish by either leaping ahead or falling further behind.[4] Moreover, equality becomes the preferred move if and only if there is an uneven distribution of valuable solutions in the search space and if the munificence of the "first move" is greater than that of any others; that is, $|V'-V|/|Q'-Q| > |V|/|Q|, |V''-V'|/|Q''-Q'|$. In other words, mimicking a competitor's move is optimal only when the move being copied is a foray into the most fertile area of the search space. This is an important result because, although we find catching up to be optimal only under a narrow set of conditions, it is observed quite frequently in reality. Although this may be due, in part, to simple imitation, it may also reflect uncertainty regarding the quality of different areas in the search space. In this sense, catching up is likely to occur and may be beneficial when a firm believes its competitors to have superior information regarding the location of valuable combinations within the search space.

---

[4] Although staying behind may be preferable to catching up when only two responses are available, in the case of four strategies, staying behind is strictly dominated by falling further behind. The intuition is that the focal firm searches the same search space in both cases (Q_F), but that, in the latter, the competition for combinations is lower (since the probability that the competitor identifies any combination in Q_F is $(Q_C'' - \alpha_C)/Q_C''$ rather than $(Q_C' - \alpha_C)/Q_C'$, where $Q_C'' > Q_C'$). This holds regardless of search space munificence or the attention of the focal firm.

Overall, these results reaffirm a core finding in the literature on competition in search: Differentiation improves performance (Katila and Chen, 2008; Katila *et al.*, 2012). At the same time, we show that firms can effectively differentiate themselves even if their search spaces are strict subsets of competitors' search spaces. In particular, we show how resource-inferior firms benefit from the oversights that resource-superior firms encounter as their attention shifts.

Considering moves in equilibrium

In the preceding analysis, we model a move (by the competitor) and a response (by the focal firm). At the same time, research has found that firms explicitly consider the likely reactions of their competitors when formulating strategy and that, under certain circumstances, they may decline to enter "races" they don't expect to win (Chen and MacMillan, 1992). The preceding formulation thus reflects a setting in which two firms' moves are not immediately visible to one another or in which the competitor is unlikely to respond, due to either resource constraints or a limited dependence on the market associated with the search space. We thus stand to gain additional insight and generalizability by relaxing this assumption and allowing the firms to anticipate one another's actions.

To do so, we construct a single-stage game of perfect information, in which the actions of each firm explicitly reflect the responses of its competitors. We introduce three additional assumptions. First, valuable combinations are uniformly distributed throughout the entire search space; thus, $|V|/|Q| = |V'|/|Q'|$ for all V and Q. Let $D = |V|/|Q|$ be the expected value of any individual combination in the search space. Second, we explicitly represent the cost to add a set of resource elements with the function w(Q), which increases with the size of the search space obtained from the elements being added. In particular, let the cost of adding K elements be

$W \cdot c(K,2)^2$, denoted as $W|Q|^2$, where W is a constant.[5] Finally, we assume the search space of one firm to be smaller than that of the other (i.e., $Q_F \subseteq Q_C$). Note that this third assumption introduces no loss of generality, since the identities of the firms can simply be re-indexed to allow either to be resource superior.

With these assumptions in place, we then determine the Nash equilibrium of the interaction. Consistent with the prior analysis, the innovativeness of each firm is as follows:

$$E[Y_C] = \mathit{min}(\alpha_C, |Q_C|)\cdot(|Q_F|/|Q_C|)\cdot D\cdot((|Q_F|-\alpha_F)/|Q_F|)^+ + \mathit{min}(\alpha_C, |Q_C|)\cdot((|Q_C-Q_F|)/ |Q_C|) - W|Q_C|^2 \quad [4]$$

$$E[Y_F] = \mathit{min}(\alpha_F, |Q_F|)\cdot D\cdot((|Q_F|-\alpha_F)/|Q_F|)^+ - W|Q_F|^2 \quad [5]$$

In words, the innovativeness of the (resource-superior) competitor consists of the expected number of valuable combinations exclusively identified within the search space shared with the (resource-inferior) focal firm, plus the expected number of valuable combinations identified in the uncontested area, less the cost of adding L_C elements. The focal firm's innovativeness consists, more simply, of the expected number of valuable and exclusive combinations in the shared search space, less the cost of adding L_F elements. Solving equations [5] and [6] simultaneously for $Q_F^*(Q_C)$ and $Q_C^*(Q_F)$, we obtain three distinct equilibria:

$$|Q_F^*| = 0, \qquad |Q_C^*| = D/2W \quad [6]$$

$$|Q_F^*| = \alpha_F \qquad |Q_C^*| = (\alpha_C\alpha_F D/2W)^{1/3} \quad [7]$$

$$|Q_F^*| = D/2W^*((|Q_C|-\alpha_C)/ |Q_C|) \qquad |Q_C^*| = (\alpha_C D\hat{}2\pm(\alpha_C^2D^4-16\alpha_C^2c^2D^2))/8W^2 \quad [8]$$

---

[5] To be precise, we assume that there is a monotonic increasing function that maps E[Y] into units of value (e.g., dollars) and that the constant W is measured in those units. The choice of a squared relationship between Q and W is arbitrary and can be substituted for any superlinear function (thus ensuring a closed, non-corner solution).

But which equilibrium will occur, and what does this imply for firm strategy? Two dynamics come into play. First, the resource-inferior focal firm (whose search space is a weak subset of its competitor's) realizes a benefit from adding resource elements only up to the point at which its search space equals its level of attention. Beyond this, the focal firm begins to accrue oversights in terms of resource combinations it is not able to evaluate due to its binding attention constraint. In contrast, the benefit to the resource-superior firm of adding resource elements increases monotonically. In particular, with each incremental addition to the resource-superior competitor's search space, the percentage of the space that is shared with the focal firm goes down, and the expected number of unique and valuable combinations identified asymptotically approaches the case in which the firm is operating in isolation ($E[|Y_j|] = min(\alpha_j|V|/|Q|, |V|)$). At the same time, the cost of adding new elements increases nonlinearly for both firms. Thus, the resource-inferior focal firm will set its search space at or below its attention constraint, while the resource-superior firm will set its search space at the intersection of its own marginal cost and benefit curves. The three equilibria thus represent the three outcomes that can occur as a function of the firms' costs (W_F, W_C) and attention (α_F, α_C).

The first equilibrium represents a form of preemption. Here, the competitor sets its search space such that $|Q_C| = D/2W_C < \alpha_C$, prompting the focal firm to minimize costs by forgoing competition and setting $|Q_F| = 0$. This might occur for three reasons. If, for example, the focal firm faces substantially higher costs (e.g., $W_C < W_F$), such that the focal firm's Q_F^* is relatively small, the competitor will set $|Q_C| = D/2W_C$ and prompt the focal firm to set $|Q_F| = 0$. Similarly, if the competitor has substantially higher attention than the focal firm (e.g., $\alpha_C > \alpha_F$), it may be able to set $|Q_C| = D/2W$ such that $\alpha_F < D/2W < \alpha_C$, thus prompting the focal firm to set $|Q_F| = 0$. Finally, though the two firms are equal in terms of their attention ($\alpha_C = \alpha_F$) and their cost of adding elements ($W_C = W_F$), one firm is able to credibly commit to setting $|Q| = D/2W < \alpha$, while its counterpart's best response would be to forgo competition.

In the second two equilibria, both firms maintain non-zero search spaces. In particular, the resource-inferior firm sets $|Q_F| = \alpha_F$ (if its cost (W_F) is low) and $|Q_F| < \alpha_F$ (if its cost (W_F) is high), and the resource-superior firm sets $|Q_C| > \alpha_C$. In this case, the focal firm pursues an exhaustive search of a smaller search space, and the competitor pursues a less thorough search of a larger space. In contrast to the previous scenario, in which the competitor's innovativeness was strictly greater than the focal firm's (zero) innovativeness, the relative performances here are indeterminate. It may be, for example, that low costs ($W_C < W_F$) and higher attention ($\alpha_C > \alpha_F$) allow the competitor to achieve higher innovativeness by adding a large number of resource elements, while the focal firm's higher costs prompt it to try to "do more with less". On the other hand, if the focal firm is able to credibly commit to setting $|Q_F| = \alpha_F$, the competitor will be "forced" to either pursue resource superiority ($|Q_C| > \alpha_C$) or forgo entry ($|Q_C| = 0$), regardless of the relative costs or attention constraints.

When will firms achieve resource equality? In this model, never. Note that if one firm's search space is a weak subset of the other's (e.g., $Q_F \subseteq Q_C$), the resource-inferior firm has no incentive to extend its search space beyond α_F. Thus, $|Q_C| = |Q_F|$ is feasible only when $|Q_C| = |Q_F| > \alpha_C, \alpha_F$. This equilibrium is unstable, however, as each firm has an incentive to reduce costs ($W \cdot |Q_j|^2$) by reducing its own search space to $|Qj| = \alpha_j$, which forces the other firm to either forgo entry ($\alpha_i = 0$) or pursue a broader search strategy ($|Q_i| > \alpha_i$). Differentiation, in other words, is the driver of firm innovativeness under competition.

DISCUSSION

This paper contributes to the literature on competition in search. Research has shown that firms can differentiate by adding idiosyncratic resources (Ahuja and Katila, 2004; Katila and Ahuja, 2002); however, it has not addressed the question of how firms unable to do so can succeed in their search for innovation. This question becomes particularly relevant when a firm's competitors render the firm resource-inferior. In this paper, we take the perspective of such resource-inferior firms, examining their innovativeness and their potential strategic responses.

Implications for research on search-based competition

We contribute to the literature on search by examining the innovativeness of firms in search-based competition. One theoretical insight of our paper is that firms can *get ahead by falling behind*. The addition of resources by a competitor can increase the innovativeness of a focal firm, despite rendering it resource-inferior. Prior work studying the impact of resource additions has focused on the consequences for the firm adding the resources (Ahuja and Katila, 2004; Katila and Ahuja, 2002), but has neglected how such additions impact other firms. Research on competition outside the realm of search, such as research on competitive moves, suggests that competitors' moves generally exhibit negative effects on a focal firm (Chen and Miller, 1994; Derfus *et al.*, 2008). We illustrate that, in search-based competition, a competitor adding resources can have a positive effect on the focal firm. In some cases, the increase in innovativeness experienced by the focal firm may be even greater than that experienced by its competitor. This suggests both a mechanism by which firms can succeed without adding resources of their own, and implies that under some conditions it is preferable to compete against resource-superior than resource-equal firms. In other words, falling behind may not just allow a focal firm to get ahead; it may allow it to actually win the race.

A second theoretical insight is the critical role of oversights in search-based competition. Such oversights have been discussed in the literature on attention, which has shown how firms may overlook great opportunities within their search spaces (Burgelman, 2002). However, extant work has neglected the consequences of such oversights for other firms. We show that firms can benefit from their competitors' oversights. Specifically, we illustrate that adding resources often generates oversights, thus creating opportunities for resource-inferior firms. Prior studies have found that inferior firms can benefit from superior firms via learning and spillovers (Katila and Chen, 2008; Pacheco-de-Almeida and Zemsky, 2012). We suggest that oversights are a complementary mechanism. For example, for Apple to benefit from Xerox's inventions (e.g., graphical user interfaces, the mouse), it was necessary for Xerox to overlook how its discoveries could be combined in valuable ways. While oversights represent missed opportunities from the competitor's perspective, they are just the opposite from the focal firm's perspective.

We also illuminate the factors that govern the impact of a competitor's resource addition on a focal firm. Prior literature has identified several variables that govern firms' innovativeness in isolation and in competition. The number of valuable combinations made possible by a resource extension (i.e., the size and complementarity of the resource extension) increase firm innovativeness by making more valuable combinations available for identification (Fang, 2011; Klevorick *et al.*, 1995). Similarly, the attention of a focal firm and its ability to identify valuable combinations within its resources increase innovativeness by making the firm more likely to see the combinations available to it (Hansen and Haas, 2001; Katila and Ahuja, 2002). Third, the degree to which firms compete head-to-head for exclusive access to opportunities decreases innovativeness by reducing the likelihood that the firms will be able to benefit from the valuable combinations they identify (Derfus *et al.*, 2008). However, while the individual impacts of these variables are clear, their joint impact is not. We find that the impact of a competitor's resource extension on a focal firm is determined, not by the variables individually, but by their combination. In particular, the ratio of the competitor's attention to the size of its search spaces (old and new) governs the impact of the extension. When the competitor has *excess attention* – that is, when the number of combinations in the extended search space is smaller than the number that the competitor can evaluate – its move has no impact on the focal firm. When it has *insufficient attention*, however, its ability to evaluate all of the combinations within its search space is taxed by its extension, resulting in oversights that can be exploited by the focal firm. The ratio of valuable combinations to total combinations in the focal firm's search space (its *munificence*) and the focal firm's own *excess attention* moderate this impact: When munificence is high and the focal firm has a high degree of excess attention, the marginal impact of a competitor's extension is greater. The degree to which firms compete head-to-head for access to valuable opportunities decreases the performance of the focal firm, as expected, but, surprisingly, does not affect the optimal response of the focal firm to its competitor's action. These findings yield better insight into the impact of competitor's actions on firm innovativeness in real world scenarios, which vary simultaneously along multiple dimensions.

Strategic responses to resource inferiority

We examine how firms should respond when their competitors become resource-superior. Our central and counterintuitive insight is that, in many cases, it is optimal for a firm to stay behind a competitor – or even to fall further behind – rather than to try to catch up or leap ahead. Where prior work has identified adding resources as a key means by which to increase innovativeness (see Laursen, 2012), we show that, when confronted with a resource-superior competitor, the best way for a firm to foster innovation is often to forego adding resources. In particular, we show that resource-inferior firms often have little to gain from adding additional resources and extending their search space, particularly when their own attention is constrained.

Our second insight is that resource-inferior firms might have a richer strategic repertoire than has been previously analyzed. Prior literature has, in general, considered three strategies available to resource-inferior firms: differentiating by adding idiosyncratic resources (Ahuja and Katila, 2004; Greve and Taylor, 2000), catching up by adding the same resources as the competitor (Katila and Chen, 2008; Pacheco-de-Almeida and Zemsky, 2012), and staying behind by focusing on current resources (Baker and Nelson, 2005; Garud and Karnøe, 2003). We add to this list by introducing a fourth strategy, termed *falling further behind*, in which a focal firm actively facilitates a competitor's further resource growth. While, at first, this strategy seems counterintuitive – prior research suggests that firms should hinder their competitors' access to resources (Capron and Chatain, 2008) – we show that fostering competitors' access to resources can be a very effective way for resource-inferior firms to succeed when confronted with resource-superior firms.

We also illuminate the mechanism and logic underlying this strategy. We show that falling further behind benefits resource-inferior firms because it diffuses competitors' attention over a larger search space and, thus, reduces competition in the shared space. The response is akin to the way in which lizards shed their tails to save their lives. The detached tail distracts the predator, which focuses on the tail while the lizard escapes in another direction. This finding thus suggests a novel reason that firms might help competitors gain access to resources. Prior work has identified two motivations for helping competitors develop resources: fostering the formation of standards (Alexy, George, and Salter, 2013; Harhoff, 1996; Henkel, 2006) and promoting complementary innovation (Cassiman and Veugelers, 2002). For example, Tesla shared its patents with other automakers in order to attract more firms into the electric vehicle industry, thus helping establish the viability of the industry and encouraging those firms to adopt Tesla's technology. Fostering competitor's resources to create standards and spur complementary innovation thus relies on a logic of *attraction*. In contrast, we propose that firms may foster their competitor's resource development using a logic of *distraction*, in which competitors' attention is guided away from the search space on which the focal firm is focused. In fact, the managers of the firms interviewed in Katila *et al*. (2012) explained that some of their moves had the explicit purpose of "diverting the attention" of their larger and better-endowed competitors. Our study illustrates both the efficacy of and mechanism underlying such a strategy.

A fourth insight of our analysis is that attention can be a means for firms to differentiate themselves from their competitors. In particular, resource-inferior firms can succeed in search by focusing their attention on a smaller search space and capitalizing on valuable resource combinations that their competitors have overlooked. In this way, the difference between the focused attention of the focal firm and the *shifted* attention of its competitors is a source of differentiation within the search process, even without the spatial (Katila *et al.*, 2012) or temporal (Katila and Chen, 2008) differentiations identified in existing literature. Empirical examples of this strategy abound. In the technology-focused ecosystem of Silicon Valley, for example, entrepreneurs such as John Arrillaga (real estate) and Tristan Walker (consumer packaged goods) have succeeded by focusing their attention on domains overlooked by their technology-oriented competitors. Anecdotal evidence can also be found in the so-called "Yale

Tale", in which an undergraduate participant of a Yale expedition seeking early hominid remains in Pakistan insisted on looking for specimens in places the other members of the expedition had dismissed as useless. The Sivapithecus skull he discovered is considered one of the most important finds from the region. In each of these cases, the focal actors succeed, not *despite* the greater resources of their competitors, but precisely *because* of them.

A new model of search-based competition

We propose that set theoretic models can be used to examine search-based competition. We illustrate and benefit from such an approach's ability to precisely specify the interdependence between the search efforts of competing firms. Moreover, a set theoretic approach allows the precise capture of the otherwise difficult concepts of search space and attention, both of which are best understood as the antecedents of search and innovation. Such a focus on the antecedents of search is particularly valuable, since archival methods, which typically employ measures such as patents and product introductions, tend to focus on the outcomes of search rather than its antecedents. We therefore suggest that set theoretic models represent a promising approach for building precise and transparent theory regarding both the antecedents of search as well as the role competition in search.

Conclusion

This analysis contributes to the literature on search-based competition (Katila and Chen, 2008; Katila *et al.*, 2012). Existing work has highlighted the central roles that both resource addition (Ahuja and Katila, 2004; Jeppesen and Lakhani, 2010) and attention (Gavetti and Levinthal, 2000; Knudsen and Levinthal, 2007) play in a firm's *own* search process, but has not explored their impact on either the innovativeness of the firm's competitors or the appropriate response of these competitors to their newfound resource inferiority. By using a formal mathematical model to depict two firms competing to identify valuable combinations within a shared search space, we thus contribute to a comprehensive and mathematically precise theory of search-based competition.

REFERENCES

Adner R, Pólos L, Ryall M, Sorenson O. 2009. The case for formal theory. *Academy of Management Review* **34**(2): 201-208.

Adner R, Zemsky P. 2006. A demand-based perspective on sustainable competitive advantage. *Strategic Management Journal* **27**(3): 215-239.

Ahuja G, Katila R. 2004. Where do resources come from? The role of idiosyncratic situations. *Strategic Management Journal* **25**: 887-907.

Alexy O, George G, Salter A. 2013. Cui bono? The selective revealing of knowledge and its implications for innovative activity. *Academy of Management Review* **38**(2): 270-291.

Allen RC. 1983. Collective invention. *Journal of Economic Behavior & Organization* **4**(1): 1-24.

Baker T, Nelson RE. 2005. Creating something from nothing: Resource construction through entrepreneurial bricolage. *Administrative Science Quarterly* **50**(3): 329-366.

Baumann O, Siggelkow N. 2013. Dealing with complexity: Integrated vs. chunky search processes. *Organization Science* **24**(1): 116-132.

Burgelman RA. 2002. Strategy as vector and the inertia of coevolutionary lock-in. *Administrative Science Quarterly* **47**: 325-357.

Capron L, Chatain O. 2008. Competitors' resource-oriented strategies: Acting on competitors' resources through interventions in factor markets and political markets. *Academy of Management Review* **33**(1): 97-121.

Cassiman B, Veugelers R. 2002. R&D Cooperation and spillovers: Some empirical evidence from Belgium. *The American Economic Review* **92**(4): 1169-1184.

Chatain O, Zemsky P. 2007. The horizontal scope of the firm: Organizational tradeoffs vs. buyer-supplier relationships. *Management Science* **53**(4): 550-565.

Chen M-J, MacMillan IC. 1992. Nonresponse and delayed response to competitive moves: the roles of competitor dependence and action irreversibility. *Academy of Management Journal* **35**(3): 539-570.

Chen M-J, Miller D. 1994. Competitive attack, retaliation and performance: An expectancy-valence framework. *Strategic Management Journal* **15**(2): 85-102.

Criscuolo P, Haas M, George G. 2013. At what cost? An attention perspective on online knowledge sharing in a global engineering firm. *Working Paper*.

Csaszar FA. 2012. An Efficient frontier in organization design: Organizational structure as a determinant of exploration and exploitation. *Organization Science*.

Csaszar FA, Siggelkow N. 2010. How much to copy? Determinants of effective imitation breadth. *Organization Science* **21**(3): 661-676.

Derfus PJ, Maggitti PG, Grimm CM, Smith KG. 2008. The Red Queen effect: Competitive actions and firm performance. *Academy of Management Journal* **51**(1): 61-80.

Fang E. 2011. The effect of strategic alliance knowledge complementarity on new product innovativeness in China. *Organization Science* **22**(1): 158-172.

Fosfuri A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. *Strategic Management Journal* **27**(12): 1141-1158.

Gambardella A, McGahan AM. 2010. Business-Model innovation: general purpose technologies and their Implications for industry structure. *Long Range Planning* **43**(2–3): 262-271.

Garud R, Karnøe P. 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research Policy* **32**(2): 277-300.

Gavetti G, Levinthal D. 2000. Looking forward and looking backward: Cognitive and experiential Search. *Administrative Science Quarterly* **4**: 113-137.

Greve H, Taylor A. 2000. Innovations as catalysts for organizational change: Shifts in organizational cognition and search. *Administrative Science Quarterly* **45**(1): 54-80.

Hansen MT, Haas MR. 2001. Competing for attention in knowledge markets: Electronic document dissemination in a management consulting company. *Administrative Science Quarterly* **46**(1): 1-28.

Harhoff D. 1996. Strategic spillovers and incentives for research and development. *Management Science* **42**(6): 907-925.

Harhoff D, Henkel J, Von Hippel E. 2003. Profiting from voluntary information spillovers: how users benefit by freely revealing their innovations. *Research Policy* **32**(10): 1753-1769.

Harrison JS, Hitt MA, Hoskisson RE, Ireland RD. 2001. Resource complementarity in business combinations: Extending the logic to organizational alliances. *Journal of management* **27**(6): 679-690.

Henkel J. 2006. Selective revealing in open innovation processes: The case of embedded Linux. *Research Policy* **35**(7): 953-969.

Inkpen AC. 1996. Creating knowledge through collaboration. *California Management Review* **39**(1): 123-140.

Jeppesen LB, Lakhani KR. 2010. Marginality and problem-solving effectiveness in broadcast search. *Organization Science* **21**(5): 1016-1033.

Katila R. 2002. New product search over time: Past ideas in their prime? *Academy of Management Journal* **45**: 995-1010.

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

Katila R, Chen EL. 2008. Effects of search timing on product innovation: The value of not being in sync with rivals. *Administrative Science Quarterly* **53**: 593-625.

Katila R, Chen EL, Piezunka H. 2012. All the right moves: How entrepreneurial firms compete effectively. *Strategic Entrepreneurship Journal*.

Katila R, Shane S. 2005. When does lack of resources make new firms more innovative? *Academy of Management Journal* **48**: 814-829.

Katz ML, Shapiro C. 1987. R and D rivalry with licensing or imitation. *The American Economic Review*: 402-420.

Klevorick AK, Levin RC, Nelson RR, Winter SG. 1995. On the sources and significance of interindustry differences in technological opportunities. *Research policy* **24**(2): 185-205.

Knudsen T, Levinthal DA. 2007. Two faces of search: Alternative generation and alternative evaluation. *Organization Science* **18**(1): 39-54.

Kotha R, George G, Srikanth K. 2013. Bridging the mutual knowledge gap: Coordination and the commercialization of university science. *Academy of Management Journal* **56**(2): 498-524.

Laursen K. 2012. Keep searching and you'll find: What do we know about variety creation through firms' search activities for innovation? *Industrial and Corporate Change* **21**(5): 1181-1220.

Laursen K, Salter A. 2006. Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal* **27**(2): 131-150.

Levinthal D, March JG. 1981. A model of adaptive organizational search. *Journal of Economic Behavior & Organization* **2**(4): 307-333.

Levinthal DA. 1997. Adaptation on rugged landscapes. *Management Science* **43**(7): 934-950.

Lim K. 2009. The many faces of absorptive capacity: spillovers of copper interconnect technology for semiconductor chips. *Industrial and Corporate Change*: dtp044.

March JG, Simon HA. 1958. *Organizations*. John Wiley & Sons: New York, NY.

Martin J, Eisenhardt KM. 2010. Rewiring: Cross-business-unit collaborations and performance in multi-business organizations. *Academy of Management Journal*.

Obloj T, Capron L. 2011. Role of resource gap and value appropriation: effect of reputation gap on price premium in online auctions. *Strategic Management Journal* **32**(4): 447-456.

Pacheco-de-Almeida G, Zemsky PB. 2012. Some like it free: Innovators' strategic use of disclosure to slow down competition. *Strategic Management Journal* **33**(7): 773-793.

Podolny JM, Stuart TE, Hannan MT. 1996. Networks, knowledge, and niches: Competition in the worldwide semiconductor industry, 1984-1991. *American Journal of Sociology* **102**(3): 659-689.

Polidoro F, Toh PK. 2011. Letting rivals come close or warding them off? The effects of substitution threat on imitation deterrence. *Academy of Management Journal* **54**(2): 369-392.

Swaminathan A. 1996. Environmental conditions at founding and organizational mortality: A trial-by-fire model. *Academy of management journal* **39**(5): 1350-1377.

Thomke S, Nimgade A, Pospisil P. 1997. Eli Lilly and company: Drug development strategy (A). *The Harvard Case, Harvard University, Cambridge, Mass*.

Toh PK, Polidoro F. 2013. A competition-based explanation of collaborative invention within the firm. *Strategic Management Journal* **34**(10): 1186-1208.

Wang RD, Shaver JM. forthcoming. Competition-driven repositioning. *Strategic Management Journal*.

Wuchty S, Jones BF, Uzzi B. 2007. The increasing dominance of teams in production of knowledge. *Science* **316**(5827): 1036.

APPENDIX

Table 1: Summary of variables

Variable	Range	Definition
L	[2, ∞]	Firm resources, consisting of |L| distinct elements.
Q	[1, ∞]	Firm search space, consisting of all pairwise combinations of elements in L.
V	[0, Q]	V ⊆ Q is the set of valuable resource element combinations.
X	[1, ∞]	X ⊆ Q is the set of combinations selected by the firm for evaluation.
Y	[0, V]	Y = X ∩ V \ X-i is the set of valuable combinations exclusively identified by the firm.
α	[1, ∞]	Firm attention, which determines |X|.

Table 2: Focal firm response to knowledge-inferiority (2 strategies)

	Focal firm has insufficient attention $\alpha_F < Q_F$	$Q_F \leq \alpha_F < Q_F'$	Focal firm has excess attention $\alpha_F \geq Q_F'$
Competitor has insufficient attention $\alpha_C < Q_C'$	STAY BEHIND if: $\frac{V}{Q_F} > \frac{V'}{Q_F'}$ CATCH UP if: $\frac{V}{Q_F} < \frac{V'}{Q_F'}$	STAY BEHIND if: $V > \alpha_F \frac{V'}{Q_F'}$ CATCH UP if: $V < \alpha_F \frac{V'}{Q_F'}$	CATCH UP Catching up is always optimal.
Competitor has excess attention $\alpha_C > Q_C'$	STAY BEHIND = CATCH UP Both strategies lead to zero exclusive valuable combinations.	STAY BEHIND = CATCH UP Both strategies lead to zero exclusive valuable combinations.	STAY BEHIND = CATCH UP Both strategies lead to zero exclusive valuable combinations.

Table 3: Focal firm response to knowledge-inferiority (4 strategies)

The expected performance of the focal firm under each strategy in each state of the world (α_F, α_C, Q_F, Q_C) is given by the expressions below. The optimal strategy for a given state is indicated by highest term in a particular cell.

	Focal has insuffic. attention $\alpha_F < Q_F$	$Q_F \le \alpha_F < Q_F'$	$Q_F' \le \alpha_F < Q_F''$	Focal has excess attention $\alpha_F \ge Q_F'$
Competitor has excess attention $\alpha_C < Q_C'$	LEAP AHEAD: $\frac{V''-V'}{Q_F''}+\frac{V'}{Q_F''}\left(\frac{Q_C'-\alpha_C}{Q_C'}\right)$ CATCH UP: $\frac{V'}{Q_C'}\left(\frac{Q_C'-\alpha_C}{Q_C'}\right)$ FALL BEHIND: $\frac{V}{Q_F}\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $\frac{V''-V'}{Q_F''}+\frac{V'}{Q_F''}\left(\frac{Q_C'-\alpha_C}{Q_C'}\right)$ CATCH UP: $\frac{V'}{Q_C'}\left(\frac{Q_C'-\alpha_C}{Q_C'}\right)$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $\frac{\alpha_F}{Q_F''}\left[V''-V'\left(\frac{\alpha_C}{Q_C'}\right)\right]$ CATCH UP: $V'\left(\frac{Q_C'-\alpha_C}{Q_C'}\right)$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $V''-V'\left(\frac{\alpha_C}{Q_C'}\right)$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$
Competitor has intermediate attention $Q_C' \le \alpha_C < Q_C''$	LEAP AHEAD: $\frac{V''-V'}{Q_F}$ FALL BEHIND: $\frac{V}{Q_F}\left(\frac{Q_C-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $\frac{\alpha_F}{Q_F''}(V''-V')$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $\frac{\alpha_F}{Q_F''}(V''-V')$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$	LEAP AHEAD: $V''-V'$ FALL BEHIND: $V\left(\frac{Q_C''-\alpha_C}{Q_C''}\right)$
Competitor has excess attention $\alpha_C > Q_C''$	LEAP AHEAD Leaping ahead is always optimal.	LEAP AHEAD Leaping ahead is always optimal.	LEAP AHEAD Leaping ahead is always optimal.	LEAP AHEAD Leaping ahead is always optimal.

Figure 1: Key model constructs

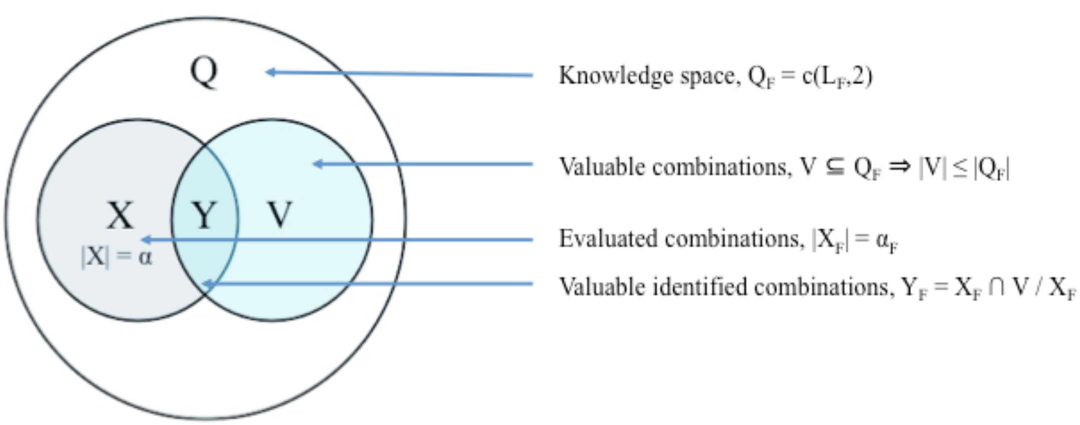


Figure 2: Search spaces following competitor's resource extension

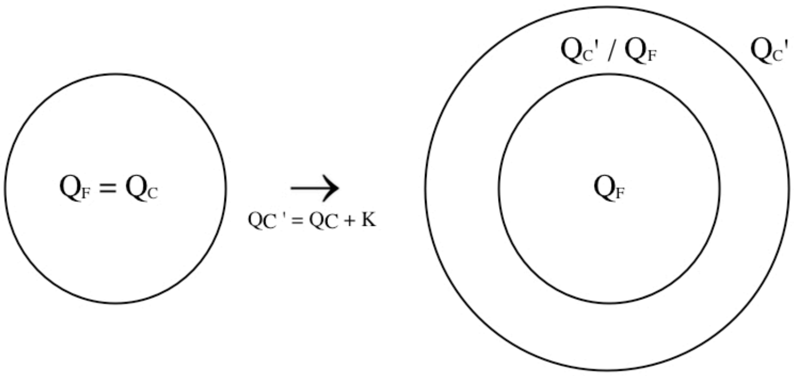


Figure 3: Firm innovativeness as a function of munificence and attention

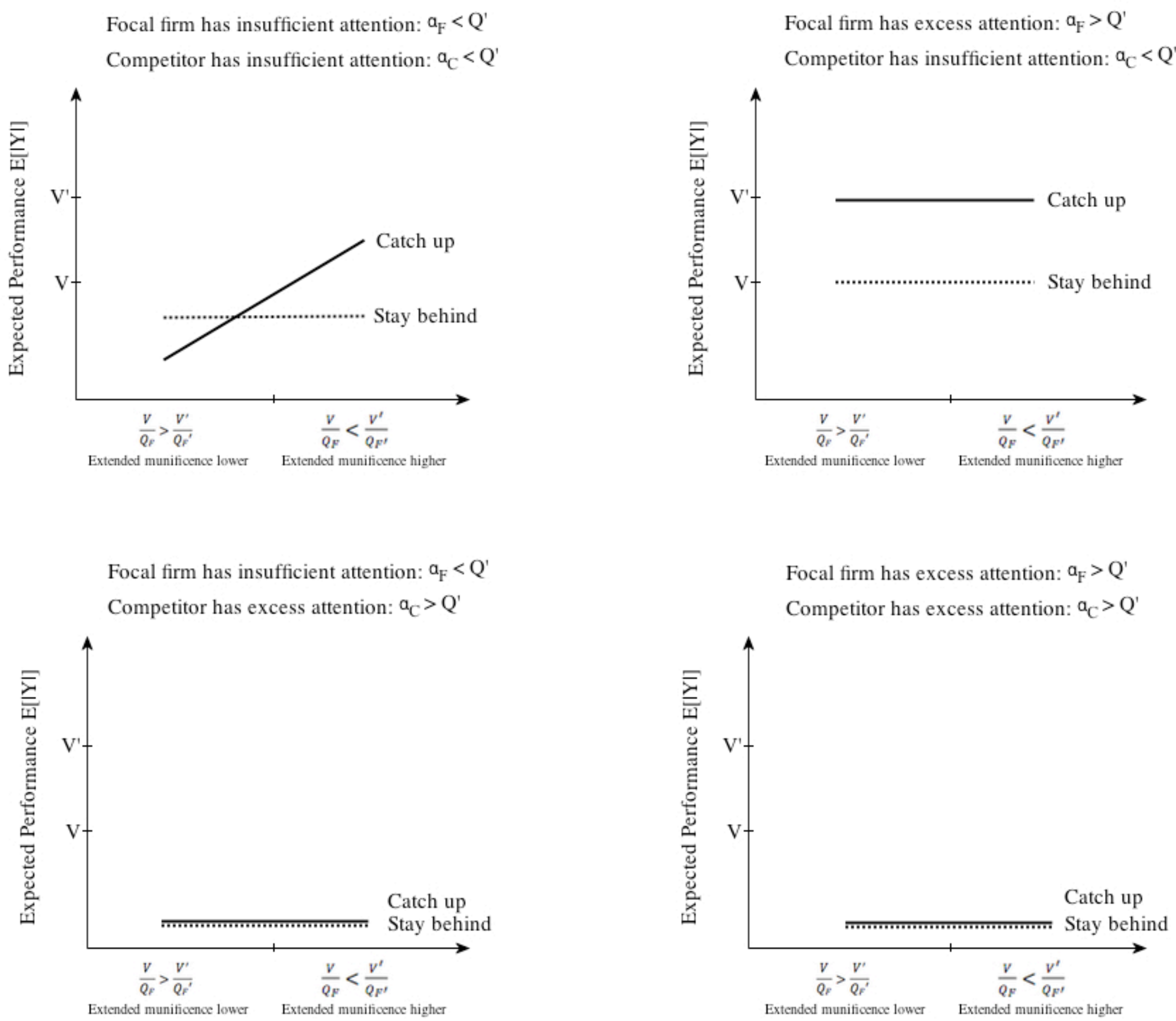
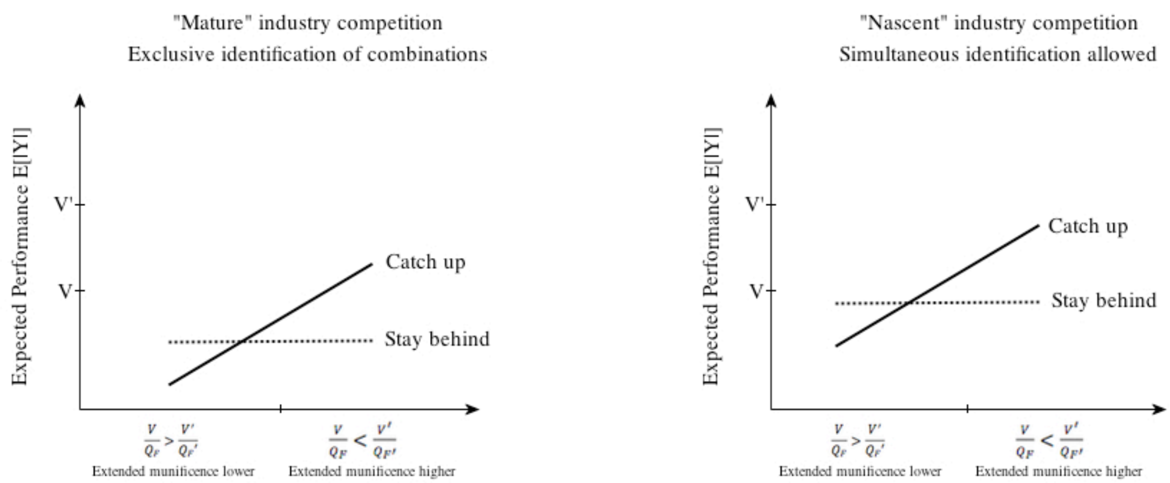


Figure 4: Firm innovativeness as a function of competition



SUPPLEMENTARY MATERIAL: PROOFS

Proposition 1: Expected Performance

$E[|Yj|] = E[|Xj \cap V \setminus Xi] = \Sigma(x)p(x \in V)p(x \notin Xj) \Rightarrow E[|Yj|] = \alpha j \cdot p(x1 \in V) \cdot p(x \notin Xi)$. Further, $p(x \in W) = (|V|/|Qj|)$ for $\alpha j < Qj$ and V if $\alpha j > Qj$, and $p(x \notin Xi) = (|Qi| - \alpha i)+/|Qi|)$, so $E|[Yj|] = \min((\alpha j \cdot |V|)/|Qj|, |V|) \cdot (|Qi| - \alpha i)+/|Qi|)$.

Proposition 2A: Expected Magnitude of Oversights

Let O denote oversights, where $O = Y_C \setminus Y_C' \Rightarrow E[O] = E[|Y_C/Y_C']$. For $\alpha_C \geq Q_C'$, $Y_C \subset Y_C' \Rightarrow E[|O|] = 0$. For $\alpha_F \geq Q_C$, $Y_C = 0 \Rightarrow E[|O|] = 0$. For $\alpha_F < Q_C$ and $Q_C \leq \alpha_C < Q_C'$, $E[|O|] = |V| \cdot (|Q_C| - \alpha_F)/|Q_F|)$. For $\alpha_F < Q_C$ and $\alpha_C < Q_C$, $E[|O|] = ((\alpha_C \cdot |V|)/|Q_C|) \cdot (|Q_C| - \alpha_F)/|Q_F|) - ((\alpha_C \cdot |V|)/|Q_C|) \cdot (|Q_C| - \alpha_F)/|Q_F|) \cdot (Q_C/Q_C')$.

Proposition 2B: Oversight Dynamics

Let $L_F \subset L_C \Rightarrow Q_F \subset Q_C$. By Proposition 1, $E[|Y_C|] = \min((\alpha_C \cdot |V|)/|Q_C|, |V|) \cdot (|Q_F| - |\alpha_F|)+/|Q_F|)$. Differentiating, FOCs reveal $\delta E[O]/\delta\alpha_C < 0$, $\delta E[O]/\delta_K > 0$, and $\delta E[O]/\delta(V/Q_C) > 0$.